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Children with poorly controlled asthma: Randomized controlled trial of a home-based environmental control intervention

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Abstract

Background: Few trials have tested targeted environmental control (EC) interventions based on biomarkers of second hand smoke (SHS) exposure and allergen sensitization in reducing asthma emergency department (ED) visits in children with poorly controlled asthma.

Methods: Overall, 222 children with poorly controlled asthma were randomized into a home-based EC intervention (INT) or control (CON) group and followed for ED visits over 12 months. All children received allergen-specific IgE serologic testing and SHS exposure biomarker testing to inform the EC intervention. Pharmacy data was examined for asthma medication fills. Cox proportional hazards and multivariate regression models were performed to examine factors associated with repeat ED visits.

Results: There was no difference in increased risk of >1 ED visit at 12 months between INT and CON groups. Most children (75%) had moderate/severe persistent asthma. Over half (56%) had SHS exposure and 83% tested positive for >1 allergen sensitization. Among children without SHS exposure, the median time to first recurrent ED visit differed by group (CON: 195; INT: >365 days) after adjusting for child age, allergic sensitization, medication fills prior to baseline, controller medication use, and the interaction between group status and SHS exposure. Children who had positive allergic sensitizations, younger, had increased controller medication use and randomized to the CON group and had no SHS exposure had increased risk for a repeat ED visit over 12 months.

Conclusions: In this study, a home-based EC intervention was not successful in reducing asthma ED revisits in children with poorly controlled asthma with SHS exposure. Allergic sensitization, young age, and increased controller medication use were important predictors of asthma ED visits.

Keywords

allergic sensitization; asthma; emergency department; environmental control; second hand smoke (SHS) exposure

1 | INTRODUCTION

Asthma affects seven million children in the US with the annual healthcare expenditures at \$56 billion.^{1,2} This high cost is primarily due to high asthma related emergency department (ED) and hospitalization rates. Although one out of five US children with asthma receive ED treatment,² ED utilization for asthma care is disproportionately higher among minority, and low income children³ with 12-month revisit rates ranging from 6% to 34% for inner-city children.^{4,5} These revisits are costly, anxiety provoking, and largely preventable.^{6,7} Discerning the risk factors associated with increased asthma ED revisits is complex since risks include adverse environmental exposures, child sociodemo-graphic and health characteristics, and caregiver asthma management practices and beliefs.^{8,9} Asthma ED revisits have been associated with exposures to indoor allergens, respiratory infections, and second hand smoke (SHS)¹⁰⁻¹⁴; controller medication underuse and short acting beta agonist (SABA) overuse,^{7,15-18} improper medication delivery device technique, parental worry about asthma medication use and younger child age.^{9,19,20}

Prior intervention studies to prevent risk for poor asthma outcomes mainly focused on reduction in environmental exposure to specific allergens.²¹⁻²³ Exposure and allergen sensitization to mouse, cockroach and dust mite allergen detected in inner-city children are associated with increased risk factor for poorly controlled asthma.²²⁻²⁶ Home-based asthma education and environmental control (EC) programs have the potential to reduce asthma morbidity and lower ED utilization,^{21,27} yet prior environmental interventions have demonstrated equivocal results in effectively reducing indoor allergens.^{22,23} Single allergen interventions, school-based and low-intensity programs are often ineffective due to the multiple environmental exposures and complex management issues experienced by inner city children.²⁷⁻²⁹ Alternatively, multifaceted home-based EC interventions addressing common indoor allergens and SHS exposures are likely to be effective especially when biomarkers confirm sensitization to indoor allergens and cotinine for SHS exposure, but few prior EC interventions target indoor allergens and SHS exposures. One multifaceted home-based intervention to reduce wheezing symptoms in young children targeted indoor allergen and tobacco smoke exposures while also addressing maternal asthma management (Childhood Asthma Prevention Study, CAPS).⁸ Despite significant reduction in home cockroach allergen and SHS exposure, there was no decrease in wheezing symptoms, ED visits, or hospitalizations.⁸

The objective of this study was to determine the efficacy of a home-based EC intervention, based on biomarkers of allergen sensitization and cotinine concentrations for SHS exposure, to reduce recurrent or repeat asthma ED visits among inner-city children with persistent asthma. Secondary analysis examined other co-factors associated with the risk of ED revisits and intervention effects on symptom free days.

2 | METHODS

2.1 | Design and study setting

This prospective randomized controlled trial tested the efficacy of an ED and home-based EC intervention among inner-city children with frequent asthma ED visits. Children aged 3–12 years with persistent asthma were recruited and enrolled during an asthma ED visit from August 2013 through February 2016. Inclusion criteria were physician diagnosed persistent asthma, having two or more ED asthma visits or >1 hospitalization over the past 12 months and residing in the Baltimore metropolitan area. Exclusion criteria included foster care and significant other non-asthma respiratory conditions. After written informed caregiver consent and child verbal assent (child age >8 years) were obtained, children were randomly assigned using random-number generation prepared by biostatistician and stratified by child age (3–5 vs 6–12 years) to ensure groups were balanced by age, into the intervention (INT), or attention control (CON) group via opaque sealed envelopes viewed by the study coordinator. Research staff collecting the data were blinded to group assignment. As shown in Figure 1, of the 554 child/caregivers screened for study enrollment, 117 children were ineligible for enrollment, and another 215 caregivers declined to participate resulting in randomization of 222 children into the study. During the enrollment ED visit, all children received allergen-specific IgE serologic testing measured by fluorescent enzyme immunoassay (FEIA) to identify allergen sensitization to ten common environmental allergens and salivary cotinine measurement to screen for exposure to SHS. Concurrently, caregivers were asked about the child's indoor exposure to mice, cockroaches, cats, and dogs. Using REDCap® application³⁰ surveys were administered to the child's caregiver at the baseline, 6 and 12 month time points in the ED or participants' homes by trained research assistants. The Johns Hopkins Medical Institutional and the University of Maryland Institutional Review Boards approved the study and the study was registered with <https://ClinicalTrials.gov>, (<https://www.clinicaltrials.gov>): NCT01981564.

2.2 | Interventions

2.2.1 | Asthma express intervention—Intervention (INT) was a home-based asthma follow-up and environmental control (EC) educational program delivered by trained nurses and nurse practitioners (NP) to the child and caregiver (Table 1). INT children received a medical follow-up visit in the ED within 7 days of the enrollment asthma ED visit to evaluate: (i) asthma symptoms; (ii) guideline-based controller and rescue medication use and inhaler technique; (iii) review allergen and cotinine lab results using graphs to represent positive allergen sensitizations and child's level of cotinine. Additionally, INT children received two home nurse visits for targeted EC education and remediation based on the child's allergen sensitization results (eg, positive mouse allergy: set up mouse traps; positive cockroach allergy: set up cockroach bait and delivered kitchen trash cans). A nurse trained in

integrated pest management conducted all home visits. For caregivers of children with positive cotinine (>1.0 ng/mL) results, brief motivational interviewing sessions were conducted to implement a total home smoking ban. Last, primary care provider (PCP) asthma care within 4 weeks was scheduled for the child.

2.2.2 | Control—The attention control (CON) group of caregivers and children received three home nurse visits over 3 months to provide (i) standard asthma education regarding guideline-based controller and rescue medication use; (ii) evaluate inhaler technique; (iii) basic EC education without home remediation; and (iv) assistance with scheduling PCP follow-up asthma care (Table 1). Child allergen and cotinine test results were mailed to CON caregivers and child's PCP; the home nurse reviewed the allergen and cotinine results with the caregiver. No active home remediation was conducted. Referrals to smoking cessation programs were provided to caregivers who had a smoker residing in the home. No motivational interviewing sessions were conducted. Fidelity checks were performed with INT and CON nurses using home visit checklists that logged behavioral and educational aspects of each home visit. No unintended effects occurred in either group.

2.3 | Outcomes

2.3.1 | Asthma healthcare utilization—The primary outcome was having >1 ED repeat asthma visit over the 12-month study period based on caregiver report and medical record review at 12 months. Other healthcare utilization measures included number of PCP visits for non-urgent asthma care, prior ICU asthma admissions, asthma specialty care visits over the past 2 years and type of health insurance reported at baseline. Number of ED visits, ICU admissions and type of health insurance were verified by review of electronic medical record (EMR) with moderate to high agreement (ED visits: 82%, ICU admissions: 81%, and type of health insurance: 99% agreement).

2.4 | Covariates

2.4.1 | Asthma severity assessment—Baseline asthma severity was based on the National Asthma Education and Prevention Program (NAEPP) guideline for asthma severity³¹ and determined by caregiver report of: (i) number of symptom days over the past 14 days and symptom nights over the past 30 nights; (ii) short-acting β_2 -agonist (SABA) use over past 14 days; (iii) activity limitation over the past 7 days; (iv) number of oral corticosteroid courses in the past year; and (v) number of asthma ED visit or hospitalizations over the past 12 months.

2.4.2 | Asthma medication use and caregiver worry about medication side effects—Pharmacy records of asthma medications dispensed over 12 months were obtained at baseline (prior 12 months) and at the 12-month follow-up (12 months post enrollment). A total of 24 months of pharmacy fill data were collected for each participant. Pharmacy records included the dispensing date, product name, strength, dosage form, and quantity dispensed. Rescue medication was defined as short acting B -agonists (SABA) and controller medications were defined as inhaled corticosteroids (ICS), leukotriene modifiers (LTM), and long acting beta agonists (LABA). Oral corticosteroid (OCS) prescription fills were analyzed separately. As a proxy of appropriate controller medication use, the asthma

medication ratio (AMR)³² or the total number controller medication canisters or equivalents divided by the total number of controller and SABA medication canisters or equivalents was calculated using 12-month pharmacy fill data. AMR ratios of 0.50 or higher have been associated with decreased asthma morbidity.³²

Caregiver worry over side effects of asthma medication was recorded at baseline, 6 and 12 months, using a single item from the Pediatric Asthma Caregiver Quality of Life Questionnaire Scale (“How worried or concerned are you about your child’s asthma medications and side effects?”).³³ Responses were categorized into two groups: “very, fairly, or somewhat worried” versus “a little, hardly or not worried.”

2.4.3 | Serologic allergen specific IgE test—Serum specific IgE testing, collected during the baseline enrollment ED visit, was performed by a private commercial laboratory using the (ImmunoCap®) fluorescent enzyme immunoassay (FEIA). Specific IgE to ten common environmental allergens were measured including mouse, cockroach, cat, dog, timothy grass, *alternaria*, and *aspergillus* molds, oak tree, common ragweed, and house dust mite. The degree of sensitization ranged from <0.35 to >100 kU/L of specific IgE to any of the allergens tested. Results of >0.35 kU/L were considered as an increased likelihood of presence of clinical allergy and thus for the purpose of this analysis were defined as “positive.”

2.4.4 | Second hand smoke (SHS) exposure—Saliva samples for cotinine measurement, a biomarker of recent nicotine exposure, were collected during the enrollment ED asthma visit, 6 and 12 months follow-up visits. Saliva was collected using a 3-cm cotton swab that was placed under the child’s tongue for 1 min to absorb 1 mL of saliva (Salimetrics, State College, PA). The swab was placed in a 2 mL vial and stored at –20° Centigrade for transport to the lab, then centrifuged, and analyzed at the Johns Hopkins Institute for Clinical and Translational Research (ICTR) lab using Enzyme Immuno-assay (EIA) analysis. The lower limit of cotinine sensitivity was 0.05 ng/mL and average intra and inter-assay coefficients of variation were less than 5.8% and 7.9%, respectively. Based on prior findings in comparable child population, positive SHS exposure was defined as a salivary cotinine level >1.0 ng/mL.³⁴

2.5 | Analyses

The primary outcome in this study was having >1 ED repeat asthma visit over the 12-month follow-up period. Assuming 90% power for a 2-sided test and alpha of 0.05, we estimated a sample size of 110 per group (total = 220) to detect a 0.17 difference in rate of children with having >1 ED repeat asthma visits over the 12-month follow-up. This is based on assumption of difference in repeat ED visit over 12 months, CON: $P_0 = 0.92$ and INT: $P_1 = 0.75$ (difference of 17%) since 100% of both groups experienced an ED visit in the prior year. This effect size was chosen based on a similar effect noted in children having a repeat asthma ED visit within 1 year (17%) following an outpatient follow-up visit versus no follow-up in a similar population.³⁵ Standard frequencies, means and standard deviations were used to describe socio-demographic and health characteristics of all children and caregivers at baseline and 12 months. Group differences in variable distributions were

assessed using Chi-square test statistic for categorical variables, and *t*-test and Mann-Whitney U test for continuous variables. Cox proportional hazards regression (HR) models, measuring the risk or cumulative probability of experiencing >1 ED revisit over the 12 month follow-up, were calculated to highlight factors associated with a repeat ED visits. Unadjusted analyses examined association between select sociodemographic and health characteristics with risk of a repeat ED visit for all participants and for atopic only children (83%). Multivariate regression stepped each factor into the model in order of significance based on univariate test results and theoretical influence (child age and allergic sensitization) to determine the combination of factors related to increased hazard of >1 ED visits. Effectiveness of the intervention to reduce the hazard of recurrent ED visits further considered potential factor dependencies and retained in final adjusted model the significant interaction effect between intervention and SHS exposure ($P < 0.05$). Analyses were conducted using SPSS Version 22 software.³⁶

3 | RESULTS

3.1 | Baseline sociodemographic and health characteristics by group

Overall 204/222 children enrolled had complete data at 12 months (92%) (Figure 1). Children were primarily male (65%), African American (94%), and Medicaid insured (94%) with a mean age of 6.3 (SD 2.7) years. (Table 2) Children were enrolled year-round with most children enrolled during the fall season but season of enrollment differences were non-significant (summer: 12%, fall: 37%, winter: 29%, spring: 22; $P = 0.45$). Caregivers were primarily the child's biological mother (94%), high school or higher educated (81%), and single (75%). Asthma severity was high with most children categorized with moderate (46%) or severe persistent (29%) asthma. Over two-thirds (68%) of children had one or more asthma ED visits over the 3 months prior to enrollment. Allergic sensitization was prominent with 83% of children testing positive to one or more allergens with the most common positive allergens as dog (60%), cat (59%), mouse (54%), oak tree (45%), timothy grass (45%), cockroach (41%), and house dust mite (41%). Indoor exposure to allergens was high; mouse (47%), cockroach (32%), cats (26%), and dog (19%) and over half (56%) of children tested positive for SHS exposure (cotinine >1.0 ng/mL). Despite the high allergen sensitization, few children received asthma specialty care (allergist or pulmonologist) at baseline and/or 12 months (Baseline: 20%; 12 months: 27%).

Medication use was primarily non-guideline based. Median controller fills over 12 months prior to enrollment was low at 2.0 fills/12 months (Interquartile Range, IQR: 0–7 fills). Moreover, SABA fills were high with over one-third (39%) having four or more fills/12 months. AMR values were low (AMR <0.50: 45%) indicating poor relative controller medication use. Over one-third (36%) of care-givers reported being worried about side effects of asthma medications. There were no group differences for any child and caregiver sociodemographic or child health characteristics at baseline.

3.2 | Asthma outcomes at 12 months by group status

INT children had significantly lower median controller medication fills than CON children (INT: 2.5, CON: 4.0 fills; $P = 0.02$) but no difference was noted between SABA fills or

AMR >0.5 (Table 3). There was no difference in symptom free nights over past month between groups, yet a trend was noted in fewer symptom free days over past 2 weeks (INT: 7.8 [SD 5.7], CON: 9.2 [SD 5.1] days; $P=0.06$). No other factors were significantly modified by the intervention including cotinine levels, exposure to mouse or cockroach, or caregiver worry about medication side effects.

3.3 | Predictors of repeat ED visits defined as >1 visits over the 12-month follow-up (Unadjusted)

As seen in Table 4, the only factors associated with any repeat ED asthma visit for all participants were increased number of controller medication fills and having 4 or more SABA fills over the 12-months prior to study enrollment. Regarding controller medication fills, for every increase in number of controller medication fills there was a 4% increase in the risk of having a repeat ED visit over the 12-month follow-up. Further, children with 4 or more SABA fills had a 58% increased risk of repeat ED visits for all children. In the unadjusted analysis, no other significant associations were noted between groups for all participants. When limiting the analysis to atopic children, defined as >1 positive allergen sensitization, similar trends were noted to result of all participants except for the categorization of children with severe asthma that was significantly associated with increased risk of >1 ED visit over the follow-up. Number of positive sensitization tests did not modify the group effect in the hazard ratio (HR) of >1 ED visit (interaction effect, $P=0.38$) nor did having 6 or more positive sensitization tests (interaction effect, $P=0.31$).

3.4 | Multivariate model for predictors of increased hazard of >1 ED visit over follow-up

As seen in the final multivariate model for predicting the hazard of a repeat ED visit over the 12 month follow-up (Table 5), children residing in homes with no SHS exposure and in the CON group had an 85% increased risk, atopic children had a 2.6 times greater risk and younger children and those with an AMR >0.50 had an increased risk for a repeat ED visit over the 12 month study period. A borderline significant increase in hazard of repeat ED visits was noted with >4 SABA fills. (Table 5). No group differences were noted for risk of repeat asthma ED visits in children with positive SHS exposure. For atopic participants only, similar results were noted with CON participants residing in homes with no SHS exposure had twice the risk of repeat asthma ED visits, and younger children and those with AMR >0.50 had increased risk for repeat asthma ED visits.

Time to first repeat ED visit did not differ by group status for children with positive SHS exposure. Among children without SHS exposure, the median time to first recurrent ED visit differed by group (CON: 195; INT: >365 days) after adjusting for child age, allergic sensitization status, SABA fills prior to baseline (4 vs <4 per year), AMR (<0.50 vs 0.50) and the interaction between group status and SHS exposure. (Figure 2). At the completion of the 12-month follow-up, the cumulative probability of a repeat ED visit in children without SHS exposure was less than 45% in the INT children compared to almost 70% of CON children.

4 | DISCUSSION

This study indicates that a home-based targeted EC intervention was not effective in reducing repeat asthma ED visits in children with persistent asthma when compared to a control group who received less intensive EC home based intervention. Effective home-based EC interventions are typically multifaceted, intensive and targeted to individual allergen sensitizations and exposures.^{8,29} While our intervention was multifaceted and targeted positive allergen sensitizations, it was not effective in reducing asthma ED visits in children with positive SHS exposure. Effective asthma home based interventions combined education and environmental remediation management ranging from cockroach bait placement to renovation of homes.²⁷ The intensity of the EC component of the intervention was likely insufficient when compared to the prior effective home-based interventions, for example, the Inner-City Asthma Study (ICAS) that provided HEPA air and HEPA vacuum cleaners with ongoing integrated pest management services.²¹ A significant relationship was noted between reduction in allergen levels and symptom days in the intervention group.²¹ However, other home environmental interventions have indicated reduction in allergen levels, but not sufficient to achieve a clinical benefit^{22,23} including decreased symptom days and healthcare utilization.

For example, significant reduction in allergen levels (cat, dog, dust mite, cockroach, mouse) was noted in sensitized and exposed inner-city adults and children with asthma and who were assigned to an intensive home based EC intervention including provision of vacuums and HEPA air-purifiers, encouraging reduction of SHS exposure, and implementing step-wise therapy with free asthma medications.²³ Yet, no reduction in symptom days/nights or use rescue medication was associated with receiving the intervention.²³ Further, a 12-month professionally delivered integrated pest management intervention for mouse-sensitized and exposed children with asthma demonstrated no statistically significant differences in symptoms days, ED visits or hospitalizations when compared to a pest management education only intervention.²² While our intervention was likely insufficient to reduce indoor mouse and pest exposures, we also targeted SHS exposure in the home and caregiver medication education similar to the Childhood Asthma Prevention Study (CAPS).⁸ Lack of achieving a clinical benefit in several of these home-based environmental interventions may be due: (i) modest allergen reductions insufficient to achieve a clinical improvement³⁷; (ii) multiple caregiver challenges (personal health problems, stressors and community violence) resulting in non-adherence to the protocol⁸; and (iii) lack of medical management of the child's asthma during the intervention.²² Rather, baseline severe asthma was significantly associated with risk of one or more ED visits over the follow-up in our study population, supporting the view that use of guideline controller medication therapy may be a greater priority in treating inner-city children.³⁷

Over half of inner-city children with asthma are exposed to SHS^{34,38,39} and it is known that tobacco smoke is an important contributor to childhood wheezing.⁴⁰ Targeting SHS exposure was major component of our intervention rather than limiting protocol to reduce specific allergen exposures. Although INT caregivers of children with positive SHS exposure received brief motivational interviewing by a trained nurse to reduce SHS exposure, no significant reduction in cotinine exposures was associated with the intervention

at 12 months. Most likely, the reduction in SHS exposure component of the intervention lacked the capacity required to eliminate all SHS exposure for the child. Avoidance of SHS exposures is a key component of NAEPP and international guidelines for the management of childhood asthma^{31,41} and was a major component of this home-based intervention. However, the brief smoking cessation motivational interviewing component of the intervention was likely insufficient for sustained smoking cessation in households with smokers. Caregiver emotional and financial strains to implement a total home smoking ban may elucidate the complexity in reducing a child's SHS exposure.^{39,42} Caregiver misunderstanding of the ubiquitous penetration of SHS in their home and/or residing in multiunit dwellings may have contributed to the null effect of the intervention.^{39,43} Alternatively, health behavior of parents who smoke may explain the lack of decreasing SHS exposure in this sample of high-risk children. Low child influenza immunization rates and/or routine asthma visits were associated with increased level of parental smoking,⁴⁴ suggesting parental reluctance to attend their child's PCP visits as to avoid tobacco smoking admonishment.⁴⁵ Notably, the home-based intervention was effective in a subgroup of children with no SHS exposure. The intervention targeted positive allergen sensitizations for remediation in the home. Perhaps in children with SHS exposure, the added level of complexity needed to reduce SHS home exposure was too difficult to achieve since over half of the children with allergies also had SHS exposure.

Having one or more positive allergen sensitizations was the overwhelming risk associated with a repeat asthma ED visits. Both the caregiver and PCP may under-appreciate the high incidence of allergen sensitization among inner-city individuals with asthma⁴⁶ and this results in under treatment. Allergic sensitization can result in increased airway inflammation and bronchoconstriction and multiple allergen sensitizations and exposure can result in greater adverse effects than sensitization and exposure to a single allergen.⁴⁷ Without knowledge of potential allergen sensitizations, nasal congestion symptoms may be attributed to viral upper respiratory infection and not treated. Notably, asthma and allergic rhinitis have interrelated inflammatory processes in the upper and lower respiratory tract.⁴⁸⁻⁵⁰ Nasal turbinate edema from allergic rhinitis can result in direct inhalation of irritants, allergens, and cold air, all potentially causing bronchoconstriction.⁴⁸ Our data support guideline recommendations that children with persistent asthma or failing current asthma management should receive allergen testing.^{31,51-53} Over 80% of children in our study had positive allergic sensitization, yet, less than one out five children received specialty asthma care. Serologic or skin prick allergy testing in children with asthma is not routinely performed in primary care visits,⁵¹ yet, these tests can inform step-wise therapy, particularly in children who may have high allergen exposures and/or poorly controlled asthma.⁵³

Younger child age was associated with increased asthma ED visits. This may be due to early lung function deficits associated with persistent asthma symptoms in children with poorly controlled asthma resulting in a fragile airway leading to bronchospasm and airway inflammation.^{54,55} Further, children attending daycare may experience a complex interaction between viruses and allergen sensitization in early life resulting in persistent asthma symptoms.⁵⁵ Otherwise, increased health-seeking behavior in caregivers of children with new onset asthma or caregivers with fewer resources to manage asthma in the home can lead to use of the ED for asthma management rather than manage symptoms at home. ⁽⁶

Unadjusted results indicate a 4% increase in likelihood of an ED visit over the follow-up and in the adjusted multivariable analysis, increased controller medication use (AMR >0.50) revisit both suggesting that study children had more severe asthma.

4.1 | Strengths and weaknesses of this study

Use of biomarkers to confirm SHS exposure and allergen sensitization to specific allergens and the high participant retention rate (92%) over 12 months are major strengths of this study. Nevertheless, there are several limitations associated with this study. The generalizability of the results is limited in that we purposely recruited children with more uncontrolled asthma and frequent asthma ED visits in order to maximize our ability to detect a difference in asthma symptoms and recurrent asthma ED visits with the intervention program. Thus, our sample of inner-city children may represent a higher percentage of very poorly controlled asthma patients than the general pediatric asthma population. Because medical management was not a component of the intervention protocol, our results may not be generalizable to other community care settings.²² The rate of enrollment in the ED; only 51% of eligible participants, further limits the generalizability but reflects the challenge to enrolling children with asthma into an environmental control intervention during an acute care visit when caregivers are highly stressed. By study design and ethical considerations, our control group received asthma education and support in the home as an attention control group and not usual asthma care. This may have resulted in a significant conservative bias in our analyses, since control group caregivers may have benefited from the receipt of asthma education and increased self-management support for their child's asthma noted in prior home-visiting programs.⁵⁶

5 | CONCLUSIONS

In conclusion, a home based EC intervention was not associated with a reduction in asthma repeat ED visits among inner-city children with persistent asthma. However, in a subset of children without SHS exposure, the median time to recurrent ED visit was significantly shorter in CON versus INT children. Achieving well-controlled asthma in high-risk young children requires knowledge of allergen sensitization and SHS exposure and a sustainable home-based EC program with ongoing intensive integrated pest management and strategies to reduce SHS exposure.

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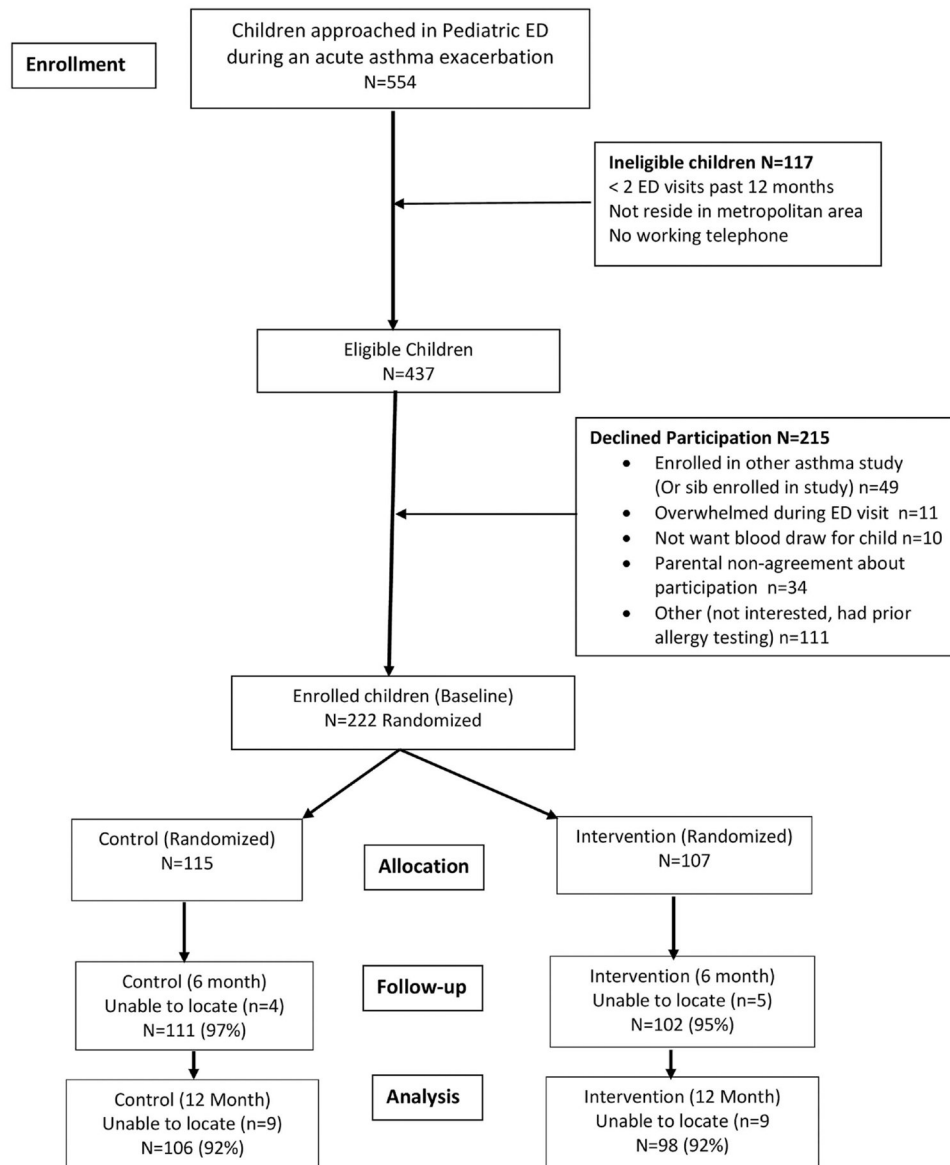


FIGURE 1.
Recruitment, Randomization and Retention of Participants Diagram

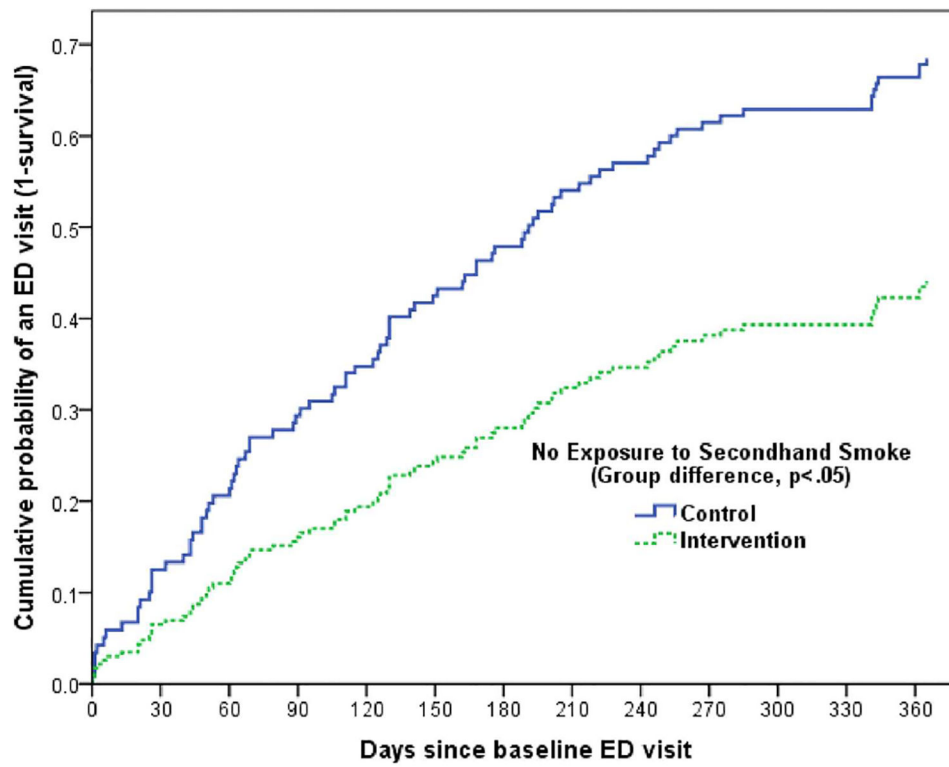


FIGURE 2.

Cumulative probability for a child participant to have a repeat ED visit with each additional day following the baseline ED enrollment visit (repeat ED visit over follow-up) presented in children residing in homes with NO SHS exposure.^a

TABLE 1

Description of Asthma Express Intervention and Control Group

	Intervention (INT)	Attention control (CON)
Interventionist	<ol style="list-style-type: none"> 1 Pediatric Nurse Practitioner (PNP) and 2 Home visiting nurse trained in integrated pest management 	Community home visiting nurse
Number of visits with family	3 visits (1 visit in Pediatric ED with the PNP and 2 home visits with nurse)	3 visits (3 home visits with nurse)
Number of home visits	2 home visits	3 home visits
Timing of 1st visit	ED visit: within 7 days of enrollment	Within 7–14 days of enrollment ED visit
Content of visits	ED follow-up visit: a medical follow-up visit in the ED within 7 days with a PNP (1) evaluate asthma symptoms, (2) evaluate guideline-based controller and rescue medication use and inhaler use; correct improper inhaler technique. Prescribe controller medication is indicated or contact PCP for controller medication prescription and (3) intensive review of allergen and cotinine lab results using graphs to represent positive allergen sensitizations and child's level of cotinine. Home nurse visits: 2 home nurse visits (nurse with specialty training in integrated pest management) to provide: <ol style="list-style-type: none"> 1 Environmental control (EC) education and remediation based on the child's allergen sensitization results (eg, positive mouse allergy; set up mousetraps, positive cockroach allergy; set up cockroach bait and delivered kitchen trashcans). 2 Brief motivational interview to implement a total home smoking ban using a contingency contract and motivational ladder. 3 Schedule primary care provider (PCP) asthma care appointment within 4 weeks. 	No ED follow-up visit. Home nurse visits: 3 home visits by asthma specialty trained nurse <ol style="list-style-type: none"> 1 standard asthma education regarding guideline-based controller and rescue medication use, contact PCP if controller medication is indicated, examine inhaler technique and correct as needed, basic environmental control education 2 review cotinine and allergen results sent to caregiver via mail but no specific home remediation provided, 3 referral to smoking cessation programs for caregivers who reported any smoker residing in home and 4 assistance with scheduling follow-up PCP asthma visit.
Fidelity of intervention checks	Checklist of content delivered at each visit and reviewed with nurse supervisor. (AB)	Checklist of content delivered at each visit and reviewed with nurse supervisor. (JK)

TABLE 2

Baseline characteristics of participants and their caregiver by group

	All participants N = 222 N (%)	CON group N = 115 N (%)	INT group (N = 107) N (%)	P-value (group difference)
Child sociodemographic characteristics				
Mean age of child, years (SD)	6.3 (2.7)	6.5 (2.6)	6.2 (2.7)	0.51
Male child	144 (64.9%)	80 (70.8%)	62 (58.5%)	0.06
Race/ethnicity				
African American	208 (93.6%)	107 (93.0%)	101 (94.4%)	0.58
White or Hispanic	7 (3.2%)	3 (2.6%)	4 (3.7%)	
Other	7 (3.2%)	5 (4.3%)	2 (1.9%)	
Medicaid insured	209 (94.1%)	109 (94.8%)	100 (93.5%)	0.91
Poor ^a	110 (57.3%)	55 (54.5%)	55 (60.4%)	0.40
Season of enrollment:				
Fall (Sep-Nov)	81 (36.8%)	36 (31.9%)	45 (42.1%)	0.45
Winter (Dec-Feb)	64 (29.1%)	35 (31.0%)	29 (27.1%)	
Spring (Mar-May)	48 (21.8%)	26 (23.0%)	22 (20.6%)	
Summer (Jun-Aug)	27 (12.3%)	16 (14.2%)	11 (10.3%)	
Caregiver characteristics				
Biological mother	205 (93.8%)	108 (94.7%)	97 (97%)	0.61
High School Graduate or +	178 (80.9%)	95 (83.3%)	83 (78.3%)	0.34
Marital status single	164 (75.2%)	88 (77.9%)	76 (72.4%)	0.11
Child health characteristics				
Asthma severity				
Mild	56 (25.3%)	29 (25.2%)	27 (25.5%)	0.51
Moderate	101 (45.7%)	49 (42.6%)	52 (49.1%)	
Severe	64 (29.0%)	37 (32.2%)	27 (25.5%)	
Allergen sensitization (positive >=1)	160 (82.5%)	80 (83.3%)	80 (81.6%)	0.76
SHS exposure + ^b	119 (55.9%)	64 (58.2%)	55 (53.4%)	0.48
Cotinine level mean (SD)	2.84(4.6)	3.14(5.4)	2.56 (3.7)	0.38
Asthma specialty				

	All participants N = 222 N (%)	CON group N = 115 N (%)	INT group N = 107 N (%)	P-value (group difference)
Care last 2 yrs				
Yes	44 (20.1)	26 (22.6%)	18 (17.3%)	0.33
Asthma medication fills over 12 month prior to enrollment				
Median controllers Rx (IQR) (1 year prior to baseline)	2 [0–7]	3 [0–8]	2 [0.5–5]	0.10
SABA >4 fills (1 year prior to baseline)	86 (38.7%)	50 (43.5%)	36 (33.6%)	0.12
AMR >0.50 (Pre-year baseline)	109 (55.3%)	56 (54.9%)	53 (55.8%)	0.90
Worried about medication side effects	79 (35.9%)	42 (36.5%)	37 (35.2%)	0.84

P-value assessed between group differences using Chi-square test statistic for categorical factors, *t*-test for average age, and Mann-Whitney U test for distribution of # controllers Rx (pre year).

^aPoor defined by household income and number of persons in household as less than the Federal poverty level.

^bSecondhand smoke exposure positive (salivary cotinine 1.00 ng/mL).

TABLE 3

Characteristics of participants at 12 months by group

N (valid %)	All participants N = 204			CON group N = 106		INT group (N = 98)		P-value (group difference) ^a
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)		
Child health								
Characteristics at 12 months								
Symptom free days/past 2 weeks	8.5 d (5.4)	9.2 d (5.1)	7.8 d (5.7)	0.06				
Symptom free nights/past month	23.9 n (9.5)	24.1 n (9.2)	23.6 n (9.8)	0.69				
Asthma control								
Well controlled	21 (10.3%)	8 (7.6%)	13 (13.3%)	0.30				
Not well controlled	100 (49.3%)	56 (53.3%)	44 (44.9%)					
Very poorly controlled	82 (40.4%)	41 (39.0%)	41 (41.8%)					
SHS Exposure +	116 (61.1%)	59 (60.8%)	57 (61.3%)	0.95				
Cotinine level mean (SD)	2.83 (4.0)	2.71 (3.9)	2.97 (4.1)	0.66				
Mice seen in home	56 (28.9%)	28 (27.7%)	28 (30.1%)	0.71				
Cockroaches seen in home	59 (30.3%)	30 (29.4%)	29 (31.2%)	0.79				
Asthma medication fills over 12 months								
Median controllers Rx (IQR) (post year)	3 [1–8]	4 [1–9]	2.5 [0–7]	0.02				
SABA >4 fills (post year)	71 (34.8%)	38 (35.8%)	33 (33.7%)	0.74				
AMR >0.50 (post year)	108 (60.3%)	60 (63.2%)	48 (57.1%)	0.41				
Worried about medication side effects (@12 mos.)	60 (30.6%)	28 (27.7%)	32 (33.7%)	0.37				

N = 204 with complete follow-up data.

^a P-value based on GLM with Poisson distribution specified for count data in evaluation of Symptom free days and nights, Chi-square test to assess distributional between group difference for categorical factors, and Mann-Whitney U test for distributional difference in controller fills.

Univariate (unadjusted) predictors of increased hazard of >1 ED visit at 12 months for ALL participants and allergen sensitization only participants

TABLE 4

	All participants N = 222		Allergen sensitized only participants N = 160 (80 per group)	
	HR ^a (95%CI)	P-value	HR ^a (95%CI)	P-value
INT vs CON group	1.10 (0.76–1.69)	0.61	1.10 (0.72, 1.67)	0.66
Child characteristics				
Age of child, years	0.96 (0.89–1.03)	0.23	0.95 (0.87, 1.03)	0.22
Male child	1.16 (0.78–1.72)	0.45	1.06 (0.68, 1.65)	0.81
Poor ^b	1.16 (0.77–1.75)	0.47	1.36 (0.85, 2.17)	0.20
Season @ enrollment:				
Fall (Sep-Nov)	-	0.75	-	0.69
Winter (Dec-Feb)	1.28 (0.82–2.02)	0.28	1.16 (0.68, 1.99)	0.58
Spring (Mar-May)	1.07 (0.64–1.77)	0.81	1.36 (0.79, 2.34)	0.27
Summer (Jun-Aug)	1.13 (0.60–2.12)	0.70	1.32 (0.67, 2.61)	0.42
Child health characteristics				
Asthma severity:				
Mild	-	0.20	0.13	-
Moderate	1.39 (0.86–2.26)	0.18	1.20 (0.71, 2.04)	0.49
Severe	1.60 (0.96–2.68)	0.07	1.75 (1.00, 3.05)	0.05
Allergen sensitization (>1 positive result)	1.46 (0.83–2.56)	0.19	-	-
SHS exposure positive(cotinine >1.0ng/mL)	0.94 (0.65–1.37)	0.75	0.89 (0.58, 1.37)	0.60
Asthma medication characteristics				
# Controllers fills/pre year	1.04 (1.00–1.07)	0.03	1.04 (0.99, 1.08)	0.08
AMR (pre year) <0.50	0.72 (0.49–1.07)	0.11	0.73 (0.47, 1.14)	0.17
SABA (pre year) >4 fills	1.58 (1.09–2.29)	0.02	1.44 (0.94, 2.20)	0.10
Caregiver worried about medication side effects	1.25 (0.86–1.83)	0.25	1.14 (0.74, 1.74)	0.55

Based on cox proportional hazards regression.

^aHR represents hazard of ED visit in any interval per unit increase for continuous variables and in patients represented by factor level listed versus reference category for categorical variables (eg, male vs female children).

^bPoor defined by "Federal Poverty Level 2015 threshold" that considers family income and number living in household.

TABLE 5

Multivariate (adjusted) predictors of increased hazard of >1 ED visit over 12-month Follow-up^a

Predictors	HR (95%CI)	P-value
Control vs intervention group ^b		
SHS exposure (NONE)	1.85 (1.02, 3.38)	0.04
SHS exposure (YES exposed)	0.82 (0.45, 1.51)	0.53
Allergic sensitization (positive vs negative)	2.63 (1.37, 5.06)	0.01
SABA pre baseline (>4 vs <4 fills/12 months)	1.52 (0.98, 2.34)	0.06
AMR pre baseline (<0.50 vs >0.50)	0.64 (0.42, 0.99)	0.05
Age of children, (per each year increase)	0.90 (0.82–0.98)	0.01

^aPredictors were determined forward selection of variables in cox proportional hazards regression analyses based on level of significance in univariate analyses (all participants) and test of interaction where directional between group differences in HR were observed (Intervention status and SHS exposure).

^bControlling for Allergen sensitization, SABA pre baseline, AMR pre baseline, age of children, interaction effect between group, and SHS exposure.