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Environmental Health Insights

Eastern Carolina Asthma Prevention Program (ECAPP): An Environmental Intervention Study Among Rural and Underserved Children with Asthma in Eastern North Carolina

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ABSTRACT

OBJECTIVE: Asthma is the most common chronic childhood condition affecting 6.3 million (US) children aged less than 18 years. Home-based, multi-component, environmental intervention studies among children with asthma have demonstrated to be effective in reducing asthma symptoms. In this study, a local hospital and university developed an environmental intervention research pilot project, Eastern Carolina Asthma Prevention Program (ECAPP), to evaluate self-reported asthma symptoms, breathing measurements, and number of asthma-related emergency department (ED) visits among low-income, minority children with asthma living in rural, eastern North Carolina. Our goal was to develop a conceptual model and demonstrate any asthma respiratory improvements in children associated with our home-based, environmental intervention.

METHODS: This project used a single cohort, intervention design approach to compare self-reported asthma-related symptoms, breathing tests, and ED visits over a 6 month period between children with asthma in an intervention study group (n = 12) and children with asthma in a control study group (n = 7). The intervention study group received intense asthma education, three home visits, 2 week follow-up telephone calls, and environmental intervention products for reducing asthma triggers in the home. The control group received education at baseline and 2 week calls, but no intervention products.

RESULTS: At the end of the study period, significant improvements were observed in the intervention group compared with the control group. Overall, the intervention group experienced a 58% (46 ± SD 26.9) reduction in self-reported asthma symptoms; 76% (34 ± SD 29.7) decrease in rescue medicine; 12% (145 ± SD 11.3) increase in controller medicine; 37% decrease in mean exhaled nitric oxide levels and 33% fewer ED asthma-related visits.

CONCLUSION: As demonstrated, a combination of efforts appeared effective for improving asthma respiratory symptoms among children in the intervention group. ECAPP is a low cost pilot project that could readily be adapted and expanded into other communities throughout eastern North Carolina. Future efforts could include enhanced partnerships between environmental health professionals at local health departments and pediatric asthma programs at hospitals to carry out ECAPP.

KEYWORDS: exhaled nitric oxide, environmental health, airway inflammation

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Introduction

Asthma is the most common chronic childhood condition among children aged less than 18 years affecting 6.8 million or 9% of children in the U.S.[1,2] Approximately 24% of children aged 5–17 years have limited activity due to asthma, and it disproportionately affects low-income and minority populations.[3] Non-Hispanic Black children are more likely to be diagnosed (22%) and experience higher rates of asthma emergency department (ED) visits, hospitalizations (per 100 persons), and asthma-related deaths than Hispanic or non-Hispanic white children.[4,5] Over the past decade, a number of asthma research studies have been published with positive results using home-based, environmental interventions among people with asthma.[6–10] In a comprehensive, systematic review of 20 studies, Crocker et al summarized that "home-based, multi-trigger, multi-component interventions with an environmental focus were effective in improving quality of life and productivity among children and adolescents with asthma."[6] In several studies, products such as non-toxic chemical cleaners, non-allergenic mattress and pillow encasings, and containers for foods and baits for rodent and cockroach control were shown to be effective in reducing allergy symptoms, the number of asthma symptoms (symptom days), missed school days, and asthma acute care visits.[6]

Asthma can be described as a chronic disease with episodic airway inflammation and reactivity that causes airflow obstruction. Asthma causes episodic symptoms or "attacks" when the airways become inflamed, and smooth muscles surrounding the airways become abnormally reactive and contract. This leads to narrowing of the airways that makes breathing difficult. An "asthma attack" can occur when an individual is exposed to an asthma "trigger." However, asthma triggers can vary among individuals and their body's immune response to substances. Examples of asthma triggers includes, airway irritants such as exposure to allergens, chemicals from cleaning products, tobacco smoke, air pollution, infections, exercise, mold, and changes in the weather. For an individual with asthma, respiratory symptoms usually include wheezing, coughing, shortness of breath, and chest pain, and can range from mild to life threatening.[11]

As one of the most common chronic childhood diseases, asthma has increasingly become a focus of clinical research and public health programs.[12] Asthma results in increased health care utilization, high health care costs, indirect costs, such as missed number of school days and missed work days for caretakers, and premature death.[1] Although asthma is a condition that most likely results from complex interactions between multiple environmental and genetic effects, it is not clear how to prevent asthma from developing.[1,5,11] Most adverse health outcomes from asthma, such as hospitalization and even death are hypothetically preventable. Measures to control and prevent exacerbations in persons with asthma have been well established in evidence-based clinical guidelines.[11]

Factors that contribute to poor indoor environmental housing quality have been shown to be inextricably linked with poor asthma control.[6,13] For example, biologic agents and housing conditions rank highly among environmental factors implicated in asthma morbidity, and may include indoor allergens from cockroaches,[14,15] rodents,[16,17] house-dust mites,[18–20] animal dander, and fungi.[21–24] A home with a relative humidity (Rh) level above 60% may create excess moisture, supporting the growth of mold, mold spores, and providing a favorable environment for dust mites.[13] Common sources of water and moisture that may cause mold in homes are roof leaks, condensation, damp foundations and crawl spaces, inadequate ventilation, activities such as bathing and cooking, and unattended plumbing problems.[25,26] Poorly maintained heating and ventilation systems can disperse allergen-containing dust and mold spores throughout the home.[13,27] Poor maintenance or improper sealing of exterior holes or cracks can provide entry points for pests, including cockroaches and mice, which may be attracted to food sources or moisture inside the home.[13] In addition, chemicals in the home, such as air fresheners, pesticides, and cleaners can serve as irritants that may trigger asthma and contribute to other respiratory concerns.[28] Several asthma studies have focused on environmental interventions in the home environment[6] and the use of specialized products to reduce asthma triggers, such as non-toxic chemical cleaners, non-allergenic mattress and pillow encasings, and containers for foods and baits for rodent and cockroach control.[11]

The eastern most 29 counties (ENC-29) of North Carolina, including Pitt County are predominately rural and underserved. In general, the region has a high percent of unemployment and suffers disproportionately from the highest rate of health disparities of chronic diseases and illnesses affecting minority populations in the state.[29] Many rural counties within ENC-29 have limited access to health care services yet the area has the highest percent of ED visits by children with asthma and asthma-related illnesses.[29,30] Pitt County is located in central eastern NC and is considered the medical and educational hub for the ENC-29 region. Vidant Medical Center and East Carolina University (ECU) are the major employers in the Pitt County community, while surrounding counties in the ENC region tend to be primarily either agricultural or manufacturing service sectors. The backdrop of the rural environment of the region is characterized by low-income, minority populations often living in poor quality housing such as dilapidated, older mobile homes. According to the U.S. Census (2008–2012), the demographics of Pitt County is comprised of 34.6% Black residents, with a median household income of $40,452.[31] Over 23% of families have children aged less than 18 years and an income below the poverty level. In 2012, an estimated 13.2% (9,990) of dwellings in Pitt County were mobile homes.[31]

Based on these factors, The Brody School of Medicine, Department of Public Health at ECU, and Vidant Medical Center Childhood Asthma Program, developed an intervention pilot study to evaluate the potential impact of reducing asthma among children in the ENC region. The study was developed under the name Eastern North Carolina Asthma Prevention Project and was targeted at children with asthma living in low-income households. In general, the creation of ECAPP primarily extended the hospital's existing childhood asthma program framework of in-home asthma visits by adding an increased level of asthma education, additional respiratory testing, environmental intervention products, services, and consultation. The goal for this study was to evaluate the effectiveness of an environmental intervention by comparing an intervention group with a control group and by measuring differences in: (1) self-reported asthma symptoms, (2) breathing tests (spirometry and airway inflammation), and (3) number of asthma-related ED visits among low-income, minority children (5–17 years) with physician-diagnosed asthma. Based on our findings, explanations and recommendations for demonstrating ECAPP as a conceptual model that could be replicated or expanded to other communities in the ENC region are offered.

Methods and Measures

A total of 19 children and their caregivers participated in the study. In two cases, siblings with physician-diagnosed asthma were included. Guidelines and recommendations from The Guide to Community Preventive Services Program[32] and National Heart, Lung and Blood Institute, National Asthma Education and Prevention Program (NAEPP), Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma[11] were used as a framework for this project. In part, both reports provide expert recommendations for long-term management of asthma and for managing asthma exacerbations including, the use of lung function tests, environmental control measures, patient education, and pharmacologic therapy.[11,32] Additional guidance and forms (ie, pre-screening and eligibility) were provided by the Seattle King County Asthma Program (KCAP) Health Department website found at http://www.kingcounty.gov/healthservices/health/chronic/asthma.aspx.

Participants. A total of 19 children (5–17 years) with physician-diagnosed asthma and their caregivers participated in the study. Participants were recruited through referrals made by asthma case managers (ACMs) employed by the childhood asthma program from the local hospital. Potential participants were screened for eligibility by telephone interview. Over 100 caregivers that had children with asthma were asked to participate via mail and hand delivered letters. Twenty-five individuals responded, and 68% (17/25) qualified. Children were considered eligible if they were between the ages of 5 and 17 years, had been physician-diagnosed with asthma (at least 6 months prior to enrollment), had persistent asthma (defined as wheezing, chest tightness, cough, limited activity, or waking up at night), had an ED or unscheduled clinic visit due to asthma, and had a family household income of 200% or less of the federal poverty level.

Data were collected between September, 2013 and February, 2014. All caregivers provided written consent and children participants provided written assent. This research project was approved by the East Carolina Institutional Review Board (IRB-#000288) prior to any data collection.

Study design and data collection. This was an intervention study developed under the guidelines of NAEPP and previous intervention studies that have demonstrated improvements in asthma respiratory symptoms using environmental intervention products (eg, HEPA vacuums, non-allergen mattress and pillow encasings, etc.) for reducing asthma triggers in the home. The project involved an intervention group and a control group study of children with persistent asthma and their caregivers. Because of the small sample size, more participants were included as cases than controls, primarily because of the previous evidence-based literature documenting the effectiveness of using environmental interventions for improved respiratory asthma outcomes.

Data was collected by the project team members during each home visit. The project team members involved to carry out this project, included three trained ACMs from Vidant Medical Center, and an environmental health professor, medical, and public health students from ECU. The ACMs were trained asthma professionals with backgrounds in social work, nursing, and respiratory therapy. All ACMs had specialized skills in asthma education and empowering families on how to properly manage asthma. The environmental health professional (EHP) was a registered environmental health specialist (REHS/RS) experienced in healthy homes and indoor air quality investigations. Medical and public health students that assisted with this project were currently graduate assistants enrolled in the Master of Public Health program at ECU.

As shown in Figure 1, following the pre-qualification phone screening, a date convenient to the caregiver and child was scheduled to complete the baseline survey, breathing tests, environmental assessment, and consent/assent forms. Once selected, participants were randomized and assigned to either an intervention or control study group. The completion of consent/assent forms, survey interviews, breathing tests, and environmental assessments were completed in the participant's home as part of the home-based visit. Caregivers in the intervention group received the environmental products (described below) with an educational demonstration on how to use the products. The control group received all of the above but no environmental intervention products. A $20 gift card was provided to the control group as an incentive to continue to participate through the study period. In addition, all environmental products and demonstrations were provided to participants in the control study group at the end of the study. Ongoing phone calls at two-week intervals were provided to caregivers in both groups to check the status of the child's respiratory condition and answer any questions. At week 12, a 3-month re-evaluation of breathing tests [spirometry and fractional exhaled nitric oxide (FeNO)] was conducted for

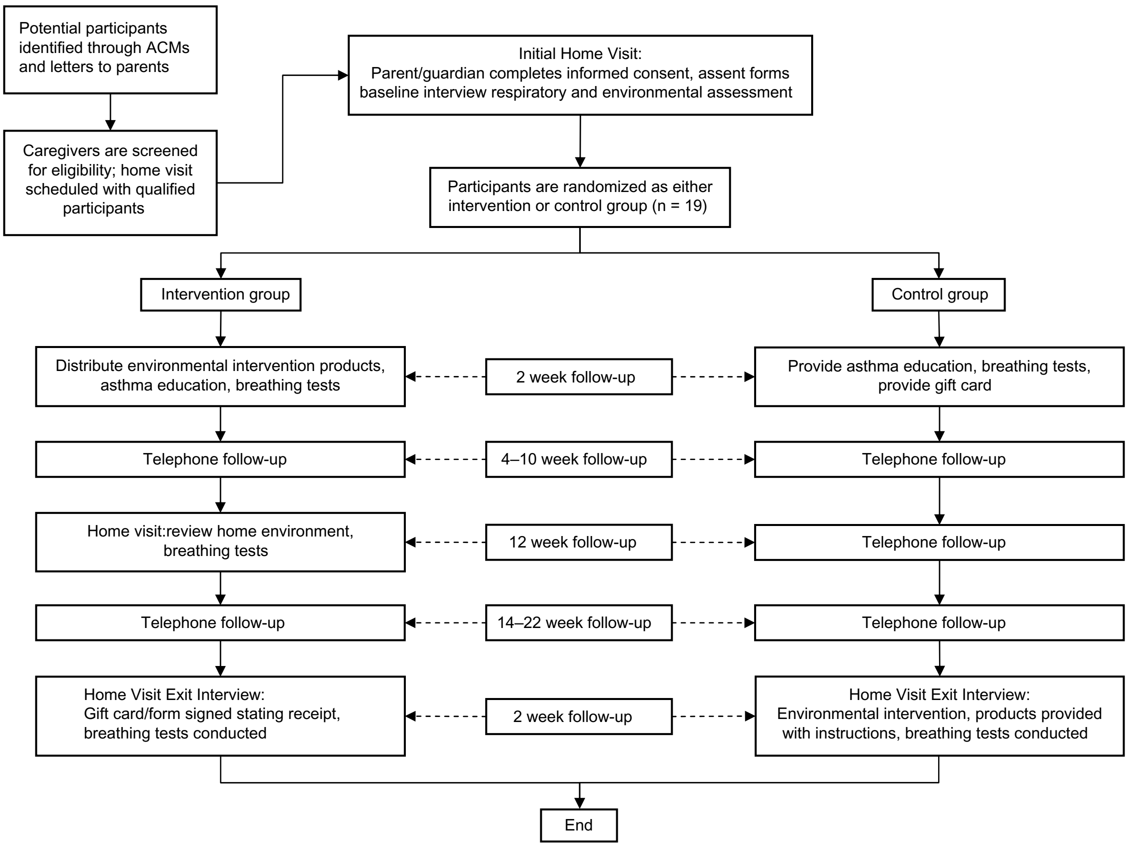

Figure 1. Flowchart of study procedures.

each child in the intervention study group. At the end of the 6-month study period, a survey, breathing tests, and an environmental assessment were conducted for child participants in both study groups.

NHLBI[11] guidelines for the diagnosis and management of asthma were used to create a questionnaire for self-reporting of respiratory and asthma symptoms. Caregivers were interviewed by ACMs and asked to self-report respiratory symptoms of their child's wheezing, coughing, and tightness of chest. Interviews with each of the caregivers took approximately 30–45 minutes to complete. Lung function tests of participants were performed using the Koko handheld spirometry system (Pulmonary Data Services, Inc., Louisville, CO, USA) on a laptop computer. Calibration of instrumentation was conducted using an impact syringe, prior to testing. All measurements among subjects were made in accordance with American Thoracic Society (ATS) guidelines (2005). Nitric oxide (NO), a biomarker that has successfully been used as an indicator for identifying eosinophilic airway inflammation for supporting the diagnoses of asthma, was assessed using the portable, Aerocrine, NIOX MINO® (Solna, Sweden, 2010). Per instructional guidelines, the subject was asked to inhale to full lung capacity through the device and then exhale using a slow controlled breath for 10 seconds at an expiratory flow of 50 mL/s. Visual and auditory signals assisted the participant with maintaining proper flow rate. Because the device is nitric sensitive, participants were asked if they had eaten, drank, or smoked within the past hour prior to the test. Spirometry and FeNO breathing tests took each participant an estimated total time of 15–20 minutes to complete.

An indoor environmental assessment of asthma triggers, including a combination of physical measurements (eg, temperature and Rh) and visual observations (eg, mold/mildew), was conducted in each dwelling by the EHP. Self-reported information on pest infestations over the past month by the participants was also recorded. Guidelines and assessment instruments for evaluating the indoor environment of each dwelling were based on the National Survey of Lead Hazards and Allergens in Housing: Resident Questionnaire developed by the U.S Department of HUD and NIEHS (OMB#2530–0012).

To assess for moisture levels that may contribute to biological growth in the dwelling, Rh, and temperature data were collected in each dwelling at baseline and exit interviews using the Digital Amprobe THWD-3 Thermo Hygrometer (Everett, WA, USA). Readings of Rh and temperature were taken in the child's bedroom and main living area of each home. During the assessment, the child's sleeping room and other rooms in the dwelling were observed by the EHP for the presence of moisture and/or mold. Wall moisture content in areas that suggested water problems (eg, from broken pipes, leaks, heavy rain, or flooding) was verified using a pin-type, moisture meter (Model M0220, EXTECH, Moisture Meter; Waltham, MA, USA). Visual inspections of the heating, ventilation, and air conditioning (HVA/C) evaporator coils and associated drain pan and unit filter (if present) were made with a flashlight for visible signs of mold and recorded by the investigator. A walk-through environmental evaluation of each dwelling took approximately 15–20 minutes to complete.

Measures. *Asthma survey.* Baseline survey questions included personal interviews by ACMs and the child's primary caregiver. Demographic and personal measures included child's age, gender, race/ethnicity, education, body mass index, insurance type, rent, or own dwelling. Measures of asthma respiratory symptoms in the past 2 weeks were assessed by self-reported questionnaire. In several cases, ACMs had established work-client relationships with the participants and knowledgeable of the child's asthma history. All interviews were conducted in the privacy of the participant's home by female ACMs with female caregivers. Self-reported respiratory symptom questions were used to evaluate asthma severity based on NAEPP guidelines and included the following;

1. "During the past 2 weeks, about how many days did [CHILD] have any asthma symptoms such as wheezing, chest tightness, cough, limited activity, or waking up at night because of asthma?) _____ days
2. During the past 2 weeks, about how many days did [CHILD] use asthma rescue medicine such as albuterol, Proventil, Ventolin, Xopenex, MaxAir or ProAir? ___ days
3. During the past 14 days, about how many days did [CHILD] use asthma controller medicine or steroids such as QVAR, flovent, pulmicort, or Advair, Asmanex, Alvesco, Dulera or Symbicort? Days__________
4. During the past 2 weeks, did [CHILD] get hospitalized or visit the emergency room for asthma? Yes__ No__

During the past 2 weeks, did [CHILD] have an unscheduled clinic visit to see a doctor or health care provider for an asthma attack? Unscheduled visit includes walk-in or scheduled less than 24 hours ahead. Yes__ No__ "

Data on ED visits related to asthma were summed to provide estimates of the total number of visits. Self-reported ED visits were cross-verified using hospital utilization data for each child for the past 6 months prior to the study and compared with the 6-month study period. Following every home visit, the child's caregiver and healthcare provider were provided with copies of the breathing test results. Case follow-up was made by the ACM every 2 weeks by telephone. Each interview took approximately 30–45 minutes to complete.

Environmental assessment. The environmental assessment included visual and physical observations of all rooms in the home, including the child's bedroom for common indoor environmental asthma triggers. Measures included the following: temperature and Rh, presence of cockroaches, rats or mice, mold and moisture, air conditioning unit and filter evaluation, dust, signs of smoking inside the dwelling, roof leaks or water damage inside the dwelling, fragrances, stuffed toys, and furry pets (eg, cats and dogs). The presence of live or dead cockroaches and rodents were assessed by visual signs of excrement, cockroach egg casings, and/or rodent holes. The presence of mold and mildew were assessed by visual signs of leaks (and probed with moisture meter), mold, water damage, and smell of mildew odor. The presence (or absence) of an air conditioning unit in the dwelling and an inspection of the HVA/C condenser unit and filter were also observed for biological growth and/or dust. The number of participants reporting smoking tobacco inside the home was also recorded.

Exhaled nitric oxide. Measurements of the fractional concentrations of exhaled NO (FeNO) in the exhaled breath were conducted with children in the intervention and control study groups at baseline, mid-study, and exit visits. Measurements were performed prior to spirometry because spirometry maneuvers have been shown to transiently reduce exhaled NO levels.[33,34] Recommended reference levels of NO above 20 ppb in children (≤12 years) and 25 ppb (>12 years) were considered elevated.[34] Follow-up of breathing tests results were provided to health care providers. In situations where FeNO levels were elevated, health care providers were contacted immediately by ACMs.

Spirometry. Objective measures of lung function were obtained for each participant using spirometry and evaluated using the forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio. The percent of predicted values were based on the NHANES III data set reference and standards of ATS.[35,36] Spirometry was conducted by a certified spirometry technician.

Intervention. Children and their caretakers in the intervention group received three home visits (baseline, mid-study, and exit visit at end of study) by the ACMs and EHP. Case managers coordinated appointments, conducted 2 week phone calls, determined needs, and reinforced education to intervention and control groups. Participants in both groups were given opportunities to call ACM for more information if needed.

At the end of the baseline interview, participants in the intervention group received environmental intervention products to assist in the cleaning and maintenance of the child's home environment and that have been shown in previous studies to reduce allergy and asthma triggers.[11] These items included: a Royal® commercial vacuum cleaner with a HEPA filter bag, non-allergen, Allersoft© cotton dust mite mattress and pillow encasings (fitted to the child's mattress and pillow), low-odor, chemical "free" furniture and floor cleaning products, storage containers for food, mouse/rat glue traps, and non-toxic cockroach baits. All cleaning products were purchased at cost from local, general merchandise stores. Vacuum cleaners, HEPA filters, mattress, and pillow encasings were purchased in bulk, at cost, over the Internet. Ancillary items including dust cloths, floor mops, and sponges were used to supplement the cleaning products and provide more convenient use for the caregiver. Educational demonstrations were provided to the parent/caregiver to show how to properly vacuum the floor (ie, crisscross and back-forth motion to cover carpet fibers) and fabric furniture. Caregivers were provided with instructions on washing mattress and pillow encasings in hot water [≥130°F (54.4 °C)] at least once per week. Instructions and guidance were provided on eliminating smoking from inside the home, and removing fragrances, furry pets, and stuffed toys. Informational packets on smoking cessation and education on asthma triggers were given to both groups at baseline visits.

Data analysis. In descriptive analysis, for categorical measures, frequencies and percentages were summarized as measures from the data for continuous measures (scales), means and standard deviations were used to describe their distributions. Differences in personal and health characteristics and behaviors were examined with crosstabs and tested with chi-square or Fishers exact tests and *t*-test as appropriate.

FeNO levels between the intervention and control groups were measured at three points: baseline, mid-study, and end of study period. FeNO measures were log-transformed to make them following a normal distribution. For repeated measures of FeNO, the generalized estimating equations (GEE) was used to evaluate the change of FeNO over time after accounting for the dependence of repeated observations within each subject. This analysis was run through the GENMOD procedure in SAS. All analyses were performed using SAS V9.4 (Cary, NC, USA) or SPSS v20 and *P*-values less than 0.05 were considered statistically significant.

Results

Demographic characteristics of participants and indoor environmental conditions in the home are shown in Table 1. There were 9 male and 10 female children participants, with the majority reporting as Black, non-Hispanic (91.7%). Most caregivers (50.0%) in the intervention and control groups reported having "some college" (education beyond 12th grade). Most participants in the intervention group (58.3%) and the control group (57.1%) lived in mobile homes, while the majority of the intervention group (75.0%) rented their homes compared with the control group (43.0%).

For environmental "triggers" in the home, the presence of cockroaches was identified in 40% of the intervention group and 33% of the control group dwellings. Traditional, chemical cleaners that contained toxic chemicals were found in all (100%) of the intervention group dwellings and 83% of control dwellings. All (100%) of homes in both groups had carpet in the child's bedroom, upholstered furniture in the main living areas, and had an HVA/C unit. Visual inspections of HVA/C units coiling coils revealed mold growth on 70% of the cooling coils in the intervention group and 67% in the control group.

As shown in Figure 2, the percent increase or decrease of the child's self-reported asthma respiratory symptoms and use of rescue and controller medicine were observed from baseline to the end of the 6 month study period. For the intervention group, overall results were as follows: self-reported asthma symptoms decreased by 58% (46 ± SD 26.9), rescue medicine decreased by 76% (34 ± SD 29.7), and controller medicine increased by 12% (145 ± SD 11.3). For the control group, self-reported respiratory symptoms increased by 14% (22.5 ± SD 2.1); use of rescue medicine increased by 53% (21.5 ± 6.4); and controller medicine decreased by 53% (134 ± 67.9). In addition, the number of asthma-related ED hospital visits for children participants over the 6 month period were compared with the number of asthma-related ED hospital ED visits 6 months prior to the study. Overall, a 33% increase in the number of asthma-related ED visits were identified in the control group and a 75% decrease in asthma-related ED visits among the intervention study group.

As shown in Figure 3, FeNO levels over the study period of time between the intervention and control groups were measured and evaluated. The results from the GEE models show that geometric mean FeNO levels among the intervention group had significantly declined from 24.74 at baseline to 16.58 ppb at the end of the study period ($P < 0.037$). FeNO levels among the control group had no significant change (ie from 9.59 at baseline to 8.55 ppb) at the end of the study period ($P = 0.69$).

Mean values for FVC, FEV_1, and FEV_1/FVC ratio for all children participants, who were able to perform lung function tests (n = 19) at the end of the study period were evaluated. Overall, average FVC, FEV_1, and FEV_1/FVC percent predicted were above 80% and considered normal (107%, 100%, and 90%, respectively). When the intervention and the control study groups were stratified, the intervention group had higher mean FEV_1 (104%), and FEV_1/FVC (93%) percent predicted values compared with the control group (93.0% and 85.0%, respectively).

Discussion

Overall, implementation of ECAPP provided for significant reductions in asthma respiratory symptoms, airway inflammation, ED visits, and medication adherence in the intervention study group compared with the control study group. The impact the environmental products had on reducing asthma among children in the intervention group compared with the control study group was not measured. Therefore, it is difficult to determine with any precision the level of effectiveness that these products had on the child's asthma respiratory symptoms. Nevertheless, NAEPP guidance and previous studies documenting reduction of asthma morbidity using multicomponent environmental interventions provides supporting evidence for the findings of our study. Overall, environmental intervention products, increased asthma education (including proper inhaler medication technique and medication usage)

Table 1. Demographic and indoor environmental dwelling characteristics of children with physician diagnosed asthma and their caregivers: comparison of intervention and control groups (n = 19).

	N = 12(%) INTERVENTION GROUP	N = 7(%) CONTROL GROUP
Demographic Characteristics		
Childs age in years: Mean (SD) [range]	9(3.96)[5–17]	10(3.05)[6–15]
5–9 years	8(66.7)	3(42.8)
10–14	3(25.0)	3(42.8)
15–17	1(8.3)	1(5.3)
Child's gender		
Male	6(50.0)	3(42.9)
Female	6(50.0)	4(57.1)
Child's race/ethnicity		
Black Non-Hispanic	11(91.7)	7(100.0)
White-Hispanic	1(8.3)	NR
Caregivers education		
Less than high school	NR	1(16.7)
HSD or GED	3(30.0)	NR
Some college	5(50.0)	3(50.0)
College graduate	2(20.0)	2(33.3)
Child's Body Mass Index (Mean)[SD]	18.11[5.31]	23.29[12.01]
Insurance Type		
Medicaid	11	6
Private	1	1
Dwelling type		
Mobile home	7(58.3)	4(57.1)
Single family house	3(25.0)	2(28.6)
Apartment/Townhouse/Duplex	2(16.7)	1(14.3)
Rent or own dwelling		
Rent	9(75.0)	3(43.0)
Own	3(25.0)	4(57.0)
Presence of indoor environmental "triggers" in dwelling		
Cockroaches or signs of cockroach excrement	4(40.0)	2(33.3)
Mice/rats or signs of rodent fecal excrement	4(40.0)	2(33.3)
Stuffed toys in child's bedroom	6(60.0)	3(50.0)
Fragrances/strong odors	4(40.0)	2(33.3)
Use of chemical cleaners/products	10(100.0)	5(83.3)
Smoker in home	4(40.0)	1(16.7)
Visible signs of dust	7(70.0)	5(83.3)
Carpet in child's bedroom	10(100.0)	6(100.0)
Upholstered furniture in main living area	10(100.0)	6(100.0)
Furry pet inside home	4(40.0)	1(16.7)
Kerosene heater or wood stove	2(20.0)	1(16.7)
Visible signs of moisture, mold and mildew	3(30.0)	NR
Roof leaks or visible signs of water damage	3(30.0)	NR
Mildew or musty odor in sleeping room		
Presence of air conditioning	12(100.0)	7(100.0)

(*Continued*)

Table 1. (*Continued*)

	N = 12(%) INTERVENTION GROUP	N = 7(%) CONTROL GROUP
H/VAC system maintenance		
Presence of biological growth on coils	7(70.0)	4(66.7)
Temperature (Mean: degrees F (SD)		
Common area	74.3(6.6)	72.6(2.3)
Relative Humidity (Mean: Rh (SD)		
Common area	57.7(10.1)	49.3(12.1)

Notes: Therefore, total may not equal N = 19. Conditions for presence of cockroaches and mice includes observed by investigator or reported seen by the occupant within the past 1 month.
Abbreviations: NR, Not Reported; H/VAC, Heating, ventilation and air conditioning system.

for the caregiver and child, 2 week reminder follow-up calls to caregivers, lead us to report that these combined components resulted in increased, well-managed asthma care among the intervention participants in our study.

The findings of our pilot project are consistent with other studies reporting on the effectiveness of multi-component, environmental intervention in reducing asthma symptoms among children.[6] In a randomized, controlled study, Morgan et al concluded that an individualized, targeted home-based environmental intervention approach for children with asthma was effective, resulting in reduced morbidity among inner-city children with asthma.[8] In a systematic review of community health workers by Postma et al, seven home-based studies consistently identified decreases in asthma symptoms, ED, and clinical visits as a result of environmental interventions.[9] However, asthma trigger reduction behavior among caregivers varied among studies. In a community-based, participatory research (CBPR) environmental intervention study conducted among children (4–17 years) with asthma (N = 50) in public housing, Levy et al identified significant reductions in respiratory symptoms after implementing integrated pest management (IPM), cleaning, and educational efforts.[37]

Environmental observations. In general, most Americans spend more than 90% of their time indoors, making asthma trigger avoidance in the indoor environment sometimes difficult.[38] In our project, nearly all of the caregivers we encountered expressed or displayed good intentions for reducing asthma triggers in their homes. However, over the course of the study period, we identified that smoking and/or keeping a furry pet (cat and/or dog) in the home stood out as triggers that caregivers had difficulty properly addressing. For example, despite the smoking cessation and education provided by the ACMs, indications of smoking by either the caregiver or by others were repeatedly observed in the same home as part of our visits. Interestingly, we witnessed an increased FeNO level (>25 ppb) in a child participant that had recently brought home a puppy. Weeks later, the pet was removed and when we re-tested, FeNO levels in the child were significantly lower (<25 ppb). We also observed as the project approached the winter season, several families in the

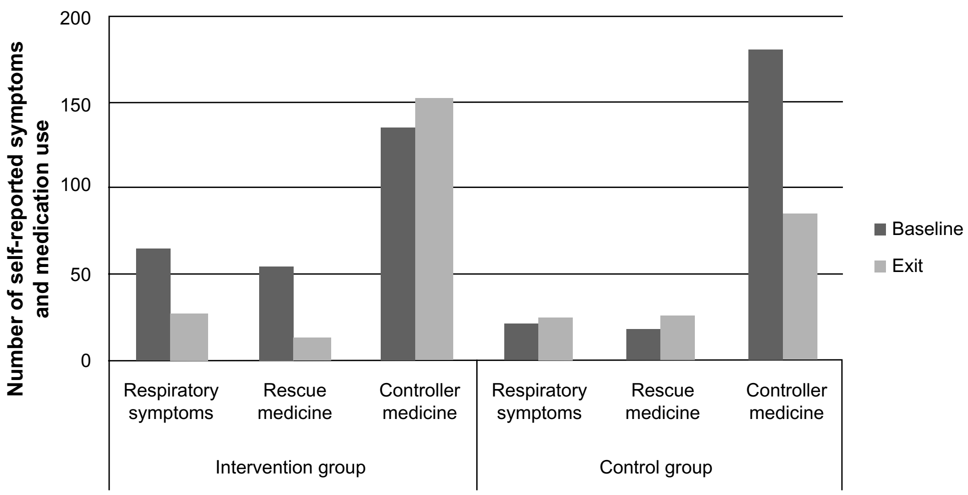

Figure 2. Number of self-reported asthma respiratory symptoms, rescue, and controller medicine use in intervention and control groups over 6 month study period.

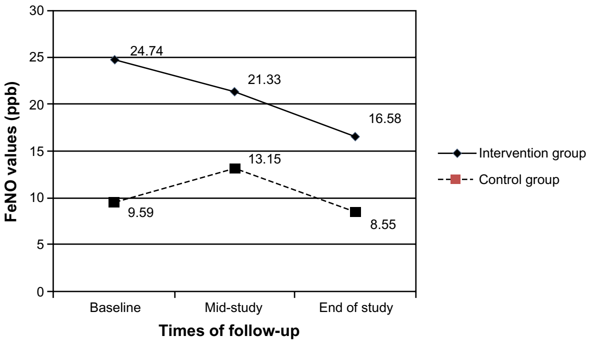

Figure 3. Geometric mean of FeNO in intervention and control groups over 6 months study period.
Note: Suggested FeNO cut points of <25 (ppb) in patients ≥12 years of age andFeNO values of <20 (ppb) in patients <12 years of age with ongoing or recent asthma-like symptoms are considered intermediate, and indicate esosinophilic inflammation and responsiveness to corticosteroids are less likely [45].

intervention group began using alternative fuel sources for heating in the home to save money. This included the use of wood stoves and/or kerosene heaters; sources of heat that produces smoke, gas, respirable particulates that can trigger asthma. Personal behavior such as pets, smoking, fragrances, and use of personal body products in the home that can trigger asthma can be sensitive issues to address with families. Nonetheless, in spite of the delicate nature, the risk of these potential asthma triggers should be addressed and discussed accordingly with the caregiver and child.

We found that the majority of participants in our study lived in rental units, with multiple, physical housing-related issues such as roof leaks, plumbing issues, cockroaches, and lack of HVA/C maintenance. In some instances, when we pointed out these problems out to, participants that were living in rental dwellings, they expressed concern, or fear of repercussions by their landlord. Nearly all of the HVA/C systems we inspected were poorly maintained with excessive biological (mold) growth and in most cases, needed moderate to high level of cleaning and/or maintenance. In some instances, the filter was either not properly inserted, had not been changed on a timely basis, or was absent. An educational session with the caregiver typically helped them to better understand the importance of having a properly cleaned and maintained HVA/C. Nevertheless, upon re-inspection of the HVA/C at the end of the study period, none of the HVA/C units had been cleaned and only the filter had been changed. We also observed in many of the rental and owner occupied dwellings, extremely high levels of cockroach infestation in the homes. In mild cases, the non-toxic baits we provided appeared to be helpful. However, in one severe case, an exterminating company had to be hired to assist with pest elimination in the home. From our perspective, this was a low cost fix and may have played an important role in helping reduce asthma respiratory symptoms as well as having a positive psychological impact on the family.

Limitations and considerations. As a pilot project, there were several limitations to this study including the self-reporting bias of asthma, respiratory symptoms, and the small sample size. Self-reporting or recall bias may have influenced the caregivers ability to properly recall the child's asthma respiratory symptoms, resulting in either an under or over estimate of the measured effect. Also, the small sample size of the study limits the generalizability of the study. Therefore, caution should be exercised when interpreting these results. Also, the environmental intervention products provided were assumed to be consistently (and properly) used by the caregivers. Initially, we administered asthma diaries to the families to keep track of house cleaning, medication management, and respiratory symptoms. However, 2 months after the project started, we collectively decided the diaries were burdensome to the caregiver and better suited as reminders rather than as a useful measure. Therefore, we included questions from the diaries into the 2 weeks follow-up calls rather than adding additional duties to the caregiver. Also, in the study design phase of the project, the investigators discussed measuring knowledge of asthma triggers among the children and caregivers. Several caregivers and children in both groups received prior education on asthma triggers by an ACM in the past. Therefore, we did not include pre- and post-knowledge questions on asthma triggers as part of the survey as we felt that they would not have provided accurate or meaningful results. Also, we did not measure the "number of missed schools days due to asthma." This was not included as a consideration, primarily because the start date of our study occurred during the summer month, before school began and then overlapped with a winter break while children were in school. Also, the study period timeframe coincided when respiratory infections and ED visits are historically high. We felt that data collected on missed school days may have questionable reliability, and considered ED visit asthma data as more reliable measures. Even though participants were randomly selected, the initial baseline self-reported asthma respiratory symptoms and geometric mean of FeNO levels were higher among the intervention group than levels of the control group. This may have indicated that the intervention group was more likely to include children with uncontrolled, persistent asthma in the intervention group than in the control group. This is something we did not control for in the study and may have resulted in a greater percent difference from initial baseline to end of study when we compared the two groups with each other.

During our home visits, we occasionally found instances when FeNO levels were clinically high (>50 ppb) and well above "normal" levels. Nearly all of our participants were Black race, which tend to have higher FeNO levels.[33] This may have been a factor in the current study and something that should be considered when interpreting these values. Another unique and interesting part of our study was the importance of using the FeNO breathing test for assessment. Over the past few years, this simple test has rapidly become more common in the clinical diagnoses of asthma, and is now included as part of the CDC, National Health and Nutrition Examination Survey.[39] We found this device to be a highly integral part of determining adherence to proper asthma medication use in our study. Currently, FeNO testing is not reimbursable to healthcare providers by Medicaid or other insurance companies in NC. Therefore, we conclude that the majority of asthma patients seen by their physicians in NC are not completing FeNO testing as part of their routine asthma clinic visits. We also identified a slight increase in self-reported rescue medicine and a decrease in the use of controller medicine in the control group. Controller medicine, also called "maintenance medicines" work over a period of time to reduce airway inflammation and help prevent asthma symptoms. Even when symptoms are not present, people with asthma should continue to take their controller medication. On the other hand, rescue medicines are quick acting bronchodilators, that react quickly when inhaled, but do not have a long-term effect. The reasoning for the increase in rescue medicine and decrease in controller medicine is not totally clear. However, Clark et al (2010) identified that 40% ($N = 936$) of African–American middle school children in Detroit were non-compliant with asthma controller medication.[40]

Because this study focused only on children, our decision to select participants aged between 5 and 17 years were based primarily on previous studies in the literature and the ability to properly perform lung function tests.[11] Children aged less than 5 years may experience difficulty performing spirometry and objective measures are difficult to diagnosis.[11] Nevertheless, future expansion of ECAPP to include children aged less than 5 years could certainly prove to be beneficial using techniques such as FeNO testing, structured asthma control tests, environmental and behavioral assessments of the home, and caregiver. Low-income families that have limited resources are forced to prioritize their needs accordingly. Food, shelter, and electricity are basic necessities that a family may set as a priority that may place medication as a secondary concern. Several times, we were reminded by caregivers of high medical costs and their limited ability to purchase asthma medication. We were told by some caregivers that daily albuterol or controller medicines were not being used in an effort to save money. Also, anecdotally, when we asked children to demonstrate proper technique for using their medication inhalers, we observed that many of the children were either using them incorrectly, did not have an inhaler spacer, or had expired medication. These are issues that can contribute to increased asthma respiratory symptoms, increased exacerbations, reduced effectiveness of medication, and additional loss of resources.

Conclusions

At the end of the project, we estimated the cost among the ECAPP intervention study group to be in the range of \$550–\$600 per family for three scheduled home visits. Costs included, environmental intervention products (vacuum cleaner, HEPA filter, mattress and pillow encasing, and cleaning products), staff time, travel, and \$20 gift cards. Costs associated with a single home based asthma visit for control group participants (without the intervention products) were considerably less than those of the intervention group. These costs can be compared with a single ED visit or several unscheduled clinic visits at \$691 and in-patient hospital stay \$7,987.[41] The impact for implementing an asthma intervention program (such as ECAPP) could generate substantial net cost saving benefits for third party insurance carriers for reducing ED and other unscheduled asthma clinic visits.[41]

We attribute much of the success of the ECAPP pilot study to the ACMs established relationships with the families, the asthma education they provided and the consistent 2 week follow-up phone calls they made as part of the on-going monitoring of respiratory symptoms. The ACMs appeared trusted among the caregivers, shared positive relationships, encouragement, and motivation to the families and children. All of the participants in the study remarked optimistically about the care and concern of the ACMs.

In light of some of the limitations mentioned, we feel that these research findings provide a unique contribution to the literature while supporting other environmental intervention and asthma studies. For example, from our review of the literature, we found that the majority of home-based, environmental intervention studies have been effective in reducing asthma, yet have centered primarily on asthma among children in urban (or inner-city) environments.[8,16,37,42] Although, our project shares similar socio-demographic characteristics, including low-income, minority, high-risk populations, as that of most urban based asthma studies, it differed by involving children and their caregivers living primarily in mobile homes in a rural area. This is an important factor to consider for future studies when examining asthma exacerbations and environmental triggers. Also, the implications of this small pilot study may offer an approach for expansion of the conceptual model of ECAPP on a much larger geographic scale. For example, in-home, asthma based visits could be implemented among partnerships between local hospitals and county health departments. Collaboration between asthma educators, nurses, and environmental health specialists could result in increased public health opportunities for reducing asthma ED visits and unscheduled asthma clinic visits in local communities. The guiding documents used for this study, were primarily developed by others, yet allowed us the flexibility to demonstrate ECAPP as a conceptual model with our targeted population. The ability to customize an asthma environmental intervention program to meet the needs of either a rural or urban community may vary. However, as demonstrated, the framework of ECAPP provides a readily adaptable model that may be well-suited for others seeking cost effective ways to reduce asthma among children in their communities.

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Author Contributions

Conceived and designed the experiments: GK, LJ, KL. Analyzed the data: XX, GK. Wrote the first draft of the manuscript: GK, LJ, DA. Contributed to the writing of the manuscript: GK, LJ, DA. Agree with manuscript results and conclusions: GK, LJ, DA, KL, JB. Jointly developed the structure and arguments for the paper: GK, LJ. Made critical revisions and approved final version: GK, LJ, KL, JB, DA. All authors reviewed and approved of the final manuscript.

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