The Breathe-Easy Home: The Impact of Asthma-Friendly Home Construction on Clinical Outcomes and Trigger Exposure

Tim K. Takaro, MD, MPH, MS, James Krieger, MD, MPH, Lin Song, PhD, Denise Sharify, BA, and Nancy Beaudet, MS, CIH

Objectives. We examined the asthma-control benefit of moving into an asthma-friendly Breathe-Easy home (BEH).

Methods. We used a quasi-experimental design to compare the asthma outcomes of 2 groups of low-income children and adolescents with asthma: 34 participants who moved into a BEH, and a local matched cohort of 68 participants who had received a previous asthma-control intervention. Both groups received in-home asthma education. BEHs were constructed with moisture-reduction features, enhanced ventilation systems, and materials that minimized dust and off-gassing.

Results. BEH residents' asthma-symptom–free days increased from a mean of 8.6 per 2 weeks in their old home to 12.4 after 1 year in the BEH. The proportion of BEH residents with an urgent asthma-related clinical visit in the previous 3 months decreased from 62% to 21%. BEH caretakers' quality of life increased significantly. The BEH group improved more than did the comparison group, but most differences in improvements were not significant. Exposures to mold, rodents, and moisture were reduced significantly in BEHs.

Conclusions. Children and adolescents with asthma who moved into an asthma-friendly home experienced large decreases in asthma morbidity and trigger exposure. (*Am J Public Health.* 2011;101:55–62. doi:10.2105/AJPH.2010.300008)

Asthma remains the most common chronic condition of childhood, affecting 9.1% of all US children. More than 6 million children have current asthma, leading to 205 000 pediatric hospitalizations and 697 000 emergency department visits each year.[1] Socioeconomic and racial/ethnic disparities in asthma prevalence and morbidity continue undiminished.[2,3] Exposure and sensitization to allergens and irritants found in the indoor environment are major factors in the development and exacerbation of asthma.[4] Low-income and racial/ethnic minority children have high levels of exposure and sensitization to indoor asthma triggers.[5–10] As much as 40% of the excess asthma risk in minority children may be attributable to exposure to residential allergens.[11] Disparities in asthma morbidity and allergic sensitization may be due in part to substandard housing.[7,12–14] Moisture and dampness, poor ventilation, deteriorated carpeting, and structural deficits can contribute to increased presence of indoor asthma triggers.[15,16]

For the past 14 years we have been studying the asthma-control effectiveness of community health worker (CHW) home visits to low-income children with asthma in Seattle and King County, Washington. In these visits, CHWs provide asthma self-management support and help participants implement multifaceted interventions that address multiple triggers. We found that such comprehensive, relatively inexpensive interventions were effective at reducing asthma morbidity and improving quality of life, and studies of other home-visit programs have found similar results.[17–21] However, many low-income children with asthma live in substandard housing that exposes them to clinically significant levels of asthma triggers. Only rarely can home visits address the structural deficiencies that lead to these exposures.

A public-housing redevelopment project in Seattle offered a unique opportunity to study the health impact that moving to specially constructed asthma-friendly homes would have on children with asthma. We assessed the effect of asthma-friendly homes on asthma-symptom days, urgent health care visits, caretaker quality of life, and exposure to indoor asthma triggers among children with asthma. We hypothesized that living in an asthma-friendly home would add benefits beyond those conferred by asthma-control education and self-management support.

METHODS

High Point is a public-housing site located in west Seattle. In 2000, High Point consisted of 716 sixty-year-old housing units in varying states of deterioration. The units had significant problems with moisture, mold, and pests. The Seattle Housing Authority used funds provided by the US Department of Housing and Urban Development[22] to redevelop High Point as a sustainable, health-promoting, mixed-income community with 1600 new publicly and privately owned housing units.

When redevelopment began, High Point was an ethnically diverse community: 36% of the residents were African or African American, 29% were Asian/Pacific Islander, 18% were White, and 17% were other races/ethnicities. A majority of household heads (61%) had been born abroad.[23] Because of the income-eligibility criteria for residing in public housing, 85% of households had incomes at or less than 30% of the median for King County.[23]

Study Design

The study had 2 goals: (1) to examine the impact that living in an asthma-friendly Breathe-Easy Home (BEH) would have on asthma clinical outcomes, and (2) to examine the impact that living in a BEH would have on exposure to environmental asthma triggers. We assessed the impact of BEH residency on clinical outcomes by using a quasi-experimental study design that compared outcomes among BEH residents with outcomes among a matched historical comparison group. The comparison group was drawn from participants in our previously conducted Healthy Homes II (HH-II) study, a randomized, controlled trial involving children and youths receiving asthma education delivered by an asthma nurse in a primary care clinic. That study tested the incremental asthma-control benefit of adding home visits by CHWs providing self-management support.

In the current study, the intervention group comprised children and adolescents with asthma who moved into a BEH. We collected clinical measurements from intervention-group participants at 2 time points: immediately before they moved into the BEH and 1 year later. We also collected descriptive cross-sectional data on house dust allergens in participants' homes at 3 time points: 1 year before they moved into the BEH, immediately before moving, and 1 year after moving.

Study Population

Household eligibility criteria for the BEH intervention group consisted of the presence of a child or adolescent aged 2 to 17 years with clinician-diagnosed persistent asthma; eligibility for residence in Seattle Housing Authority housing (i.e., demonstration of successful tenancy in the past 2 years, income below 50% of area median income, and no household members with serious criminal convictions—felonies, violent crimes committed against other persons or property, or any repeated, ongoing criminal activity—in the previous 7 years); caretaker's primary language being English, Spanish, or Vietnamese; and residence location in King County, Washington. Asthma was considered persistent if the caretaker reported that the child had symptoms or used beta-agonist medications more than twice per week, the child was using daily controller medication, or the child had had an asthma-related hospitalization, emergency department visit, or unscheduled clinic visit during the previous 6 months.[24] Exclusion criteria were: the household was planning to move within the next 12 months, the primary caretaker had a significant disability that precluded participation, the household appeared to be unsafe for home visitation, the child had other serious chronic medical conditions (e.g., cystic fibrosis, sickle cell disease), or the child was participating in another asthma study.

Enrollment of the BEH group occurred from February 2005 through June 2006. We recruited BEH participants from Seattle Housing Authority resident lists and community and public health clinics. All but 1 of the families who moved into the BEHs completed the study, and these are the households included in the intervention group (n=34).

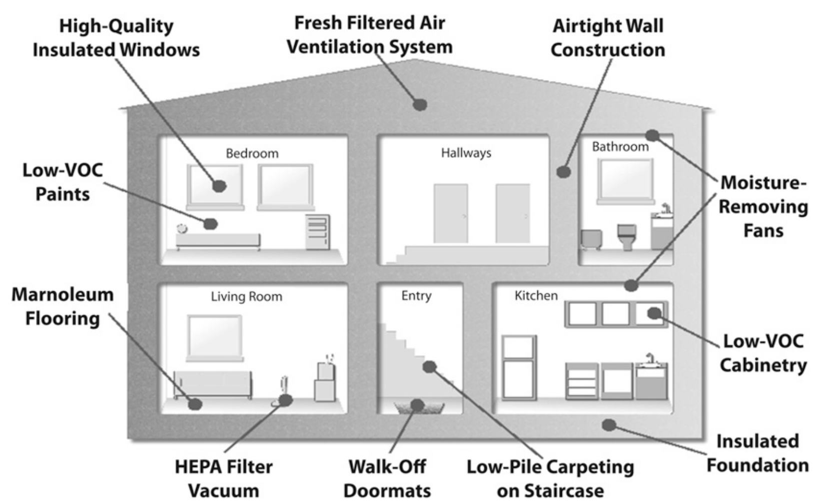
Eligibility and exclusion criteria for HH-II study participants were similar to those for the BEH group. HH-II inclusion criteria consisted of the presence of a child or adolescent aged 3 to 13 years with clinician-diagnosed persistent asthma; income below 200% of the 2001 federal poverty threshold, or child enrolled in Medicaid; caretaker's primary language being English, Spanish, or Vietnamese; and reisdence location in King County, Washington. HH-II enrollment occurred from November 2002 through October 2004. Participants primarily were recruited from community and public health clinics.

We created the HH-II comparison group by matching 2 HH-II participants to each participant in the BEH cohort by age group (3–6 years, 7–17 years), season of enrollment (winter and other), and asthma-control level (well-controlled, not well-controlled, and very poorly controlled[24]), for a total of 68 HH-II participants. If there were more than 2 HH-II cases in a matching stratum, we randomly selected 2 HH-II participants from the stratum to match with a BEH participant. The final sample size of 34 BEH participants and 68 HH-II participants had 80% power to detect across-group differences of 2.1 symptom-free days, 0.7 units in the quality-of-life score, and 30% in urgent health services utilization, with α set at 0.05. The minimum clinically significant difference in quality of life was 0.5.[25]

Breathe-Easy Homes Intervention

The primary intervention was occupancy of a BEH, a subset of housing units at the High Point site. All High Point homes were built to high standards, including energy-efficiency features and use of sustainable products.[26] The BEHs had additional features in 3 main categories: (1) an enhanced exterior envelope to optimize moisture-proofing; (2) interior finishes, flooring, and other materials that minimized dust accumulation and off-gassing; and (3) an energy-efficient heat-exchange ventilation system with filtration and continuous fresh air supply (Figure 1). The total additional cost of BEH-specific upgrades ranged from $5000 to $7000 per home. (Details about BEH are presented in Appendix 1, available as a supplement to the online version of this article at http://www.ajph.org.)

BEH families also received in-home asthma education addressing self-management and trigger reduction, which was provided by CHWs using standard protocols[18,27]; information specific to operation and maintenance of a BEH; high-efficiency particulate-air-filter vacuums; allergen-impermeable bedding encasements; and cleaning supplies. We offered allergy skin-prick testing[28] to all participants, to determine their



Note. VOC=volatile organic compound; HEPA=high efficiency particulate air.

FIGURE 1—Features of the Hight Point Breathe-Easy Homes.

sensitization to common indoor allergens; 22 of the 34 participants received the test. CHWs used this information to prioritize educational interventions based on sensitivities and to motivate parents to address allergen sources. Finally, families signed a lease agreement that prohibited pets and tobacco smoke in the home.

Healthy Homes II Intervention

We described the HH-II intervention in a previous publication.[18] Briefly, CHWs made 1 intake visit and an average of 4.5 follow-up visits to each participant over 1 year. During these visits, they provided education and taught skills to help caretakers reduce exposure to triggers and to help them use medications and action plans more effectively. CHWs provided bedding encasements for the participant's bed, a low-emission vacuum with power head and embedded dirt finder, replacement vacuum bags, a door mat, a cleaning kit, and medication boxes. Participants also met in the clinic with an asthma nurse (average of 2 visits per participant) who developed a client-specific asthma-management plan and provided asthma education. Enrollment began in 2002, and data collection ended in 2005.

Environmental Measures

In both studies the CHW conducted a baseline home assessment[27] through direct observation and an interview with the caretaker. The assessment included housing conditions, dust-control behaviors, presence of moisture, and the presence of triggers (mold, pests, pets, and tobacco smoke). Smoking was assessed by the question, "Did anyone have a cigarette inside the home during the past 7 days?"

We assessed exposure to asthma-related allergens by collecting samples of house dust from the participant's bedroom floor at 3 different time points: (1) in the participant's old home, 1 year before moving into the BEH; (2) in the participant's old home, just before moving into the BEH; and (3) in the BEH, after 1 year of residence there. It was not always feasible to collect dust samples in the home; thus, the data presented here are from a convenience sample that includes different homes at each time point. We measured concentrations of the Der p1 protein, the Fel d1 protein, and ergosterol (an estimate of fungal mass) in sieved dust using a standard protocol,[29] sampling from a total of 2 m^2. We used the HVS4 sampling vacuum (Cascade Stack Sampling Systems Inc, Bend, OR) to take the sample.[30] Der p1 and Fel d1 were measured by enzyme-linked immunoassay and reported as µg of allergen per gram of house dust.[31] Ergosterol was heat-extracted from house dust, concentrated, and measured using high-performance liquid chromatography with a variable-wavelength ultraviolet/visible detector.[32,33] We used cutpoints of 10 ng/g of Der p1[34–38] and 8 ng/g of Fel d1[35,37] to define exposures associated with increased risk of asthma morbidity.

Clinical Outcome Measures

Primary prespecified outcomes were asthma-symptom-free days (self-reported number of 24-hour periods during the previous 2 weeks without wheeze, tightness in chest, cough, shortness of breath, slowing down of activities because of asthma, or nighttime awakening because of asthma), Pediatric Asthma Caregiver's Quality of Life Questionnaire[39] score (ranging from 1 to 7, with higher scores indicating better quality of life), and proportion of participants with self-reported asthma-related urgent health service use during the previous 3 months (emergency department, hospital, or unscheduled clinic visit). Secondary prespecified outcomes included asthma attack frequency ("a time when asthma symptoms were worse, limiting activity more than usual or making you seek medical care") and rescue medication use. Pulmonary function measurements included FEV_1 (forced expired volume in first second), PEF (peak expiratory flow), FVC (forced vital capacity), FEF_{25-75} (force expiratory flow between 25th and 75th percentiles), and FEV_1/FVC for participants aged 6 years and older who could consistently perform the maneuver. We used a KoKo Digidoser spirometer (Grace Medical Marketing Inc, Kennesaw, GA) and followed American Thoracic Society protocols.[40]

Analysis

We used the χ^2 test to examine baseline differences between the BEH group and the HH-II group, and we used the McNemar test or paired *t* tests to assess within-group pre/post changes for the 2 groups. To compare the magnitude of pre/post changes across groups, we used the *t* test to compare within-group pre/post changes for continuous variables, and we used logistic regression to compare exit values for binary variables, adjusted for the value at baseline. We used Stata version 9.0 (StataCorp LP, College Station, TX) for analyses.[41] A *P* value of less than .05 indicated a statistically significant difference. All analyses were 2-tailed.

RESULTS

Table 1 displays participant characteristics. The households in both the BEH and HH-II groups had low income and were diverse in language and race/ethnicity. Caretakers had limited educational attainment, and half were not employed at the time of the study. Most children were atopic (i.e., they had had at least 1 positive allergy test), and most had persistent asthma. The BEH and HH-II groups were similar with respect to child's age, asthma severity at baseline, and season of enrollment (matched characteristics), as well as child's gender, atopic status, and caretaker's age, employment status, and education. The cohorts differed in that caretakers in the HH-II group were more likely to be Hispanic and speak Spanish in the home and less likely to be Black or Asian and speak Vietnamese in the home.

The clinical response after 1 year of residence in a BEH was dramatic (Table 2). The primary outcomes of children's asthma-symptom-free days in the previous 2 weeks, urgent clinical visits over the previous 3 months, and caretaker quality of life all improved significantly in the new homes. Secondary outcomes also improved significantly. The proportion of participants with well-controlled asthma increased; the proportions with rescue medication use, activity limitations, symptom nights in the previous 2 weeks, and asthma attacks in the previous 3 months all decreased. Lung function measured by FEV_1 improved (data presented in Appendix 2, available as a supplement to the online version of this article at http://www.ajph.org).

The analysis comparing changes between baseline and exit within each group across the 2 cohorts showed no significant differences in primary outcomes, although the degree of improvement in the BEH group was greater for all measures except FEV_1. Similarly, all secondary measures improved to a greater degree in the BEH group than they did in the HH-II

TABLE 1—Baseline Characteristics: Children and Adolescents With Asthma, Seattle, WA, 2002–2007

Characteristics	BEH, % (n = 34)	HH-II, % (n = 68)	*P*
Male	67.7	69.1	.88
Age, y			N/A
3–6	26.5	26.5	
7–17	73.5	73.5	
Atopic (at least 1 positive allergy test)	68.2	61.8	.587
Asthma severity			.688
1 (mild intermittent)	11.8	16.2	
2 (mild persistent)	38.2	33.8	
3 (moderate persistent)	26.5	33.8	
4 (severe)	23.5	16.2	
Asthma-control level			N/A
Well-controlled	76.5	76.5	
Not well-controlled/poorly controlled	23.5	23.5	
Baseline during December–February	8.8	8.8	N/A
Caretaker race/ethnicity			.023
White	2.9	7.4	
Black	29.4	17.7	
Vietnamese	29.4	10.3	
Other Asian/Pacific Islander	14.7	11.8	
Hispanic	14.7	44.1	
Other/unknown	8.8	8.8	
Primary language in home			< .001
English	47.1	44.1	
Spanish	11.8	39.7	
Vietnamese	26.5	16.2	
Other	14.7	0	
Caretaker age, y			.532
22–44	85.3	89.6	
45–64	14.7	10.5	
Caretaker employment status			.739
Employed	52.9	44.8	
Out of work	11.8	14.9	
Homemaker	32.4	32.8	
Other	2.9	7.5	
Caretaker education			.954
Less than high school	38.2	37.3	
High school diploma/GED	35.3	31.3	
Some college	20.6	25.4	
College graduate	5.9	6.0	

Note. BEH = Breathe-Easy Home; HH-II = Healthy Homes II; N/A = not applicable because there was no difference between the BEH and HH samples.

group, although only nocturnal asthma symptoms improved significantly more. Rescue medication use (P=.079) and asthma attack rates (P=.063) showed marginally significant improvements in the BEH group. In addition, mean trigger score improved significantly more in the BEH intervention than in the HH-II intervention.

Exposure to asthma triggers as measured by home inspection declined substantially and significantly after moving into a BEH (Table 3). The prevalence of household members who smoked and presence of roaches were exceptions because of the low prevalence of roaches and smokers at baseline. At the end of the study, only 1 home continued to have a household member who smoked inside. The average number of asthma triggers per home (presence of rodents, roaches, pets, mold, moisture, or smoking) decreased from 1.5 in the old homes to 0.03 in the BEHs. Descriptive data on house-dust exposures showed decreases from baseline in the old home to 1 year later, just prior to moving out, and further reductions after living in the BEH for 1 year. These data are cross-sectional from distinct sets of BEH households at each collection time (a convenience sample) and are not necessarily representative of all homes, which precluded statistical analysis or interpretation as changes over time within a single cohort of households (Appendixes 3 and 4, available as supplements to the online version of this article at http://www.ajph.org).

DISCUSSION

This study is the first that we know of that demonstrates how moving into an asthma-friendly home can benefit children and adolescents with asthma. Compared with families who received evidence-based, guideline-recommended home asthma education visits alone, this pilot study showed that those who also moved into a BEH experienced additional improvements in a wide range of clinical outcome and trigger exposure measures, although when the 2 studies are compared, the improvements were only statistically significant for night-time symptoms. This study therefore suggests, but does not prove, that the BEH intervention added benefits beyond those conferred by in-home asthma education alone. Within the group that moved into the BEHs, dramatic and significant improvements occurred in all primary outcomes and all but 1 secondary clinical outcome. The consistency and large magnitude of the observed changes suggest that the improvements are real and meaningful. Our data suggest that 1 year of CHW or BEH intervention may be at least as effective as 1 year of optimized budesonide

TABLE 2—Within-Group and Across-Group Clinical Outcomes: Children and Adolescents With Asthma, Seattle, WA, 2002–2007

	BEH (n = 34)				HH-II (n = 68)				BEH vs HH-II[a]	
Outcomes	Baseline	Exit	Change (95% CI)	*P*	Baseline	Exit	Change (95% CI)	*P*	Change (95% CI)	*P*
Primary outcomes										
Symptom-free days/previous 2 wk, mean	8.6	12.4	3.8 (1.7, 5.9)	.001	8.2	11.2	3.0 (1.7, 4.3)	< .001	0.74 (−1.6, 3.1)	.532
Caretakers' quality of life, mean	5.0	5.8	0.86 (0.3, 1.4)	.002	5.6	6.3	0.68 (0.4, 1.0)	< .001	0.18 (−0.4, 0.8)	.522
Urgent clinical care in previous 3 mo, %	61.8	20.6	−41.2 (−65.9, −16.5)	.002	48.5	22.1	−26.5 (−41.8, −11.1)	.001	0.85 (0.3, 2.4)	.753
FEV_1[b] (L/min), mean	2.612	2.851	0.240 (0.095, 0.384)	.002	1.910	2.159	0.25 (0.13, 0.37)	< .001	−0.010 (−0.213, 0.194)	.925
Secondary outcomes										
Asthma well-controlled, %	23.5	47.1	23.5 (2.0, 44.8)	.021	23.5	41.2	17.6 (2.7, 32.6)	.014	1.29 (0.54, 3.05)	.558
Days rescue medicine used/previous 2 wk, mean	6.0	1.9	−4.1 (−6.1, −2.1)	.002	4.1	2.2	−2.0 (−3.3, −0.57)	.006	−2.1 (−4.5, 0.25)	.079
Days activity limited /previous 2 wk, mean	4.0	1.2	−2.8 (−4.8, −0.7)	.01	1.9	0.3	−1.5 (−2.3, −0.8)	.066	−1.24 (−3.0, 0.5)	.169
Nights with symptoms/previous 2 wk, mean	4.4	1.0	−3.5 (−5.4, −1.5)	.001	2.6	1.1	−1.4 (−2.5, −0.4)	.008	−2.0 (−4.0, −0.06)	.044
Asthma attacks/previous 3 mo, mean	6.2	1.1	−5.1 (−8.7, −1.5)	.007	2.7	0.6	−2.1 (−3.5, −0.6)	.005	−3.0 (−6.2, 0.2)	.063

Note. BEH = Breathe-Easy Home; CI = confidence interval; FEV_1 = forced expired volume in first second; HH-II = Healthy Homes II study.
[a]Based on *t* test comparing within-group change across groups or logistic regression comparing exit values adjusted for baseline values.
[b]Sample smaller because not all children could perform the spirometry maneuver (n = 22).

therapy in reducing urgent care for asthma and improving symptom-free days and FEV_1 in children and adolescents.[42]

In BEHs, exposure to mold, dampness, and rodents decreased dramatically and significantly, and smoking in the home and roaches showed large but nonsignificant declines. After 1 year of BEH residence, evidence of moisture was rare, rodents had been eliminated, and the combined trigger score measuring the average number of triggers per home was close to zero. Analysis of cross-sectional descriptive data on in-home dust showed a pattern of lower levels of ergosterol, Der p1, and Fel d1 in the BEHs.

The additional costs for the BEH features were modest, ranging from $5000 to $7000 over those of the standard high quality homes built at High Point, adding approximately 5% to the costs. Considering the potential savings in asthma care costs and missed work and school days, these costs could be recouped over a relatively short time. It was not difficult for the Seattle Housing Authority and the contractors to include the BEH features in the base homes they were building, suggesting that replicating the BEH in other settings is feasible.

Our study contributes to the growing literature on home-based asthma interventions. We found that home design and construction can incorporate asthma-friendly features at a modest cost, and moving from a substandard home to an asthma-friendly home can have a dramatic impact on childhood asthma. The asthma-control benefits of an asthma-friendly home are additive to the benefits of educational

TABLE 3—Within-Group and Across-Group Trigger-Exposure Outcomes: Children and Adolescents With Asthma, Seattle, WA, 2002–2007

	BEH (N = 34)				HH-II (N = 68)				BEH vs HH-II[a]	
Outcome	Baseline	Exit	Change (95% CI)	*P*	Baseline	Exit	Change (95% CI)	*P*	Change in OR (95% CI)	*P*
Mold in the home,[b] %	64.7	0	−64.7 (−83.7, −45.7)	< .001	48.5	14.7	−33.8 (−47.9, −19.7)	< .001	N/A	
Household member smokes, %	14.7	11.8	−2.9 (−18.7, 12.9)	.655	27.9	19.1	−8.8 (−18.1, 0.5)	.034	0.98 (0.21, 4.54)	.98
Smoking inside the home,[b] %	5.9	2.9	−2.9 (−15.8, 9.9)	.564	5.9	5.9	0 (−8.5, 8.5)	N/A	0.48 (0.05, 4.54)	.521
Roaches,[b] %	8.8	2.9	−5.9 (−20.2, 8.4)	.317	17.6	16.2	−1.5 (−13.3, 10.4)	.782	0.18 (0.02, 1.49)	.112
Rodents,[b] %	17.6	0	−17.6 (−33.4, −1.9)	.014	7.4	2.9	−4.4 (−12.2, 3.4)	.18	N/A	
Any pet in the home,[b] %	0	0	0		23.4	25.0	−1.6 (−8.1, 11.2)	.706	N/A	
Water damage/condensation/leaks/drips,[b] %	41.2	0	−41.2 (−60.7, −21.7)	< .001	30.9	7.4	−23.5 (−36.6, −10.4)	< .001	N/A	
Trigger score, mean	1.38	0.06	−1.32 (−1.70, −0.95)	< .001	1.34	0.71	−0.63 (−0.92, −0.34)	< .001	0.69 (0.21, 1.17)	.005

Note. BEH = Breathe-Easy Home; CI = confidence interval; HH-II = Healthy Homes II; N/A = not applicable; OR = odds ratio. *P* not applicable when odds ratio could not be calculated, either because exit value in BEH group was 0 or because there was no change
[a]Difference in change score for continuous variables or odds ratio for binary variables.
[b]Component of trigger score (see last row).

interventions, which often cannot remediate structural asthma triggers or effectively reduce triggers. For example, a recent systematic review of CHW asthma interventions in the United States noted inconsistent success in asthma-trigger reduction.[43]

However, many studies and several reviews have shown that interventions that address home environmental conditions are effective in reducing trigger exposures or asthma morbidity.[17–19,44–53] The effect size for these widely varied interventions ranges from no significant effect to nearly 50% improvement, depending upon the clinical endpoint, type of intervention, baseline housing quality, and geographic locale. Findings from some prenatal asthma prevention studies suggest that home environmental interventions may also prevent asthma if begun early in life.[54] The question of whether improvements in home design and construction can actually prevent asthma warrants further study on a larger scale.

Limitations

This study has several important limitations. The quasi-experimental design was necessary, but it limited our ability to interpret the relationship between housing and the clinical improvements we observed. Our findings may have been influenced by temporal trends, regression to the mean, or the Hawthorne effect.[55] Indeed, studies of other housing interventions that used a randomized-control design generally showed modest improvements in the control groups.[47,48] We were unable to randomly assign families to move into a BEH or remain in their old home because the housing authority needed to lease the BEHs quickly, and the community advisory group with whom we worked on the project did not support that approach. The advisory group's opinion anticipated the findings of the 2005 Institute of Medicine report on ethical considerations in housing research with children.[56] The absence of random assignment raises the possibility that the HH-II and BEH cohorts could have differed with respect to unmeasured variables, despite being matched for a number of characteristics. However, the clinical and environmental exposure effect sizes were quite large within the BEH group, suggesting a real impact beyond that expected from regression to the mean or other threats to internal validity.

We were not able to collect complete data from all study participants. For example, the youngest children could not perform the spirometry consistently enough to meet quality criteria. Few other clinical endpoints had missing data (1 each for nights with symptoms and days with limited activity, and 2 for asthma attacks in the past 3 months). Logistical challenges impeded uniform collection of dust samples from all participants, making it impossible to examine changes across time in dust analytes, because different households were included in the samples obtained at each time point, and the included homes were not necessarily representative of all homes in the study. It was impossible to blind data collection. Although the home environmental assessment was not performed by the CHW engaged in educational visits, the home assessor could not be blinded to the type of home.

There was no "usual care" comparison group. Twenty-two of the BEH residents had received HH-II-style home visits from trained CHWs during their final year in their old home, a benefit not typically part of usual care. This intervention improved the baseline outcome (data not shown) and exposure measures. The beneficial effects of the BEH are therefore likely to be underestimated relative to usual care.

Our study took place among very-low-income residents of public housing. The results are relevant to populations with similar demographics, but we cannot generalize our findings to dissimilar populations. However, the public-housing population is at high risk of asthma morbidity, so making BEH available to them would create an important impact on the total asthma burden in a community. Still, there is a need to evaluate the effectiveness of these interventions among higher-income groups.

Conclusions

In light of the additive improvements in the BEH group compared with the group that received only home education and support, it would be worthwhile to conduct a larger-scale randomized controlled trial comparing these 2 interventions or studying the marginal benefit of the BEH beyond the benefits of in-home asthma education and support. The relative cost-effectiveness and return on investment of the 2 approaches merit further investigation. The impact of BEH-type interventions in varying climatic conditions is also of interest. In addition, some families may benefit more from the passive protection of living in a BEH, particularly those who are unable or unwilling to make the behavioral changes required for a successful educational intervention or who live in homes with structural deficits that cannot be remediated. Resources could be targeted more efficiently if the characteristics of homes and families suitable for tailoring interventions could be identified.

In summary, this pilot study suggests that moving low-income children with asthma into asthma-friendly housing reduces exposure to indoor asthma triggers and improves clinical outcomes over and above what is seen with in-home asthma education alone. Other studies have also found that improving housing conditions can aid in asthma control. In light of these findings, building codes, financing for housing, and construction practices should be modified to address the environmental conditions that promote asthma triggers in the home. ■

About the Authors

Tim K. Takaro is with the Faculty of Health Sciences, Simon Fraser University, Burnaby, British Columbia, Canada. James Krieger and Lin Song are with the Department of Public Health, Seattle & King County, Seattle, WA. Denise Sharify is with Neighborhood House, Seattle. Nancy Beaudet is with the Northwest Pediatric Environmental Health Specialty Unit, University of Washington, Seattle.

Correspondence should be sent to Tim K. Takaro, Simon Fraser University, 8888 University Drive, Blusson Hall, Room 11300, Burnaby, BC V5A1S6, Canada (e-mail: ttakaro@sfu.ca). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints/Eprints" link.

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Contributors

T.K. Takaro designed and directed the BEH intervention. T.K. Takaro, J. Krieger, and L. Song developed the study's comparison strategy. L. Song carried out the analyses. D. Sharify directed the intervention field team. N. Beaudet oversaw the collection of environmental measures. All authors participated in writing the article and approving the final version.

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Human Participant Protection

The University of Washington institutional review board approved the Breathe-Easy home study, and the Children's Hospital and Regional Medical Center institutional review board approved the Healthy Homes II study.

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