Brief report

Reduced prevalence of childhood asthma after housing renovations in an underresourced community

Andrew F. Beck, MD, MPH,[a] Larry Wymer, MS,[b] Eugene Pinzer, PhD,[c] Warren Friedman, PhD,[c] Peter J. Ashley, DrPH (retired),[c] and Stephen Vesper, PhD[b] *Cincinnati, Ohio, and Washington, DC*

Background: Despite improvements in asthma symptom management and asthma morbidity, the prevalence of asthma in the United States remains high, especially in underresourced communities.

Objective: Our goal was to determine whether housing renovations affect the prevalence of asthma in an underresourced community.

Methods: The Fay Apartments (~800 units) in Cincinnati, Ohio, were renovated to "green building" standards between 2010 and 2012 and renamed the Villages at Roll Hill. The prevalence of asthma among 7-year-olds in the Villages at Roll Hill was determined by accessing Ohio Medicaid data for the years 2013 to 2021.

Results: In the first 6 years after the renovations (2013-2018), the prevalence of asthma among 7-year-olds in the community averaged 12.7%. In contrast, in postrenovation years 7 through 9 (2019-2021), the average prevalence of asthma was 5.9%. Logistic regression modeling for the log odds of asthma diagnosis in this age group was used to test the statistical significance of asthma prevalence for 2013-2018 versus for 2019-2021. The model resulted in demonstration of a significant ($P < .001$) reduction in asthma prevalence between 2013-2018 and 2019-2021.

Conclusions: The renovation of an underresourced community's housing resulted in a lower prevalence of asthma for 7-year-olds who were born after the renovations had been completed. (J Allergy Clin Immunol Global 2023;2:100143.)

Key words: *African American, asthma, Black, green building, infants*

Abbreviations used
BEH: Breath-easy home
EPA: US Environmental Protection Agency

INTRODUCTION

Links between housing and health are well established.[1] Housing disparities[2] are thought to play a role in higher asthma rates in underresourced, urban communities.[3,4] In turn, the higher prevalence of asthma perpetuates disparities in asthma-related morbidity despite progress in symptom management.[5] New approaches are needed to achieve primary prevention, reducing prevalence of asthma in underresourced communities.

There are many risk factors associated with asthma development,[6] with increasing evidence that asthma has its origins early in life.[7] For example, exposures to high levels of mold during the first year of infancy were associated with asthma being diagnosed by a physician in children at age 7 years.[8] Longitudinal studies are needed to quantify the long-term health impacts of interventions such as housing renovations.

The approximately 800-unit Fay Apartments, which are located in the City of Cincinnati, in Hamilton County, Ohio, were built in the 1960s and encompass the zip code 45225. With support from the US Department of Housing and Urban Development (HUD), the Fay Apartments were renovated to "green building" standards and renamed the Villages at Roll Hill. The green building renovations were completed between 2010 and 2012.[9] The renovations included structural repairs, removal of water damage and mold, insulation, new energy-efficient windows and doors, and new roofs. The residents of the Fay Apartments (now the Villages at Roll Hill) are a low-income (average income <$15,000 per year), primarily (98%) African American/Black community.

Our hypothesis was that infants born to families living in this community after the renovations were completed in 2012 would be less likely to develop asthma by age 7 years (ie, in 2019 and thereafter). To test our hypothesis, Ohio Medicaid data were queried for the yearly prevalence of asthma among 7-year-olds from 2013 until 2021 by Honest Broker, a division of IBM, which has the sole source contract with Ohio to access Ohio Medicaid data for research purposes. A complete Ohio Medicaid data set was available only for 2013 through 2021. Honest Broker determined asthma diagnosis on the basis of the International Classification of Diseases codes[10] (Table I). Member cohort eligibility was based on continuous residence in the zip code 45225 for 24 months (ie, the cohort year and previous year).

From [a]the Cincinnati Children's Hospital Medical Center and University of Cincinnati College of Medicine; [b]the Center for Environmental Measurement and Modeling, US Environmental Protection Agency, Cincinnati; and [c]the US Department of Housing and Urban Development, Washington.

Received for publication February 18, 2023; revised May 15, 2023; accepted for publication May 17, 2023.

Available online July 10, 2023.

Corresponding author: Stephen Vesper, PhD, US Environmental Protection Agency, Center for Environmental Measurement and Modeling, 26 W Martin Luther King Drive, Cincinnati, OH 45268. E-mail: vesper.stephen@epa.gov.

2772-8293

https://doi.org/10.1016/j.jacig.2023.100143

TABLE I. International Classification of Diseases codes used in the analysis of the prevalence of asthma for 7-year-olds in the zip code 45225

ICD version code	Principal diagnosis code	Principal diagnosis
10	J4520	Mild intermittent asthma, uncomplicated
10	J4521	Mild intermittent asthma with (acute) exacerbation
10	J4522	Mild intermittent asthma with status asthmaticus
10	J4530	Mild persistent asthma, uncomplicated
10	J4531	Mild persistent asthma with (acute) exacerbation
10	J4532	Mild persistent asthma with status asthmaticus
10	J4540	Moderate persistent asthma, uncomplicated
10	J4541	Moderate persistent asthma with (acute) exacerbation
10	J4542	Moderate persistent asthma with status asthmaticus
10	J4550	Severe persistent asthma, uncomplicated
10	J4551	Severe persistent asthma with (acute) exacerbation
10	J4552	Severe persistent asthma with status asthmaticus
10	J45901	Unspecified asthma with (acute) exacerbation
10	J45902	Unspecified asthma with status asthmaticus
10	J45909	Unspecified asthma, uncomplicated
10	J45990	Exercise induced bronchospasm
10	J45991	Cough variant asthma
10	J45998	Other asthma
9	49300	Extrinsic asthma not specified
9	49301	Extrinsic asthma with status asthmaticus
9	49302	Extrinsic asthma with exacerbation
9	49310	Intrinsic asthma not specified
9	49311	Intrinsic asthma with status asthmaticus
9	49312	Intrinsic asthma with exacerbation
9	49320	Chronic obstructive asthma not specified
9	49321	Chronic obstructive asthma with status asthmaticus
9	49322	Chronic obstructive asthma with exacerbation
9	49381	Exercise induced bronchospasm
9	49382	Cough variant asthma
9	49390	Unspecified asthma
9	49391	Unspecified asthma with status asthmaticus
9	49392	Unspecified asthma with exacerbation

Clinical condition was based on the principal diagnosis code on the claim.

TABLE II. Medicaid data for 7-year-olds in the Villages of Roll Hill diagnosed with asthma in the years after renovations

Data year	Years after renovations	Members of cohort	Diagnosed with asthma	Prevalence (%)
2013	1-2	344	35	10.17
2014	2-3	344	35	10.17
2015	3-4	340	55	16.18
2016	4-5	321	40	12.46
2017	5-6	327	38	11.62
2018	6-7	162	23	14.2
2019	7-8	196	11	5.61
2020	8-9	248	18	7.26
2021	9-10	329	16	4.86

Member cohort eligibility was based on continuous residence in zip code 45225 for 24 months (ie, the cohort year and the previous year). The numbers of members in each cohort year are shown in column 3. The numbers from each cohort who were diagnosed with asthma are shown in column 4, with the calculated percentage (%) prevalence (number diagnosed divided by the total number in the cohort) shown in column 5.

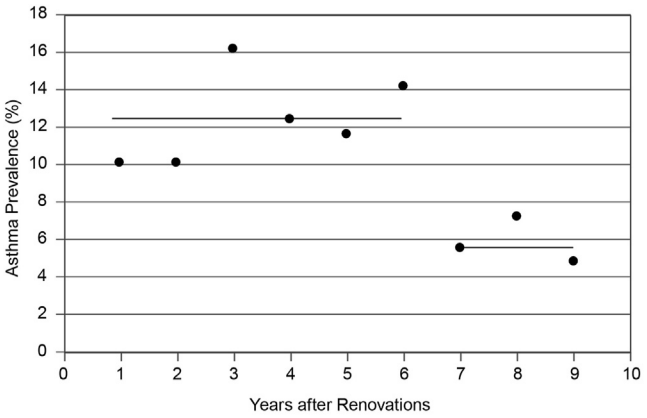

FIG 1. Prevalence of childhood (at age 7) asthma in the Villages at Roll Hill in each year after the renovations were completed, based-on Ohio Medicaid data. *Black lines* are the averages for 2013-2018 and 2019-2021.

Historical prevalence of asthma before 2013 had to be estimated because Ohio Medicaid data were unavailable before 2013. One estimate was from the National Survey of Children's Health.[11] A second was based on the 2011 Child Well-Being Survey of Cincinnati residents.[12] A third estimate used a 2011 study of asthma morbidity by Cincinnati neighborhood.[13] Although not a documentation of asthma prevalence, this study reported asthma hospitalization rates in 2011 for each of 93 Cincinnati neighborhoods, including the Fay Apartments.

With these prevalence estimates, we assessed changes in asthma prevalence from before to after the renovations. Logistic regression modeling was used to obtain the log odds of asthma diagnosis in the cohorts of 7-year-olds. We tested statistical significance of the general downward trend over time (2013-2021) and an apparent shift in the trendline in asthma prevalence after 2018 (2013-2018 vs 2019-2021).

RESULTS AND DISCUSSION

The National Survey of Children's Health, from 2007, estimated that 13% of children in Greater Cincinnati had asthma.[11] The 2011 Child Well-Being Survey estimated that 17% of children living within Cincinnati had asthma.[12] Also in 2011, children from the Fay Apartments were hospitalized for asthma at twice the rate of the rest of Greater Cincinnati.[13] Therefore, the prevalence of childhood asthma in the prerenovation Fay Apartments was likely at least 12%. This is consistent with the higher prevalence of asthma documented in underresourced African American/Black communities across the United States.[14] Moreover, in 2011, at least 7.5% of those identifying as Black lived in substandard housing.[2] Of note, correlations previously made between race and asthma rates may be correlations between race and housing disparities, including increased urban habitation in older homes.[15,16]

Table II shows Medicaid data for 7-year-olds in the Villages of Roll Hill who were diagnosed with asthma in the years after renovations. Asthma prevalence before 2019 averaged 12.7% and declined to 5.9% from 2019 to 2021 (Fig 1). Table III illustrates results from logistic regression analyses of the log odds of asthma prevalence. A general linear downward trend by itself was significant ($P < .001$). Introduction of a dummy variable (ie, $X = 0$ for data from 2013-2018 and $X = 1$ for data from 2019-2021) into the model resulted in a significant ($P < .001$) downward shift and negated the significance ($P = .29$) of the linear trend. In other

TABLE III. Results from competing logistic regression analyses on log odds of prevalence of asthma (see Table II)

Model	Intercept	Independent variables	
		Year	2019 event
Trend only	–1.85	–0.090 (<0.001)	NA
Trend + 2019 event	–2.07	0.046 (0.29)	–1.04 (<0.001)
2019 event only	–1.96	NA	–0.82 (<0.001)

The potential independent variables include (1) trend over time and (2) a single "dummy" variable, x, representing whether data is from the period before 2019 ($x = 0$) or from the period from 2019 through 2021 ($x = 1$). The numbers in parentheses are P values for the respective independent variables. Year represents the difference of the actual year from the year 2013 for equivalent interpretation of intercept values.
NA, Not applicable.

words, it seems that the significance of our result was driven largely by a change in the period 2019-2021, thus illustrating the potential impact of housing renovations.

Our findings should be interpreted in the context of nearly 2 decades of studies testing various approaches to reducing the health impact of asthma in underresourced communities. One of the most common approaches is application of various forms of green housing renovations. Although forms of renovation vary across many of the studies conducted, a common goal is to provide sustainable, quality housing and reduce adverse exposures. For example, 1 study considered the health of families before and after they moved into "green healthy" housing (n = 325).[17] Self-reported health status, visual assessments of housing conditions, and indoor-air sampling were used to assess the impact of the changes. Although asthma symptoms were self-reported to have improved after the move into green housing, reduced use of medical interventions for asthma could not be substantiated.[18]

In a separate study conducted in Minnesota, Breysse et al[19] found significant environmental improvements following low-income housing renovations carried out by using Enterprise Green Communities specifications. One year after the renovations, Breysse et al[19] found no improvement in adult or children's asthma; however, this could be due to the short duration of the follow-up. In a study in Seattle, public housing units were built to breath-easy homes (BEHs) standards.[20] These standards call for use of positive pressure house ventilation systems with air filtering, tempered fresh air supply, and heat recovery to improve indoor air quality. In this study, survey responses of families of children with asthma who moved into BEH renovated housing were compared with those of families receiving only clinic-based education or in-home asthma help and support.[20] As a result of the move into BEH-type housing, asthma symptoms improved but FEV_1 values did not change.[21] Finally, Colton et al[22] compared health outcomes for children with asthma who moved from conventional to new green public housing in Boston with the health outcomes of those remaining in conventional public housing. Managers of the green properties also adopted integrated pest management and tobacco smoke prohibitions within the properties. Children with asthma who moved into "green homes" had significant reductions in asthma symptoms compared with children in conventional homes.

We believe that a common limitation of the aforementioned studies was the short follow-up period. This is understandable because of the generally limited funding, and therefore limited duration, of the studies. Still, more extended follow-up would likely have provided clearer results. For the renovated Villages at Roll Hill, it was not until the cohort of infants born after the renovation had reached 7 years of age that a significant reduction in asthma prevalence was captured in the Medicaid data. This would be consistent with the hypothesis that asthma development has its origins in infancy or very early childhood.

Our study has limitations. It is impossible to know from deidentified Medicaid data how many children born after the renovations lived in the community until age 7 years. However, because of the dramatic improvement in the quality of the housing after renovations, we think that it is reasonable to suggest that most families stayed. Another limitation was the possible impact of the coronavirus disease 2019 (COVID-19) pandemic, which began in the United States in March 2020. The pandemic kept many vulnerable people from seeking routine medical care,[23] but the situation improved by late 2020.[24] Still, the asthma prevalence estimates based on Ohio Medicaid data for 2020, may be an underestimate. Finally, we lacked Medicaid data for the years before renovation, potentially limiting the accuracy of pre-renovation prevalence estimates. Still, we have been monitoring childhood asthma morbidity in Cincinnati neighborhoods for many years, with emergency visits and hospitalizations occurring at high rates since at least 2009.[25] In addition, in the first 6 years after renovation, the prevalence of asthma based on Medicaid data averaged more than 12%. It is therefore unlikely that community prevalence would have been substantially lower in the years before the renovations than immediately after the renovations.

It appears that if green building renovations result in a reduction in childhood asthma prevalence, the reduction will not be immediately measurable. Therefore, to document the impacts of housing renovations on health, the community should be monitored for many years. Although no cause(s) of the reduction in the prevalence of asthma can be identified from our study because the renovations altered many potentially problematic exposures, a comprehensive approach to improving substandard housing seems promising. And finally, we suggest that clinicians and community health workers could improve asthma management by making themselves aware of links between asthma and housing, between zip code and health outcomes. In turn, they can ensure that anticipatory guidance includes discussions of trigger avoidance and that they can connect with community partners (eg, health and building departments, the housing authority, policymakers) adept at mitigating adverse housing conditions.

DISCLOSURE STATEMENT

Supported, in part, by a Cincinnati Children's Research Foundation Academic and Research Committee Award and the Agency for Healthcare Research and Quality (grant 1R01HS027996 [to A.F.B.]).

Disclosure of potential conflict of interest: The authors declare that they have no relevant conflicts of interest. The views expressed in this article are those of the authors and do not necessarily represent the views or policies of the US Environmental Protection Agency (EPA). Any mention of trade names, products, or services does not imply an endorsement by the US government or the EPA. The EPA does not endorse any commercial products, services, or enterprises. The findings and

conclusions in this article are those of the authors and do not necessarily represent the official positions of the EPA or US Department of Housing and Urban Development.

We dedicate this article to the memory of pediatrician Albert Vesper, III, MD.

Clinical implications: Clinicians could improve asthma management by engaging in discussions related to trigger avoidance and connecting with community partners adept at mitigating adverse housing conditions.

REFERENCES

1. Weitzman M, Baten A, Rosenthal DG, Hoshino R, Tohn E, Jacobs DE. Housing and child health. Curr Probl Pediatr Adolesc Health Care 2013;43:187-224.
2. Jacobs DE. Environmental health disparities in housing. Am J Public Health 2011; 101:S115-22.
3. Eggleston PA. The environment and asthma in US inner cities. Chest 2007; 132(Suppl):782S-8S.
4. Grant T, Croce E, Matsui EC. Asthma and the social determinants of health. Ann Allergy Asthma Immunol 2022;128:5-11.
5. Akinbami LJ, Bryant-Stephens T. Increasing the resolution and broadening the focus on childhood asthma disparities. Pediatrics 2022;150:e2022057206.
6. Miller RL, Grayson MH, Strothman K. Advances in asthma: new understandings of asthma's natural history, risk factors, underlying mechanisms, and clinical management. J Allergy Clin Immunol 2021;148:1430-41.
7. Russo D, Lizzi M, Di Filippo P, Di Pillo S, Chiarelli F, Attanasi M. Time-specific factors influencing the development of asthma in children. Biomed 2022;10:758.
8. Reponen T, Vesper S, Levin L, Johansson E, Ryan P, Burkle J, et al. High Environmental Relative Moldiness Index during infancy as a predictor of age seven asthma. Ann Allergy Asthma Immunol 2011;107:120-6.
9. Coombs KC, Chew GL, Schaffer C, Ryan PH, Brokamp C, Grinshpun SA, et al. Indoor air quality in green-renovated vs. non-green low-income homes of children living in a temperate region of US (Ohio). Sci Total Environ 2016;554-555:178-85.
10. World Health Organization. ICD-10: international statistical classification of diseases and related health problems: tenth revision, 2nd ed. 2004. World Health Organization. Available at: https://apps.who.int/iris/handle/10665/42980. Accessed October 12, 2021.
11. The National Survey of Children's Health. Data Resource Center for Child & Adolescent Health. 2007. Available at: https://www.childhealthdata.org/learn-about-the-nsch. Accessed December 12, 2021.
12. Child Well-Being Survey. 2011. Available at: https://www.HealthFoundation.org. Accessed January 12, 2022.
13. Beck AF, Moncrief T, Huang B, Simmons JM, Sauers H, Chen C, et al. Inequalities in neighborhood child asthma admission rates and underlying community characteristics in one US county. J Pediatr 2013;163:574-80.
14. Simons E, Curtin-Brosnan J, Buckley T, Breysse P, Eggleston PA. Indoor environmental differences between inner city and suburban homes of children with asthma. J Urban Health 2007;84:577-90.
15. Aligne CA, Auinger P, Byrd RS, Weitzman M. Risk factors for pediatric asthma. Contributions of poverty, race, and urban residence. Am J Res Crit Care Med 2000;162:873-7.
16. Everhart RS, Kopel S, McQuaid EL, Salcedo L, York D, Potter C, et al. Differences in environmental control and asthma outcomes among urban Latino, African American, and Non-Latino White families. Ped Allergy Immun Pul 2011;24:165-9.
17. Jacobs DE, Breysse J, Dixon SL, Aceti S, Kawecki C, James M, et al. Health and housing outcomes from green renovation of low-income housing in Washington, DC. J Environ Health 2014;76:8-16.
18. Jacobs DE, Ahonen E, Dixon SL, Dorevitch S, Breysse J, Smith J, et al. Moving into green healthy housing. J Public Health Manag Pract 2015;21:345-54.
19. Breysse J, Jacobs DE, Weber W, Dixon S, Kawecki C, Aceti S, et al. Health outcomes and green renovation of affordable housing. Public Health Rep 2011; 126(suppl 1):64-75.
20. Takaro TK, Krieger J, Song L, Sharify D, Beaudet N. The breathe-easy home: the impact of asthma-friendly home construction on clinical outcomes and trigger exposure. Am J Public Health 2011;101:55-62.
21. Krieger J, Takaro TK, Song L, Beaudet N, Edwards K. A randomized controlled trial of asthma self-management support comparing clinic-based nurses and in-home community health workers: the Seattle-King County Healthy Homes II Project. Arch Pediatr Adolesc Med 2009;163:141-9.
22. Colton MD, Laurent JG, MacNaughton P, Kane J, Bennett-Fripp M, Spengler J, et al. Health benefits of green public housing: associations with asthma morbidity and building-related symptoms. Am J Public Health 2015;105:2482-9.
23. Baggio S, Vernaz N, Spechbach H, Salamun J, Jacquerioz F, Stringhini S, et al. Vulnerable patients forgo health care during the first wave of the Covid-19 pandemic. Prev Med 2021;150:106696.
24. Adjemian J, Hartnett KP, Kite-Powell A, DeVies J, Azondekon R, Radhakrishnan L, et al. Update: COVID-19 pandemic–associated changes in emergency department visits — United States, December 2020–January 2021. MMWR Weekly 2021;70:552-6.
25. Correa-Agudelo E, Ding L, Beck AF, Brokamp C, Altaye M, Kahn RS, et al. Understanding racial disparities in childhood asthma using individual- and neighborhood-level risk factors. J Allergy Clin Immunol 2022;150:1427-36.