ASTHMA AND THE HOME ENVIRONMENT OF LOW-INCOME URBAN CHILDREN: PRELIMINARY FINDINGS FROM THE SEATTLE–KING COUNTY HEALTHY HOMES PROJECT

JAMES W. KRIEGER, MD, MPH, LIN SONG, PHD, TIMOTHY K. TAKARO, MD, MPH, AND JAMES STOUT, MD, MPH

ABSTRACT

Objectives. Childhood asthma is a growing public health concern in low-income urban communities. Indoor exposure to asthma triggers has emerged as an important cause of asthma exacerbations. We describe indoor environmental conditions related to asthma triggers among a low-income urban population in Seattle/King County, Washington, as well as caregiver knowledge and resources related to control of these triggers.

Methods. Data are obtained from in-person, structured, closed-end interviews with the caretakers of children aged 4–12 years with persistent asthma living in households with incomes less than 200% of poverty. Additional information is collected during a home inspection. The children and their caregivers are participants in the ongoing Seattle–King County Healthy Homes Project, a randomized controlled trial of an intervention to empower low-income families to reduce exposure to indoor asthma triggers. We report findings on the conditions of the homes prior to this intervention among the first 112 enrolled households.

Drs. Krieger and Song are from Seattle Partners for Healthy Communities/Public Health—Seattle and King County; Drs. Krieger and Takaro are from the Department of Medicine, University of Washington; Drs. Krieger and Stout are from the Department of Health Services, University of Washington; Dr. Stout is from the Department of Pediatrics, University of Washington; and Dr. Takaro is from the Department of Environmental Health, University of Washington.

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Correspondence and reprint requests: James Krieger, MD, MPH, Public Health—Seattle and King County, 999 Third Avenue, Suite 1200-EPE, Seattle, WA 98104-4039. (E-mail: james.krieger@metrokc.gov)

Results. A smoker was present in 37.5% of homes. Mold was visible in 26.8% of homes, water damage was present in 18.6% of homes, and damp conditions occurred in 64.8% of households, while 39.6% of caregivers were aware that excessive moisture can increase exposures to allergens. Dust-trapping reservoirs were common; 76.8% of children's bedrooms had carpeting. Cockroach infestation in the past 3 months was reported by 23.4% of caregivers, while 57.1% were unaware of the association of roaches and asthma. Only 19.8% of the children had allergy-control mattress covers.

Conclusions. Many low-income urban children with asthma in King County live in indoor environments that place them at substantial risk of ongoing exposure to asthma triggers. Substandard housing and lack of resources often underlie these exposures. Initiatives involving health educators, outreach workers, medical providers, health care insurers, housing agencies, and elected officials are needed to reduce these exposures.

KEY WORDS Asthma, Child, Indoor Air Pollution, Indoor Environment, Knowledge/Behaviors, Low-Income Populations.

INTRODUCTION

Asthma has become a major public health issue in urban areas because of its increasing prevalence[1] and disproportionate impact on low-income and minority urban communities.[2–5] While the cause of increasing asthma morbidity is not clear, exposure to allergens and irritants in the indoor environment has emerged as an important cause of asthma exacerbations. Dust mites, roaches, rodents, tobacco smoke, molds, and pets have all been implicated as common indoor environmental asthma triggers.[5–11] Wheezing, asthma, and exposure to asthma triggers have also been associated with specific home environmental conditions, including dampness, water damage, humidifiers, gas stoves, carpeting, double-glazed windows, and possibly exposure to volatile organic compounds, NO_2, O_3, and particulates.[6–9,12–16]

Previous studies provide limited information regarding the prevalence of these triggers among urban populations, and none report on the frequency of the full range of suspected triggers and risk factors. Some evidence suggests that they may be more common in substandard housing occupied by low-income residents.[17,18] Furthermore, little is known about the knowledge and resources of low-income households regarding control of the triggers. The few publications indexed in Medline that address these topics[19–22] did not include information on urban low-income US groups, except for one report of a focus group.[23]

In this paper, we describe the indoor environment and housing conditions in a low-income, multiethnic urban population of children with asthma. We also describe the knowledge and resources of this population regarding control of these triggers.

Our findings are derived from preliminary data from the Seattle–King County Healthy Homes Project. Healthy Homes is a randomized controlled trial to evaluate whether outreach, education, and simple tools can reduce exposures to indoor asthma triggers and asthma morbidity. Outreach workers conduct an initial home environmental assessment, develop a home action plan, and complete eight additional visits over the next year. They offer a comprehensive package of education and social support, encouragement of behavior changes, provision of materials to reduce exposures (allergy-control bedding covers, vacuums, doormats, cleaning kits), help in locating assistance for making structural improvements to reduce moisture and control pests, and help in advocating for improved housing conditions.

METHODS

Setting and Study Population

The Seattle–King County Healthy Homes Project is located in King County, Washington, an urban area that includes Seattle. A household is eligible to participate if it includes a child aged 4–12 years with asthma of at least mild persistent severity.[24] A child is considered to have asthma if review of medical records or verification with a medical provider confirms the diagnosis. Additional inclusion criteria consist of household income less than 200% of poverty or Medicaid enrollment and the child spending at least half of the nights in the same bed. Households are excluded if the child has a coexisting nonasthmatic cardiopulmonary disease (e.g., cystic fibrosis or congenital heart disease) or has participated in other intensive asthma interventions in past 2 years (e.g., case management or outreach programs).

We are recruiting households through several channels. Sixteen clinics (community health centers, public health clinics, public hospital clinics, and other providers of care for low-income populations), the major children's hospital in the region, the county public hospital, and several emergency departments provide lists of children with recent asthma encounters. Staff of many government and community agencies (e.g., welfare offices, Head Start programs, public schools, public housing, community and recreation centers, libraries, and youth agencies) refer children to the project. An invitational letter is mailed to each of these families, and up to six attempts to establish telephone contact during a 6-week period are made to those who do not reply to the letter. The project is also promoted through local media outlets. Outreach through churches, community events, sororities, and community organizations is an additional source. Enrollment began in January 1999 and will be completed in March 2000.

Data Collection and Measures

Baseline data are collected through an initial interview in the home with the child's primary caregiver. At a second home visit, the Home Environmental Assessment List–II (HEAL-II) is completed to conclude baseline data collection. The caregiver and interviewer use the HEAL-II to inspect the home jointly, while the interviewer asks questions and makes observations of indoor environmental conditions. The HEAL-II is a modification of the original HEAL developed by the Master Home Environmentalist program.[25] Baseline data are collected by community home environmental specialists, project staff recruited from the community. They are diverse ethnically (African-American, Latina, and Vietnamese) and have completed high school, but not higher education. Training consists of 100 hours of didactic and field learning and includes instruction on interviewing skills, use of the interview instruments, asthma pathophysiology, and identification and control of asthma triggers.

Selection of items for inclusion in the interviews and HEAL-II was based on a review of models of determinants of asthma morbidity[7,26–30] and a general model of the physical, biological, and social determinants of health.[31] We also obtained expert consultation, reviewed National Asthma Education and Prevention Program (NAEPP) and Global Initiative for Asthma guidelines,[24,29] and emphasized inclusion of topics addressed by Healthy Homes protocols.

Draft questions were discussed first with the Project Advisory Group for relevance, validity, and acceptability. The Project Advisory Group consists of parents of children with asthma who meet eligibility criteria, and it advises project staff on all phases of project implementation. Revised questions then were administered to 10 community volunteers, who also met eligibility criteria, to assess comprehension, interpretation, and acceptability. Questions were adopted from previously developed questionnaires when possible[8,28,32–34] (J. Essien, MD, MPH, ZAP Asthma Caregiver Asthma Knowledge Survey Instrument, personal communication, January 1998), and such questions are referenced accordingly in the following paragraphs. Otherwise, we developed specific questions relevant to this project.

We collect data for the overall randomized controlled trial in the following domains: knowledge, beliefs, and practices concerning asthma control activities; exposure to environmental sensitizers and triggers; resources to control exposures; asthma-related morbidity and quality of life; access to and use of appropriate medical services and asthma education; social support; caregiver empowerment; socioeconomic status and other demographic information; and immune system reactivity (skin prick tests to 10 common antigens). This report includes

findings on the following topics: exposures in the home environment, caregiver knowledge of indoor asthma triggers, household resources to control asthma, and demographic information.

The home environment: exposures We collect data on exposure to tobacco smoke and other respiratory irritants, dust and dust mite reservoirs, pets, roaches, rodents, and mold, as well as evidence of excessive moisture and poor ventilation. We used and modified items from existing questionnaires if appropriate[8] (J. Essien, MD, MPH, ZAP Asthma Health and Environment Survey Instrument, personal communication, January 1998). Tobacco smoke exposure is measured by asking about smoking by the caregiver[32,35] and others in the home and by noting a tobacco smoke odor in the house. Presence of irritants is determined by questioning on use of irritant products[36] (e.g., bleach, ammonia, volatile organic compounds, drain and oven cleaners, air fresheners) and heating or cooking sources (wood stoves and unvented kerosene, gas, or propane heaters or stoves).

Dust and dust mite exposure is assessed by observing the presence and type of bedding materials, carpets and rugs, drapes, upholstered furniture, and stuffed toy animals. In addition, use and condition of filters in forced-air heating systems are examined.

Presence of roaches, rodents, and pets is described by self-report and observation during the HEAL-II. Conditions favoring roach infestation[37] (presence of food debris or unsealed stored food, clutter, trash, etc.) are also noted.

Evidence of excessive moisture is collected by questions on humidifier use, fog on glass surfaces, measurement of relative humidity, presence of vapor barriers and vents in crawl spaces, and direct inspection for mold, leaks, wet carpeting, and water damage. A home is considered "damp" if windows other than those in the bath and kitchen fog often during the heating season or if bathroom glass surfaces remain fogged for more than 15 minutes after showering. Ventilation is assessed by observing the presence and use of exhaust fans in kitchen and bath and testing the function of the fan by observing whether it generates sufficient suction to hold a piece of two-ply tissue paper against the grille. The presence of operable windows in kitchen and bathroom is also noted.

A home is considered to have a major asthma trigger if any of the following are present[5–11,38,39]: a smoker in the home, visible mold or a moldy odor, roaches reported in the past 3 months, rodents reported in the past 3 months, furred/feathered pets in the home, or exposure to dust mites (defined as lack of allergy-control mattress covers). This definition is used to define a measure of total exposure across multiple triggers and sensitizers.

Caregiver knowledge of indoor asthma triggers Most of the questions to assess knowledge and practices concerning indoor asthma triggers were developed specifically for this study because available questions did not include sufficient detail on indoor environmental factors (e.g., ref. 40). We adapted a limited number of previously used questions if appropriate[41,42] (J. Essien, MD, MPH, ZAP Asthma Caregiver Asthma Knowledge Survey Instrument, January 1998). Questions address knowledge of indoor asthma triggers (e.g., dust and dust reservoirs, dust mites, roaches, rodents, pets, mold, tobacco smoke, air pollution, irritants). Subjects are asked whether "asthma symptoms can be made worse by . . ." and then presented a list of 15 items that includes generally accepted triggers (e.g., cockroaches) and others that are not (e.g., mosquitoes). Additional questions assess household conditions that increase exposure to these triggers (e.g., moisture and water damage), practices to reduce exposures (e.g., household cleaning and dust control, removal of carpets and drapes, use of allergy-control bedding covers, washing bedding and stuffed animals, increasing ventilation, adequate home heating to reduce condensation, mold removal, use of HEPA [high-efficiency particulate arrester] air filters, pet removal, pest eradication, and strategies to reduce tobacco smoke exposure).

Household resources to control asthma We ask about the presence of both allergy-control mattress covers and pillow covers, vacuum (with allergy filtration and power head), water for washing sheets hot enough to kill mites (≥130°F, measured by running hot water for 5 minutes at tap nearest washer and recording temperature with a thermometer), pest control activities by client or professional, and HEPA air filters.

Demographic information We collect information regarding caregiver's and child's ages; caregiver's race/ethnicity (white, black, Asian/Pacific Islander, or Hispanic, with Hispanic classified as a race), income, education, insurance coverage, home ownership, and employment status; child's residential stability; and household composition.

Additional topics In addition to these measures, baseline data are also collected on additional measures not included in this report: spirometry, asthma morbidity (symptoms, missed days of school or work, use of rescue medications, and NAEPP severity classification),[24,34,43–48] asthma medication use and compliance[49–52] (J. Essien, MD, MPH, ZAP Asthma Health and Environment Survey Instrument, personal communication, January 1998), education and services received from medical providers, health services utilization,[34] social support for asthma-related issues,[53] caregiver's sense of self-efficacy to control the child's asthma,[54–57] care-

giver actions to control triggers, and asthma-related quality of life of the caregiver and of children 7 years and older.[58,59] Additional environmental assessment measures include a quantitative estimate of dust by measuring the weight of fine dust (passed through a 100-mesh screen) collected from 1 m^2 of carpet using a HVS^3 sampling vacuum,[60] detection of the presence of roaches by baited roach traps (Trapper® glue traps TM2600, Bell Laboratories, Madison, WI), and assessment of relative humidity (Radio Shack indoor humidity gauge thermometer 63-1013).

Human Subjects and Community Review

All protocols and questionnaires were approved by the Institutional Review Board of Children's Hospital and Medical Center, Seattle, Washington. In addition, the project has been approved by Seattle Partners for Healthy Communities, a community-researcher collaborative, which has a goal to ensure that community-based research is respectful of and responsive to community preferences.

RESULTS

Recruitment and Enrollment

In this preliminary analysis, we present baseline data from the first 112 enrolled subjects. We have identified 541 children with asthma from medical record review and community recruitment. We have been able to contact 335 (62%) to determine eligibility and interest in participation in the project. Incorrect or disconnected phone numbers, no answer after six attempts at phone contact, and no response to a second mailed invitation were the primary reasons for not reaching the remaining 206. Of those we have reached, 155 (46%) were eligible, and of those eligible, 131 (85%) have agreed to participate. The eligible participants and nonparticipants do not differ significantly with regard to age of child, household income, enrollment in Medicaid, frequency of use of asthma medications in past 2 weeks, frequency of asthma symptoms in past 2 weeks, or residence in or outside Seattle.

The enrolled caregivers (Table I) are diverse racially (predominantly Vietnamese, African-American, Hispanic, and white), have low incomes (70.9% have incomes less than the federal poverty level), and low educational attainment (43.2% had not completed high school), rent their homes (89.1%), and have limited duration of tenancy at their current address (82.5% for less than 5 years). Many are single caretakers (41.1%). In contrast, among the total King County population, 17.6% are non-white,[61] 8.0% have incomes below poverty, 11.8% of persons aged 25 years and older have less than a high school education, 37.7%

TABLE I Study Population

Characteristic	Percentage, N = 112
Age (years)	
4–5	31.3
6–9	45.5
10–12	23.2
Caregiver's race	
Vietnamese	30.4
Other Asian	3.6
African-American	25.0
Hispanic	17.9
White	17.0
Native American	1.8
Other	4.5
Caregiver's education	
Less than high school	43.2
High school graduate/GED	21.6
Some college	26.1
College graduate	9.0
Single-caretaker household	41.1
Household income as percentage of poverty	
<100	70.9
100–149	19.1
150–200	10.0
Renter	89.1
Length at current address	
<1 year	24.1
1–2 years	19.5
2–5 years	38.9
>5 years	17.6

rent their homes, and 44.7% have lived for less than 5 years at their current address.[62] Nearly all enrolled children have persistent asthma (91.2%), and most have moderate-to-severe persistent asthma (59.9%) based on NAEPP criteria.[24]

THE HOME ENVIRONMENT: EXPOSURES

At least one major asthma trigger is present in nearly all (98.2%) homes (Table II), and most contain multiple triggers (62.5% with two or more and 29.5% with three or more). A smoker is present in 37.5% of homes. Mold and moisture problems are common. Mold is visible in 26.8% of homes, and water damage is present in 18.6%. Evidence of dampness is reported by 64.2% of households, in part because 38.7% of bathrooms and 26.7% of kitchens are ventilated inadequately. Chemical irritants such as air fresheners or ammonia are used in 21.7%

TABLE II Home Environment

Exposure	Percentage, N = 112
Tobacco	
Primary caretaker smokes	21.4
Caretaker or babysitter smokes	31.3
Smoking caretaker always goes out to smoke	58.3
Smoker in house	37.5
Mold and moisture	
Home smells moldy or musty	18.9
Windows (other than kitchen/bath) fog during heating season	
Rarely	40.8
Sometimes	21.4
Often	37.8
Bathroom window/mirror remains fogged >15 minutes after shower	59.6
Water damage	
Child's bedroom	12.5
Kitchen	7.5
Bath	5.3
Any of the above	18.6
Mold/mildew visible	
Child's bedroom	14.0
Kitchen	13.8
Bath	11.6
Any of the above	26.8
Other ventilation	
Lack functional* stove ventilation	26.7
Lack functional* bathroom fan	38.7
Irritants	
Heat source	
Electric	79.4
Gas	21.9
Oil	2.1
Wood stove	13.5
Gas stove	2.1
Chemicals	
Air fresheners	21.7
Ammonia	15.5
One or more chemicals	89.7
Dust	
Carpet in child's bedroom/sleep area	76.8
Cloth-covered furniture in child's bedroom/sleep area	20.0
Drapes/curtains in child's bedroom/sleep area	39.5
Pets	
Dander-producing pet inside the home (cat, dog, bird, rodent)	28.6

(*continued*)

TABLE II Continued

Exposure	Percentage, N = 112
Pests	
Rodent problem in past 3 months	8.1
Cockroach problem in past 3 months	23.4
Visible roaches during HEAL	18.1
Dust Mites	
Water temperature less than 130°F (<120°F)	84.7 (22.4)
Type of cover*	
Comforter	71.7
Wool blanket	26.1
Cotton blanket	6.5
Acrylic blanket	10.9
Stuffed toys visible in child's bedroom	55.3

*Present, working, and vented to outside.

*The categories are not mutually exclusive because a child may have had more than one type of blanket.

and 15.5% of homes, respectively, and 89.7% of homes have at least one irritant present. Nearly all homes (92.7%) use electricity for cooking, and very few homes have unvented gas or kerosene heat sources, suggesting that NO_2 exposure may be low. Few households use wood stoves (13.5%), and most of these used them less than 10 times in the past year.

Dust-trapping reservoirs are common in the child's bedroom/sleeping area: 76.8% have carpeting (49.3% of these carpets are shag or plush, which trap more deep dust[63]) 20.0% have cloth-upholstered furniture, 39.5% have drapes or curtains, and 55.3% have stuffed toys. Additional reservoirs for dust mites include use of comforters or wool blankets on 89.1% of children's beds and nonencased pillows and mattresses (see below). Few homes (15.3%) have wash water sufficiently hot[64] (≥130°F) to kill dust mites.

Many (28.6%) of the homes have dander-producing pets. Of homes that permitted cats or dogs to enter the house, 31.8% allow them in the child's bedroom. Cockroach infestation in the past 3 months is reported by 23.4% of caregivers, and 46.4% report ever having roaches. Interviewers observed roaches during completion of 18.1% of HEAL-II interviews. While only 8.1% report a recent rodent problem, 50.9% note ever having rodents.

CAREGIVER KNOWLEDGE OF INDOOR ASTHMA TRIGGERS

Caregivers are informed about some triggers and how to control them, but also show important limitations in their knowledge (Table III). Most are aware that

TABLE III Caregiver Knowledge of Indoor Asthma Triggers

Knowledge	Percentage, N = 112
Tobacco smoke	
Aware asthma symptoms made worse by tobacco smoke	97.3
Aware clothing/furniture trap smoke	91.8
Mold and moisture	
Aware asthma symptoms are made worse by mold/mildew/fungi	82.0
Aware mold-damaged carpet/furniture cannot be cleaned	13.4
Aware excess moisture bad for asthma	39.6
Aware carpet on basement floor is undesirable	58.0
Aware humidifiers are not helpful	28.6
Aware keeping rooms warm decreases humidity	62.8
Dust	
Aware asthma symptoms made worse by dust	96.4
Aware of need to remove shoes and use mat	73.4
Pets	
Aware asthma symptoms made worse by birds	57.7
Aware asthma symptoms made worse by hamsters	73.9
Aware of benefit of HEPA filter if pets present	46.8
Pests	
Aware asthma symptoms made worse by roaches	42.9
Aware asthma symptoms made worse by rodents	52.7
Aware leaking faucets contribute to roach problem	51.8
Dust mites	
Aware mites found in every home	86.5
Aware cold water wash does not kill mites	40.2
Aware of stuffed animals as source of trigger	76.8
Aware of upholstered furniture as source of trigger	75.7
Aware bedding covers reduce exposure	70.5
Irritants	
Aware asthma symptoms made worse by wood smoke	85.7
Aware asthma symptoms made worse by perfume, air fresheners	81.3
Aware asthma symptoms made worse by cleaning products	84.8

tobacco smoke, molds, dust, and irritants can induce asthma exacerbations, but fewer have knowledge regarding roaches and rodents. Knowledge is also less complete about methods to reduce exposures. Less than half of caregivers know that excessive moisture can be bad for a child with asthma, that mold-damaged materials cannot be cleaned, that humidifiers are not generally helpful, that HEPA air filters can help remove pet dander, and that washing with cold water does not kill dust mites.

TABLE IV Caregiver Resources to Control Indoor Triggers

Resource	Percentage, N = 112
Have allergy-control mattress covers	19.8
Have vacuum in house	69.6
If yes, vacuum has power head	65.4
If yes, vacuum has HEPA-quality filter	11.5
Have a doormat	
All doors	38.9
Some doors	37.0
No doors	24.1

HOUSEHOLD RESOURCES TO CONTROL ASTHMA

Caregivers lack basic tools for effective control of indoor asthma triggers (Table IV). Only 19.8% of their children with asthma have allergy-control mattress covers, 11.5% have a vacuum with an effective air exhaust filtration filter, and 38.9% have doormats at every door.

DISCUSSION

Low-income urban children with asthma in King County live in indoor environments that place them at substantial risk of ongoing exposure to asthma triggers. Through interviews and home inspections of the first 112 participants in a randomized crossover trial of home environmental interventions, we have identified substandard housing—characterized by poor ventilation, visible mold and moisture damage, and cockroach infestation—as a major contributor to these exposures. Dust reservoirs such as carpets, drapes, upholstered furniture, and stuffed animals are common. Pets and cockroaches also are reported frequently. More than a third of households include a smoker. Irritant chemicals are found in most homes. Exposure to combustion by-products is generally low because gas and wood stoves are uncommon.

Caregiver knowledge of indoor triggers and how to control them is well developed for environmental tobacco smoke and dust, but could be improved for moisture, dust mites, and cockroaches. Caregivers, even if well informed, often cannot use their knowledge to protect a child because they lack the resources to do so. Most do not have allergy-control bedding covers, adequate vacuum cleaners, or sufficient doormats. Many did not have access to wash water hot enough to kill mites, perhaps because of regulations that require water heaters to be set to no more than 120°F to avoid scald injuries.[65]

Comparison to Other Studies

We found few published studies that document the prevalence of indoor asthma triggers and associated housing conditions in households with children with asthma. Environmental tobacco smoke is best described, and our rate is consistent with those found in Seattle public schools[8] and users of a Montreal emergency department[9] and is lower than observed in the National Cooperative Inner City Asthma Study[7] and a Canadian community survey.[6] Several studies have documented the prevalence of damp or moldy housing[6,8,9,66] (ranging from 24% to 64%), as well as the proportions of households with gas stoves (9–89%) and gas or oil heat (6–62%). Infante-Rivard[9] and Joyce et al.[22] found fewer homes had carpet (56% and 47%, respectively) compared to those described in this report, while Dekker et al.[6] and Joyce et al.[22] observed more to have furry or feathered pets (43%). Joyce et al. also reported that cockroaches were noted by 11% of participants in their study, and that stuffed animals were present in 81% of children's rooms. Rosenstreich et al. detected cockroach allergen in housedust in 50% of children's bedrooms.[72] Otherwise, we found no information on the additional factors described here. Of note is the wide variability in the prevalence of triggers and predisposing factors, reflecting the geographic, socioeconomic, and cultural diversity of the subjects and houses included in these studies. These findings underscore the importance of assessing local conditions before implementing initiatives to control exposure to asthma triggers.

Few published studies report on participants' knowledge of indoor asthma triggers, and none focused on American, urban, low-income populations. Our participants showed a higher level of awareness of tobacco smoke compared to rates reported in the limited available literature (36–90%) and similar rates regarding dust and pets (85–90%).[20–22]

Limitations

This study has several limitations pertaining to external and internal validity. Because participants enroll voluntarily, its findings may not apply to the general population of low-income urban households with asthmatic children. However, there were no significant differences on key demographic and asthma-related variables among those who did and did not enroll. The participants enrolled in our study are similar to those enrolled in the National Cooperative Inner-City Asthma Study[34] (a cohort of 1,528 children with asthma from eight urban inner-city areas) with respect to educational attainment of the caregiver, gender of the caregiver, and household income. The proportion of Asian participants is higher in our study, while the proportion of African-Americans is lower. We also note that we do not assess conditions in higher income households and therefore

cannot address the question of whether exposures and knowledge differ across income strata.

Internal validity may be compromised because we report on exposures assessed by caregiver self-report and staff field observation without physical or biological measurements such as antigen load in dust, ambient tobacco levels, urinary/salivary cotinine levels, or levels of volatile organic compounds.[67] We are collecting quantitative dust samples and will report in future publications on dust loading of bedroom carpets (μg dust/m^2 carpet), allergen concentrations (mite, roach, cat, and dog) in dust (μg allergen/g dust), and fungal spore concentrations and type. In addition, we are collecting temperature and humidity data for a 2-week period in each household to improve our assessment of excessive moisture. Additional measurement of tobacco exposure is beyond the resources of this project. A recent report[68] indicates that observational and self-report data regarding environmental exposures correlate well with biophysical measurements. Likewise, caregiver activities are also assessed by self-report and are subject to bias from social desirability. However, we know of no other practical way to assess these activities, and use of self-reported health behavior data is common practice.[35]

In addition, we have been unable to find standard, validated measures of exposures, knowledge, and activities for many of the study variables. We believe our questions have face validity, and they have been subjected to review by program staff and participants to ensure that they are meaningful and unambiguous in the context of participants' lives. However, we have not validated our questions against other "gold standard" questions. Validation of questions that measure self-reported exposure against biophysical measures would be useful.[68]

Exposure to allergens is necessary, but not sufficient, to induce asthma symptoms; current understanding of asthma pathophysiology[26] suggests that the child must also be sensitized (allergic) to the allergen as well. Knowledge of sensitivity is useful in interpreting the results of exposure data; exposures are more likely to cause morbidity among persons who are sensitized to the agent in question. While we are collecting sensitization data through skin prick testing, these data are not yet available. In addition, in clinical practice, many inner-city children with asthma are not skin tested (because of lack of referral or logistical problems). In our population, only 42.4% had been tested prior to enrollment. Practically speaking, then, this information may not be available for many urban children and thus cannot guide intervention strategies.

A final limitation is that these data are preliminary and reflect the experience of the first 112 subjects enrolled of a planned total of 300. Future reports will describe the baseline experience of the total cohort and will contain additional

information regarding caregiver activities related to control of indoor environmental triggers, information received by caregivers from clinical providers, spirometry results, improved estimation of moisture levels, and analysis of carpet dust loading and dust allergen concentration. We will examine the association of asthma severity, race, and language preference in relation to exposures, knowledge, practices, and resources. The relationships of knowledge and resources to self-efficacy and exposures will also be presented.

Implications

Despite these limitations, these data have immediate implications for control of asthma in urban low-income populations.[5] Health educators and providers should provide clients with more information regarding the indoor environment and asthma, especially regarding moisture, dust mite control, and cockroaches. Several resources provide excellent client information.[38,69] Ongoing efforts to assist low-income smokers in quitting should be supported. Health insurers should include allergy-control bedding covers as a durable medical equipment benefit given the evidence that they are effective in reducing asthma morbidity.[70,71] Public health advocates should work with policy makers to address concerns related to substandard housing so children with asthma and their households can live in housing free of asthma triggers. Strategies may include development of "healthy homes"[39] for low-income tenants at public housing sites, assistance to landlords of low-income tenants for making structural improvements to improve indoor air quality, and expanded tenants' rights to protect tenants when they request that landlords make improvements in indoor air quality. Finally, strategies to empower low-income families to improve the quality of the indoor environment need to be developed and evaluated. The Seattle–King County Healthy Homes project is one among several ongoing efforts to do so. Others include ZAP Asthma (Joyce Essien, MD, MPH, personal communication, September 1999), the Inner City Asthma Study (James Stout, MD, MPH, personal communication, September 1999), and Community Action Against Asthma (Edith Parker, PhD, and Thomas Robins, MD, MPH, personal communication, September 1999).

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REFERENCES

1. Centers for Disease Control and Prevention. Asthma mortality and hospitalization among children and young adults—United States, 1980–1993. *MMWR Morb Mortal Wkly Rep.* 1996;45:350–353.
2. Wissow LS, Gittelsohn AM, Szklo M et al. Poverty, race and hospitalization for childhood asthma. *Am J Public Health.* 1988;78:777–782.
3. Carr W, Zeitel L, Weiss K. Asthma hospitalization and mortality in New York City. *Am J Public Health.* 1992;82:59–65.
4. Weiss KB, Gergen PJ, Crain EF. Inner city asthma: the epidemiology of an emerging US public health concern. *Chest.* 1992;101(suppl):S362–S376.
5. Malveaux FJ, Fletcher-Vincent SA. Environmental risk factors of childhood asthma in urban centers. *Environ Health Perspect.* 1995;103(suppl 6):59–62.
6. Dekker C, Dales R, Bartlett S, Brunekreef B, Zwanenburg H. Childhood asthma and the indoor environment. *Chest.* 1991;100:922–926.
7. Eggleston PA, Buckley TJ, Breysse PN, Wills-Karp M, Kleeberger SR, Jaakkola JJK. The environment and asthma in US inner cities. *Environ Health Perspect.* 1999;107(suppl 3):439–450.
8. Maier WC, Arrighi HM, Morray B, Llewellyn C, Redding GJ. Indoor risk factors for asthma and wheezing among Seattle school children. *Environ Health Perspect.* 1997;105: 208–214.
9. Infante-Rivard C. Childhood asthma and indoor environmental risk factors. *Am J Epidemiol.* 1993;137:834–844.
10. Etzel R, Rylander R. Indoor mold and children's health. *Environ Health Perspect.* 1999; 107(suppl 3):463.
11. Sarpong SB, Karrison T. Sensitization to indoor allergens and the risk for asthma hospitalization in children. *Ann Allergy Asthma Immunol.* 1997;79:455–459.
12. Strachan DP. Damp housing and childhood asthma: validation of reporting of symptoms. *BMJ.* 1988;297:1223–1226.
13. Bruunekreef B, Dockery DW, Speizer FE et al. Home dampness and respiratory morbidity in children. *Am Rev Respir Dis.* 1989;140:1363–1367.
14. Ostro BD, Lipsett MJ, Mann JK, Weiner MB, Selner J. Indoor air pollution and asthma: results from a panel study. *Am J Respir Crit Care Med.* 1994;149:1400–1406.
15. Atkinson W, Harris J, Mills P et al. Domestic aeroallergen exposures among infants in an English town. *Eur Respir J.* 1999;13:583–589.
16. Wieslander G, Norback D, Bjornsson E, Janson C, Boman G. Asthma and the indoor environment: the significance of emission of formaldehyde and volatile organic compounds from newly painted indoor surfaces. *Int Arch Occup Environ Health.* 1997;69: 115–124.
17. Gelber LE, Seltzer LH, Bouzoulkis JK et al. Sensitization and exposure to dust mite allergens as risk factors for asthma among patients presenting to hospital. *Am Rev Respir Dis.* 1993;147:573–578.
18. Pollart SM, Chapman MD, Giocco GP et al. Epidemiology of acute asthma: IgE antibodies to common inhalant allergens as risk factors for emergency room visits. *J Allergy Clin Immunol.* 1989;83:875–882.
19. Bernard-Bonnin AC, Pelletier H, Allard-Dansereau C. Parental knowledge about their asthmatic children. *Pédiatrie.* 1991;46:489–497.
20. Spykerboer JE, Donnelly WJ, Thong YH. Parental knowledge and misconceptions about asthma: a controlled study. *Soc Sci Med.* 1986;22(5):553–558.
21. Moosa SE, Henley LD. An evaluation of parental knowledge of childhood asthma in a family practice setting. *S Afr Med J.* 1997 Jan;87(1):42–45.
22. Joyce DP, Chapman KR, Balter M, Kesten S. Asthma and allergy avoidance knowledge and behavior in postpartum women. *Ann Allergy Asthma Immunol.* July 1997;79(1):35–42.

23. Munro JF, Haire-Joshu D, Fisher EB, Wedner HJ. Articulation of asthma and its care among low-income emergency care recipients. *J Asthma.* 1996;33:313–325.
24. National Asthma Education and Prevention Program. *Expert Panel Report 2: Guidelines for the Diagnosis and Management of Asthma.* Bethesda, MD: National Heart, Lung, and Blood Institute; 1997.
25. Leung R, Koenig JQ, Simcox N, van Belle G, Fenske R, Gilbert SG. Behavioral changes following participation in a home health promotional program in King County, Washington. *Environ Health Perspect.* 1997;105:1132–1135.
26. Platts-Mills T, Chapman MD, Squillace SP et al. The role of allergens. In: Holgate ST, Austen KF, Lichtenstein LM, Kay AB, editors. *Asthma: Physiology, Immunopharmacology and Treatment.* New York: Academic Press; 1993:27–39.
27. Burney PGJ. Current questions in the epidemiology of asthma. In *Asthma: Physiology, Immunopharmacology and Treatment.* Holgate ST, Austen KF, Lichtenstein LM, Kay AB, editors. New York: Academic Press; 1993:3–16.
28. Mitchell H, Senturia Y, Gergen P et al. Design and methods of the National Cooperative Inner-City Asthma Study. *Pediatr Pulmonol.* 1997;24:237–252.
29. Global Initiative for Asthma. *Global Strategy for Asthma Management and Prevention: NHLBI/WHO Workshop Report.* Bethesda, MD: National Institutes of Health; 1995. NHLBI publication no. 95-3659.
30. Beggs PJ, Curson PH. An integrated asthma model. *Arch Environ Health.* 1995;50:87–94.
31. Evans RG, Barer ML, Marmor TR, editors. *Why Are Some People Healthy and Others Not?* New York: Aline de Gruyter; 1994.
32. Clark NM, Starr-Schneidkraut NJ. Management of asthma by patients and families. *Am J Respir Crit Care Med.* 1994;149:S54–S66.
33. Clark NM, Brown RW, Parker E et al. Childhood asthma. *Environ Health Perspect.* 1999; 107(suppl 3):421–429.
34. Kattan M, Mitchell H, Eggleston P et al. Characteristics of inner-city children with asthma: the national cooperative inner-city asthma study. *Pediatr Pulmonol.* 1997;24:253–262.
35. Powell-Griner E, Anderson JE, Murphy W. State-and sex-specific prevalence of selected characteristics-behavioral risk factor surveillance system, 1994 and 1995. *MMWR Morb Mortal Wkly Rep.* 1997;46(SS-3):1–31.
36. Department of Health and Human Services. *NIOSH Pocket Guide to Chemical Hazards.* Washington, DC: US Government Printing Office; June 1997. CDC/NIOSH publication no. 97-140.
37. Rust MK, Owens JM, Reierson, DA. *Understanding and Controlling the German Cockroach.* New York: Oxford University Press; 1995.
38. United States Environmental Protection Agency. *Clear Your Home of Asthma Triggers.* Washington DC: US Environmental Protection Agency; 1999. EPA/402-F-99-005.
39. Warde J. *The Healthy Home Handbook.* New York: Times Books; 1997.
40. Fitzclarence CAB, Henry RL. Validation of an asthma knowledge questionnaire. *J Paediatr Child Health.* 1990;26:200–204.
41. Hazzard A, Angert L. Knowledge, attitudes and behavior in children with asthma. *J Asthma.* 1986;23:61–67.
42. Mesters I, Meertens R, Crebolder H, Parcel G. Development of a health education program for parents of preschool children with asthma. *Health Educ Res.* 1993;8:53–58.
43. Rosier MJ, Bishop J, Nolan T et al. Measurement of functional severity of asthma in children. *Am J Respir Crit Care Med.* 1994;149:1434–1441.
44. Simons FE. A comparison of beclomethasone, salmeterol, and placebo in children with asthma. Canadian Beclomethasone Dipropionate-Salmeterol Xinafoate Study Group. *N Engl J Med.* 1997;337:1659–1665.
45. Evans DJ, Taylor DA, Zetterstrom O, Chung KF, O'Connor BJ, Barnes PJ. A comparison of low-dose inhaled budesonide plus theophylline and high-dose inhaled budesonide for moderate asthma. *N Engl J Med.* 1997;337:1412–1418.
46. Murray AB, Ferguson AC. Dust-free bedrooms in the treatment of asthmatic children with house dust or house dust mite allergy: a controlled trial. *Pediatrics.* 1983;71:418–422.

47. Wahlgren DR, Hovell MF, Matt GE et al. Toward a simplified measures of asthma severity for applied research. *J Asthma.* 1997;34:291–303.
48. Santanello NC, Barber BL, Reiss TF et al. Measurement characteristics of two asthma symptom diary scales for use in clinical trials. *Eur Respir J.* 1997;10:646–651.
49. Rand CS, Wise RA. Measuring adherence to asthma medication regimens. *Am J Respir Crit Care Med.* 1994;149:S69–S76.
50. Haynes RB, Taylor DW, Sackett DL. Can simple clinical measures detect patient noncompliance? *Hypertension.* 1980;2:757.
51. Sackett DL, Haynes RB, Guyatt GH, Tugwell P. *Clinical Epidemiology: a Basic Science for Clinical Medicine.* 2nd ed. Boston: Little, Brown and Company; 1991:258.
52. Inui T. Screening for noncompliance among patients with hypertension. Is self-report the best available measure? *Med Care.* 1981;19:1061–1072.
53. Wade S, Weil C, Holden G et al. Psychosocial characteristics of inner-city children with asthma: a description of the NCICAS psychological protocol. *Pediatr Pulmonol.* 1997;24:263–276.
54. Bandura A. *Social Foundations of Thought and Action: a Social Cognitive Theory.* Englewood Cliffs, NJ: Prentice-Hall; 1986.
55. Schlosser M, Havermans G. A self-efficacy scale for children and adolescents with asthma: construction and validation. *J Asthma.* 1992;29:99–108.
56. Katz PP, Yelin EH, Smith S, Blanc PD. Perceived control of asthma: development and validation of a questionnaire. *Am J Respir Crit Care Med.* 1997;155:577–582.
57. Bartholomew LK, Parcel GS, Swank PR, Czyzewski DI. Measuring self-efficacy expectations for the self management of cystic fibrosis. *Chest.* 1993;103:1524–1530.
58. Juniper EF, Guyatt GH, Feeny DH et al. Measuring quality of life in the parents of children with asthma. *Qual Life Res.* 1996;5:27–34.
59. Juniper EF, Guyatt GH, Feeny DH et al. Measuring quality of life in children with asthma. *Qual Life Res.* 1996;5:35–46.
60. American Society for Testing Materials. *Standard Practices for Collection of Dust from Carpeted Floors for Chemical Analysis: Method D5438-94.* Philadelphia, PA: ASTM; 1994.
61. Department of Social and Health Services. *Washington State Adjusted Population Estimates.* Olympia, WA: DSHS; April 1999.
62. Bureau of the Census. *Census of Population and Housing, 1990: Summary Tape File 3.* Washington, DC: Bureau of the Census; 1991.
63. Roberts JW, Clifford WS, Glass G, Hummer PG. Reducing dust, lead, dust mites, bacteria, and fungi in carpets by vacuuming. *Arch Contam Toxicol.* 1999;36:477–484.
64. McDonald LG, Tovey E. The role of water temperature and laundry procedures in reducing house dust mite populations and allergen content of bedding. *J Allergy Clin Immunol.* 1992;90:599–608.
65. Feldman KW, Schaller RT, Feldman JA, McMillon M. Tap water scald burns in children. *Pediatrics.* 1978;62:1–7.
66. Martin CJ, Platt SD, Hunt SM. Housing conditions and ill health. *BMJ.* 1987;294: 1125–1127.
67. Marbury MC, Hammond SK, Haley NJ. Measuring exposure to environmental tobacco smoke in studies of acute health effects. *Am J Epidemiol.* 1993;137:1089–1097.
68. Dharmage S, Bailey M, Raven J et al. A reliable and valid home visit report for studies of asthma in young adults. *Indoor Air.* 1999 September;9:188–192.
69. Soap and Detergent Association. *Clean and Healthy. Managing Asthma and Allergies: a Consumer Cleaning Guide.* New York: SDA; 1999.
70. Etzel R. Indoor air pollution and childhood asthma: effective environmental interventions. *Environ Health Perspect.* 1995;103(suppl 5):55–58.
71. Shapiro GG, Wighton TG, Chinn T et al. House dust mite avoidance for children with asthma in homes of low-income families. *J Allergy Clin Immunol.* 1999;103:1069–1074.
72. Rosenstreich DL, Eggleston P, Kattan M et al. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. *N Engl J Med.* 1997;336:1356–1363.