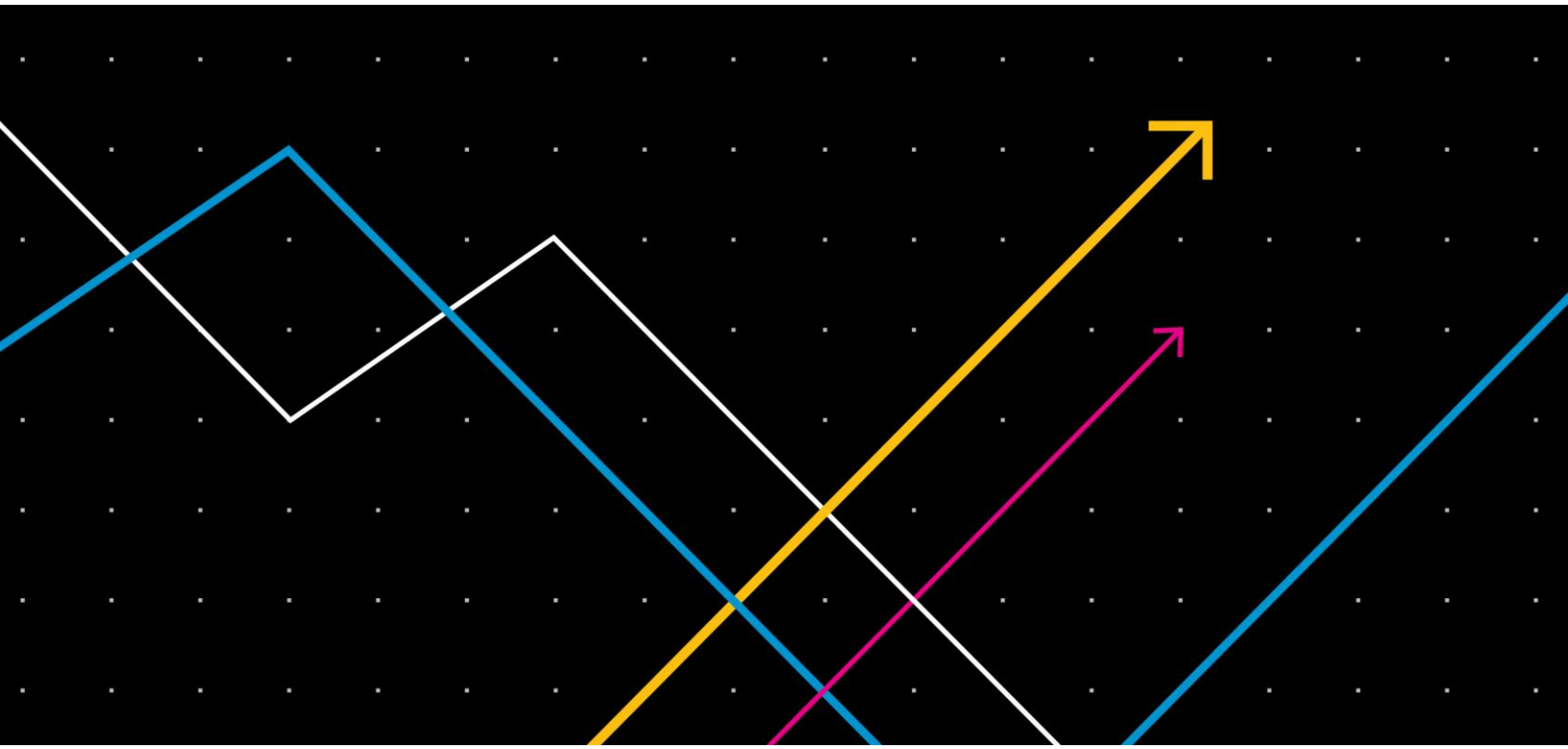

RESEARCH REPORT

The Relationship between Housing and Asthma among School-Age Children

Analysis of the 2015 American Housing Survey

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Executive Summary

Interest in the intersection between health and housing is rising within both sectors as they work together to prevent asthma attacks and reduce related emergency room (ER) and hospital use. Although the exact causes of asthma are uncertain, many common irritants that trigger symptoms can be found in the home, including mold, pests, and tobacco smoke. Initiatives to reduce these triggers are under way across the country, from home remediation to new regulations (e.g., a public housing smoking ban).

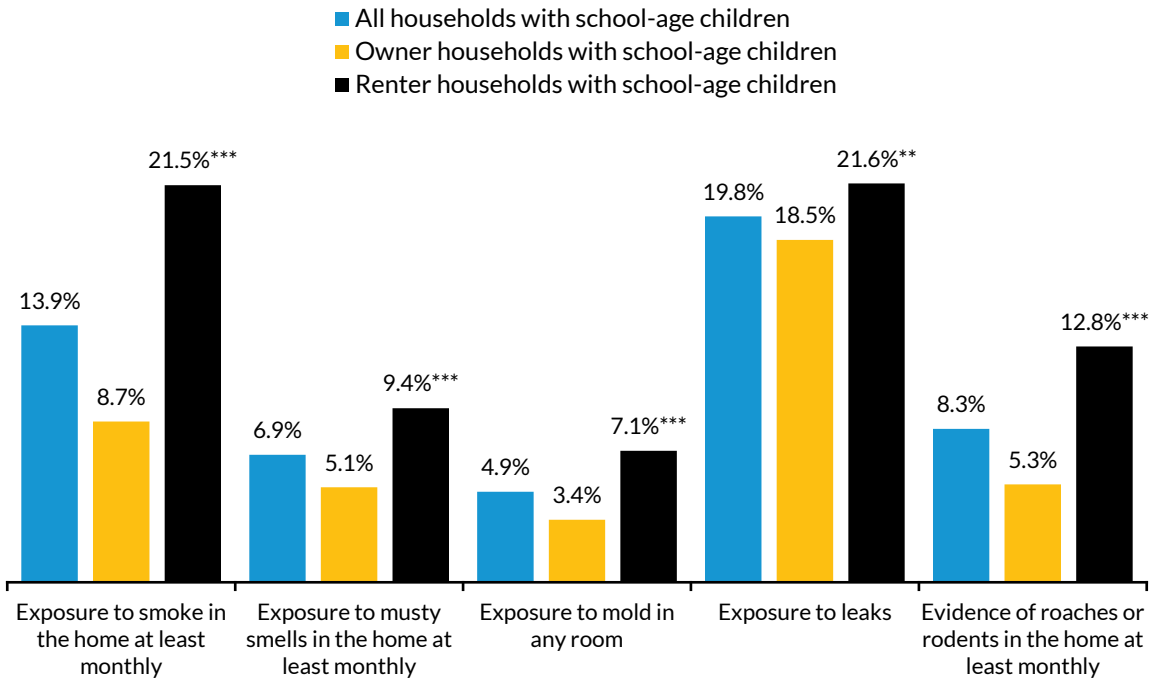
Understanding the relationship between asthma, ER and urgent care visits, and housing-related triggers is difficult because most health surveys lack data on housing conditions, and most housing surveys lack data on health conditions. But the 2015 American Housing Survey (AHS) included a special module with questions on asthma and triggers in the home. This dataset helped us explore variations in asthma prevalence and asthma-related ER use among school-age children (ages 5 to 17) by a wide array of housing and household characteristics, including exposure to asthma triggers (e.g., smoke, mold, rodents, and cockroaches) tenure (renter or owner), and receipt of government assistance in paying rent.

Key Findings

- **Asthma prevalence.** Households with kids are more likely to have at least one with asthma when they also report exposure to smoke, mold, and leaks in their home.
- **Emergency room and urgent care visits.** Smoking inside the home and mold in the bedroom are associated with more ER and urgent care visits among households with an asthmatic child.
- **Housing tenure.** Renters with kids are more likely to have asthma triggers in their homes than owners (figure ES.1) and are more likely to have at least one child with asthma.
- **Rental assistance.** Assisted renters have higher exposure to certain indoor asthma triggers (e.g., smoke, mold) than other low-income renters not receiving any government rental assistance and are more likely to have at least one child with asthma in the household.

FIGURE ES.1

Exposure to Asthma Triggers among Households with School-Age Children, Overall and by Tenure



Source: Authors' analysis of the 2015 American Housing Survey.
Notes: Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. ** Estimate is significantly different from estimate for owner households at the 0.05 level. *** Estimate is significantly different from estimate for owner households at the 0.01 level.

Policy Implications

The positive association between asthma rates and certain housing and household characteristics, including the presence of asthma triggers, suggest several areas for action and research.

- Current policies and programs may be missing asthma triggers. Complaint-based building inspections and federally mandated housing quality inspections may overlook less visible but threatening hazards, such as smoke, mold, and leaks. These hazards require a different approach, but few programs and resources train inspectors to look for more comprehensive problems or to help property owners resolve these issues.
- Renters are particularly vulnerable. Rental housing inspections, federally mandated housing-quality inspections of assisted housing, smoke-free policies, and integrated pest management

may reduce renters' exposure to asthma triggers, particularly smoke, mold, and leaks. Renters may have fewer means to address these issues on their own because of lease restrictions or building-wide problems, so action by the US Department of Housing and Urban Development, private landlord education, and legal aid for tenants may be required.

- Reduced exposure to tobacco smoke may be key to reducing asthma-related ER and urgent care visits. Promising practices include smoking cessation programs or referrals for parents and other adult household members. The public housing ban on smoking may help reduce asthma exacerbations, but its effects and enforceability remain to be seen.

The Relationship between Housing and Asthma

Asthma, Triggers, and Children: What We Know

Asthma is one of the most common chronic illnesses in the United States, especially among children. Per the Centers for Disease Control and Prevention (CDC), about 1 in 12 people, or 25 million Americans, have asthma, and the numbers have been increasing (CDC 2011). In 2014, an estimated 6.2 million children from birth to age 17 had asthma, or 8.6 percent of children.1 Of these, 44.7 percent experienced an asthma attack in 2014.2 In addition, among school-age children (ages 5 to 17) with asthma, 49.0 percent missed at least one school day because of their asthma in 2013.[3] Asthma is also a major cause of emergency room (ER) use. In 2013, asthma was among the 20 leading causes of ER use among children under age 15 (Rui, Kang, and Albert, n.d.). In 2010, pediatric asthma ER visits cost state Medicaid programs a combined $272 million (Pearson et al. 2014).

Although asthma's cause is not known, it is thought to be related to a combination of genetic and environmental factors. Environmental factors include exposure to viral infections during childhood,[4] contact with indoor allergens (Wu and Takaro 2007), dampness and mold exposure (Mudarri and Fisk 2007; Fisk, Lei-Gomez, and Mendell 2007), exposure to cockroaches and rodents (Wang, Abou El-Nour, and Bennett 2008, Sheehan et al. 2010), environmental tobacco smoke (IOM 2000), neighborhood characteristics (Alexander and Currie 2017, Cagney and Browning 2004), and outdoor air quality (Orellano et al. 2017). In addition, housing conditions such as plumbing leaks, roof leaks, and inadequate ventilation contribute to mold formation, especially in older and poorly maintained buildings (Rauh, Landrigan, and Claudio 2008).

Previous literature shows that asthma prevalence differs across housing characteristics. Renters tend to have higher asthma prevalence than owners (Rosenbaum 2008). Studies have demonstrated that the quality of housing conditions was lower on average for renters compared with owners (Rohe and Lindblad 2013). This difference could explain differences in health outcomes, particularly for health conditions exacerbated by allergens (Macintyre et al. 2003). Studies also show that asthma prevalence also differs between metropolitan and nonmetropolitan areas and across regions. Gern (2010) showed

that childhood asthma is not distributed evenly throughout the population, and children who grow up in urban neighborhoods have higher rates of asthma and experience greater morbidity because of asthma.

Research shows that low-income renters receiving housing assistance also have higher asthma prevalence than the general population, possibly related to housing conditions, such as pest infestations, deteriorated asbestos, lead hazards, dampness and mold, inadequate ventilation and temperature control, and crowded conditions (Helms, Sperling, and Steffen 2017). In addition, about one-third of renters receiving housing assistance from the US Department of Housing and Urban Development (HUD) smoke, almost two times the rate within the general population but similar to other low-income renters not receiving housing assistance (Helms, King, and Ashley 2017; Helms, Sperling, and Steffen 2017). Half of adults receiving housing assistance who smoke had children in the home up to age 17 (Helms, King, and Ashley 2017).

For children with asthma, environmental asthma triggers in the home are also correlated with ER visits. The National Heart, Lung, and Blood Institute recommends limiting exposure to environmental asthma triggers, such as tobacco smoke, mold, and allergens, to improve asthma control in children.[5] Children with well-controlled asthma experience fewer hospitalizations, ER visits, missed school days, and symptomatic days than children with poorly controlled asthma (CDC 2013; Dean et al. 2010; Meng et al. 2008). In addition, studies have found that reducing asthma triggers in the home, particularly for children sensitive to those triggers, may reduce ER visits and hospitalizations among children with asthma (Crocker et al. 2011). The National Heart, Lung, and Blood Institute and the Community Preventive Services Task Force both recommend multicomponent home-based asthma education and asthma trigger remediation services for children with sensitivities to indoor allergens to improve quality of life and reduce exacerbations.[6]

Finally, a large body of literature shows that asthma prevalence differs by race, gender, income, and parental level of education. The CDC identifies race and ethnicity, poverty status, and parental education as risk factors for asthma and asthma attacks (Standards 2016). 2015 national data from the CDC show that asthma prevalence is disproportionately high among African American children, and a recent study shows that neighborhood factors may be a missing link in explaining this differential (Alexander and Currie 2017). Studies also show that asthma prevalence is correlated with income and education characteristics (Litonjua et al. 1999) and that single parenthood, typically in female-headed households, tends to be associated with uncontrolled childhood asthma, likely driven by lower incomes among single parents (Moncrief et al. 2014). The effects of income on asthma prevalence may be related to neighborhood characteristics, as low-income areas may have more exposure to environmental hazards (Ross and Mirowsky 2001).

Data and Methods

The 2015 American Housing Survey

The American Housing Survey (AHS) is sponsored by HUD and administered by the Census Bureau. The survey is conducted in person and via telephone in odd-numbered years. The AHS had a national sample size of about 69,500 housing units in 2015. The AHS provides information on housing supply, demand, conditions, and cost and allows for assessment of changes over time. In 2015, the AHS included a special topical module on health and safety hazards in homes that was fielded to half of the sample. This module included questions about school-age children with asthma living in the home and the presence of certain indoor asthma triggers. The addition of this topical module made the AHS the first national survey to combine detailed information about housing characteristics and conditions with data on childhood asthma prevalence and health care use. Our analyses use this dataset to explore the relationship between indoor asthma triggers and asthma prevalence among school-age children and the relationship between asthma triggers and asthma-related ER and urgent care visits for school-age children with asthma.

There were 57,641 occupied single- or multifamily housing units in the national sample of the 2015 AHS (table 1), representing a weighted total of over 111 million households. Of these, about 6,626 were single-family or multiunit households with children ages 5 to 17 who responded to the asthma questions in the health and safety hazard module, representing over 25 million households with school-age children nationwide. We dropped manufactured housing units, mobile homes, boats, and recreational vehicles from this analysis because sample sizes were small and preliminary analysis showed those units faced different circumstances than single- and multifamily units. Almost 19 percent of respondents answering the asthma questions, or 1,334 respondents, reported having at least one school-age child with asthma. Respondents reporting at least one school-age child with asthma were also asked if the youngest school-age child with asthma had received ER or urgent care treatment for their asthma in the past 12 months. The healthy homes module also asked about exposure to asthma triggers in the home, including the frequency of musty smells in the home in the past 12 months (daily, weekly, monthly, a few times, once, or never), the frequency of exposure to secondhand smoke in the home in the past 12 months, and the frequency of evidence of roaches and rodents in the home in the past 12 months. We supplemented these triggers with information on mold in any room in the past 12 months, evidence of leaks inside or outside the home in the past 12 months, and frequency of smoking in the home by household members or visitors in the past 12 months from the main survey.

TABLE 1

Sample Sizes and Weighted Totals for Analyses

	Sample size	Weighted total
Total households (single- and multifamily units)	**57,641**	**111,355,694**
Households with children ages 5–17 in final sample	**6,626**	**25,569,649**
Owner households with children	3,589	15,211,317
Renter households with children	3,037	10,358,322
Assisted renter households with children	815	1,442,430
Households with at least one asthmatic child	**1,334**	**4,810,213**

Source: Authors' analysis of the 2015 American Housing Survey.

Methodology

We conducted descriptive analyses to explore the relationship between asthma prevalence and ER and urgent care use for asthma among children ages 5 to 17 and housing characteristics, household characteristics, and indoor asthma triggers. In addition, we conducted descriptive analyses focused on differences in exposure to asthma triggers and other housing characteristics by tenure (renter or owner) and receipt of housing assistance among renters with household incomes at or below 200 percent of Census poverty (low-income renters). We also estimated ER and urgent care visit rates among households with a school-age child with asthma by housing characteristics and exposure to asthma triggers.

We then estimated regression models to further explore the relationship between asthma prevalence and tenure and exposure to asthma triggers in the home, using two specifications: one without asthma triggers and one with asthma triggers.[7] Our asthma triggers included the following:

- **Exposure to smoke in the home at least monthly.** This variable captures households with school-age children who reported that a household member or visitor smoked in the home at least monthly or that secondhand smoke entered the home at least monthly in the past 12 months.
- **Exposure to musty smells in the home at least monthly.** This variable captures households with school-age children who reported experiencing musty smells in the home at least monthly during the past 12 months.
- **Evidence of pests in the home at least monthly.** This variable captures households with school-age children who reported seeing evidence of cockroaches in the home at least monthly over

the past 12 months or evidence of mice or rats in the home at least monthly over the past 12 months.

- **Exposure to mold in any room.** This variable captures households with school-age children who reported seeing mold in any room of the home in the past 12 months, including basements.
- **Exposure to leaks.** This variable captures households with school-age children who reported a leak in the home from inside or outside sources in the past 12 months.

We included various housing characteristics (e.g., age of unit, overcrowding, type of structure, and location), household characteristics (e.g., income, number of children), and householder characteristics (e.g., education, race, ethnicity, sex) in our analysis. Many of these characteristics are risk factors for asthma and asthma exacerbations[8] or were identified as associated with asthma or asthma exacerbations in the literature. Using the same regression specifications, we also examined the relationship between receipt of housing assistance and asthma prevalence among low-income renters. Receipt of housing assistance was identified using a HUD-developed flag that matches survey responses to HUD administrative data on housing assistance recipients across the public housing, voucher, and assisted multifamily programs portfolio.

Last, we examined the relationship between exposure to asthma triggers and asthma-related ER and urgent care visits for school-age children for the sample of households with a school-age child with asthma. We created three models, one without asthma triggers, one with asthma triggers, and one with exposure to mold in any bedroom in place of exposure to mold in any room, as the former may be more strongly associated with asthma exacerbations.

All analyses were conducted at the household level using Stata 14 and appropriate survey weights provided by the Census Bureau.

Study Limitations

This study has several notable limitations. First, sample sizes are small, particularly for the analysis of renter households with school-age children and the analysis of ER and urgent care visits among households with a school-age child with asthma. Also, an ER or urgent care visit in the past 12 months was only reported for the youngest school-age child in the household with asthma among households with multiple school-age children with asthma, likely underestimating the share of households with at least one asthma-related ER or urgent care visit. All survey datasets include measurement error, and we

expect that some respondents may have misreported housing characteristics, household incomes, asthma trigger exposure, asthma diagnoses, and ER visits because of asthma. In particular, items asking respondents to recall their experiences over the past 12 months may be subject to recall bias, meaning survey respondents may not accurately or completely recall all ER events or asthma trigger exposures over a 12-month period.

Finally, the dataset does not include other potentially important contributors to asthma rates and asthma ER visits, including the following:

- We cannot observe outdoor air quality and other conditions outside the home that are related to asthma prevalence and exacerbations, including smog, proximity to highways, and overall outdoor air quality. These factors may be correlated with the asthma triggers found in the home, and omitting them may confound the relationships reported here.
- We also lack information on other factors, such as asthma prevalence among the child's parents and other health issues facing children that could interact with the asthma triggers.
- Asthma rates vary substantially across the country, but our data do not allow us to disaggregate results to examine specific areas.
- Health insurance status is an important predictor of ER use, but we do not have access to information on the health insurance status of AHS respondents. In addition, other factors, such as the availability of after-hours care, can affect ER use, and access to primary care can affect asthma diagnosis and severity.

Findings

Housing and Household Characteristics of Children with Asthma and Asthma Prevalence

In our sample, 18.8 percent of households with school-age children (ages 5 to 17) reported having a school-age child with asthma. Table 2 shows the housing and household characteristics and exposure to asthma triggers among households with at least one school-age child with asthma compared with households without any asthmatic school-age children. Table 3 shows asthma prevalence among households with school-age children by various characteristics. Notable patterns include the following:

- Households with school-age children with asthma were more likely to report exposure to each of the five asthma triggers included in our study than households that did not report a child with asthma. These include exposure to smoke in the home at least monthly (18.1 versus 12.9 percent), exposure to musty smells in the home at least monthly (8.3 versus 6.6 percent), exposure to mold in any room (7.7 versus 4.2 percent), exposure to leaks (25.3 versus 18.5 percent), and evidence of roaches or rodents in the home at least monthly (10.6 versus 7.8 percent) (table 2).
- Households with school-age children with asthma were more likely to rent their unit than households that did not report a school-age child with asthma (47.0 versus 39.0 percent) and were more likely to receive rental assistance (10.3 versus 4.6 percent) (table 2).
- Households with school-age children with asthma were more likely to have incomes below 200 percent of Census poverty than those without asthmatic school-age children (45.4 versus 37.1 percent) and were more likely to be female-headed (59.8 versus 48.5 percent) (table 2).
- Households with school-age children with asthma were more likely to live in units built before 1960 than those without asthmatic school-age children (32.3 versus 28.7 percent) (table 2).
- Twenty-two percent of households with school-age children with asthma were headed by a black, non-Hispanic adult, compared with 12.7 percent of households without school-age children with asthma (table 2).
- Renter households had a childhood asthma rate of 21.8 percent, compared with 16.7 percent for owner households (table 3). Households receiving rental assistance had a childhood asthma rate of 34.3 percent, compared with 19.8 percent for renter households not receiving rental assistance (table 3).
- The childhood asthma rate in low-income households was 22.1 percent, compared with 15.5 percent among high-income households (table 3).
- Childhood asthma rates among households with school-age children were higher among households headed by a black, non-Hispanic adult than among households headed by a non-Hispanic white adult (28.6 versus 17.4 percent) (table 3).

TABLE 2

Housing Characteristics, Household Characteristics, and Exposure to Asthma Triggers among Households with School-Age Children, by Presence of a Child with Asthma

	Share of households with children that have characteristic (%)	Share of households with a child with asthma that have characteristic (%)	Share of households with no children with asthma that have characteristic (%)
Housing characteristics			
Owner	59.5	53.0	61.0***
Renter	40.5	47.0	39.0***
Receiving rental assistance	5.6	10.3	4.6***
Unit built before 1960	29.4	32.3	28.7**
Unit built 1960–79	24.3	24.5	24.3
Unit built 1980–99	25.0	25.8	24.9
Unit built 2000 or later	21.2	17.4	22.1***
Crowded unit (more than 1 person per room)	6.9	8.1	6.6
Single-family building	81.3	80.5	81.5
Multiunit building	18.7	19.5	18.5
In a metropolitan area	87.3	89.4	86.9*
Household characteristics			
Household income at or below 200% of Census poverty	38.7	45.4	37.1***
Household income 200–400% of Census poverty	29.7	28.5	30.0
Household income more than 400% of Census poverty	31.6	26.0	32.9***
One child in unit	37.6	30.1	39.3***
Two children in unit	38.3	39.8	38.0
Three or more children in unit	24.1	30.1	22.7***
Householder characteristics			
Householder has high school education or less	37.2	36.5	36.1
Householder is white, non-Hispanic	55.5	51.4	56.5**
Householder is black, non-Hispanic	14.4	22.0	12.7***
Householder is Hispanic	21.7	18.7	22.4**
Householder is other, non-Hispanic	8.3	7.9	8.4
Householder is female	50.6	59.8	48.5***
Asthma triggers			
Exposure to smoke in the home at least monthly	13.9	18.1	12.9***
Exposure to musty smells in the home at least monthly	6.9	8.3	6.6*
Exposure to mold in any room	4.9	7.7	4.2***
Exposure to leaks	19.8	25.3	18.5***
Evidence of roaches or rodents in the home at least monthly	8.3	10.6	7.8***

Source: Authors' analysis of the 2015 American Housing Survey.

Notes: Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. * Estimate is significantly different from estimate for "Share of households with a child with asthma that have characteristic" at the 0.10 level. ** Estimate is significantly different from estimate for "Share of households with a child with asthma that have characteristic" at the 0.05 level. *** Estimate is significantly different from estimate for "Share of households with a child with asthma that have characteristic" at the 0.01 level.

TABLE 3

Asthma Prevalence among Households with Children, by Housing, Household, and Householder Characteristics

	Share of households with a child with asthma (%)
All	18.8
Housing characteristics	
Owner[a]	16.7
Renter	21.8***
Receiving rental assistance[a]	34.3
Not receiving rental assistance	19.8***
Unit built before 1960[a]	20.7
Unit built 1960–79	19.0
Unit built 1980–99	19.4
Unit built 2000 or later	15.4***
Crowded unit (more than 1 person per room)[a]	22.1
Not a crowded unit (1 or fewer persons per room)	18.6
Single-family building[a]	18.6
Multiunit building	19.6
Not in a metropolitan area[a]	15.8
In a metropolitan area	19.3*
Household characteristics	
Household income at or below 200% of Census poverty[a]	22.1
Household income 200–400% of Census poverty	18.1***
Household income more than 400% of Census poverty	15.5***
One child in unit[a]	15.0
Two children in unit	19.6***
Three or more children in unit	23.5***
Householder characteristics	
Householder has high school education or less[a]	19.0
Householder has some college education or more	18.7
Householder is white, non-Hispanic[a]	17.4
Householder is black, non-Hispanic	28.6***
Householder is Hispanic	16.3
Householder is other, non-Hispanic	17.8
Householder is male[a]	15.3
Householder is female	22.2***
Asthma triggers	
Exposure to smoke in the home at least monthly[a]	24.6
No exposure to smoke in the home at least monthly	17.9***
Exposure to musty smells in the home at least monthly[a]	22.6
No exposure to musty smells in the home at least monthly	18.5*
Exposure to mold in any room[a]	29.6
No exposure to mold in any room	18.3***
Exposure to leaks[a]	24.1
No exposure to leaks	17.5***
Evidence of roaches or rodents in the home at least monthly[a]	23.9
No evidence of roaches or rodents in the home at least monthly	18.4***

Source: Authors' analysis of the 2015 American Housing Survey.

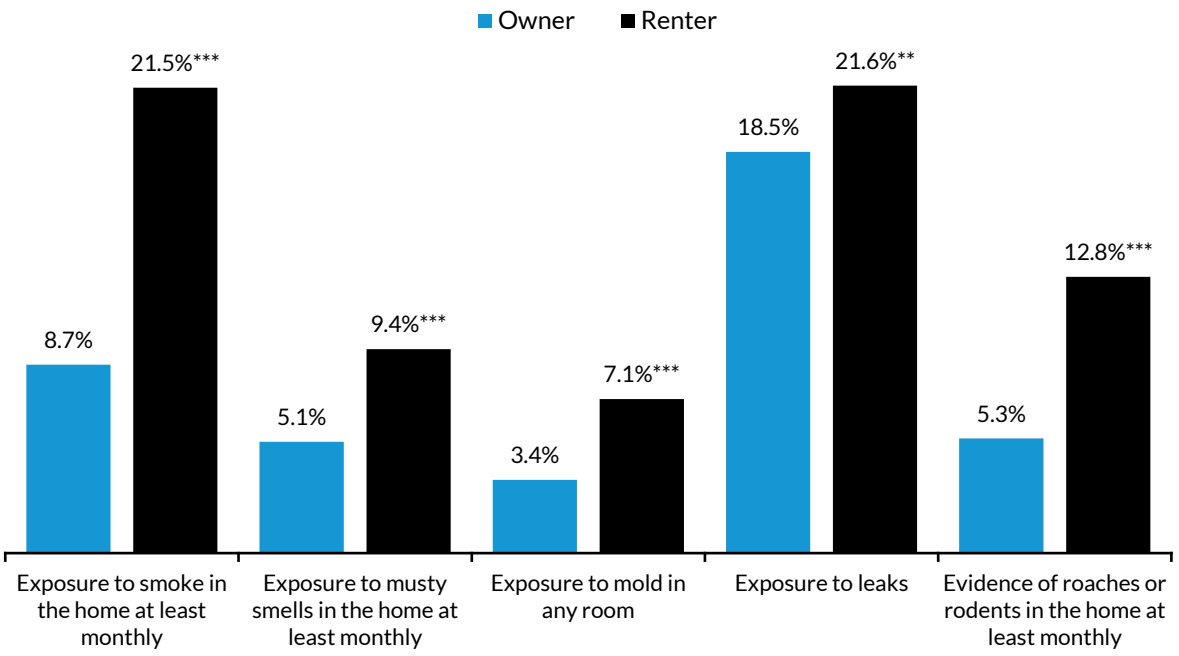
Notes: Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. [a] Denotes reference group. * Estimate is significantly different from estimate for reference group at the 0.10 level using two-tailed tests. ** Estimate is significantly different from estimate for reference group at the 0.05 level using two-tailed tests. *** Estimate is significantly different from estimate for reference group at the 0.01 level using two-tailed tests.

Tenure, Triggers, and Asthma Prevalence

Renters were more likely than owners to be exposed to all five asthma triggers included in this study (figure 1). Renter households were more than twice as likely to be exposed to smoke in the home at least monthly and to have evidence of roaches or rodents in the home at least monthly than owner households, and renter households were more likely to report exposure to musty smells in the home at least monthly, exposure to leaks, and exposure to mold in any room. These disparities in exposure may be related to renters' inability to make changes to their home because of lease restrictions (Gruber et al. 2016). In addition, some conditions, such as pests, leaks, or mold, may be present throughout the building, making remedies difficult for individual renters.

FIGURE 1

Exposure to Asthma Triggers among Households with School-Age Children, by Tenure



Source: Authors' analysis of the 2015 American Housing Survey.
Notes: Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. ** Estimate is significantly different from estimate for owner households at the 0.05 level. *** Estimate is significantly different from estimate for owner households at the 0.01 level.

Renter households exposed to musty smells in the home at least monthly, exposed to leaks, and with evidence of roaches or rodents in the home at least monthly were more likely to report a school-age child with asthma than owner households exposed to the same asthma triggers (table 5).

TABLE 5

Childhood Asthma Prevalence among Households with School-Age Children, by Tenure and Exposure to Asthma Triggers

	Share of Households with a School-Age Child with Asthma (%)		
	All	Owner	Renter
Asthma triggers			
Exposure to smoke in the home at least monthly	24.6	22.4	25.9
Exposure to musty smells in the home at least monthly	22.6	17.2	26.9**
Exposure to mold in any room	29.6	25.8	32.2
Exposure to leaks	24.1	21.8	26.9*
Evidence of roaches or rodents in the home at least monthly	23.9	17.5	27.8**

Source: Authors' analysis of the 2015 American Housing Survey.
Notes: Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. * Estimate is significantly different from estimate for owner households at the 0.10 level. ** Estimate is significantly different from estimate for owner households at the 0.05 level.

Households with school-age children exposed to certain asthma triggers reported higher childhood asthma prevalence rates, controlling for observed factors (table 6). In particular, households with school-age children that report at least monthly exposure to smoke in the home and exposure to mold in any room or leaks in the home over the past 12 months were more likely to report a school-age child with asthma after controlling for differences in tenure, housing characteristics, household characteristics, and householder characteristics.

Renter-occupied households with school-age children were more likely to report having a school-age child with asthma than owner-occupied households after controlling for housing characteristics, household characteristics, and householder characteristics. This relationship was slightly weaker, but not eliminated, when controlling for differential exposure to asthma triggers.

TABLE 6

Association between Asthma Prevalence and Housing and Household Characteristics

	Model 1: Without Asthma Triggers		Model 2: With Asthma Triggers	
	Coefficient	**SE**	**Coefficient**	**SE**
Housing characteristics				
Renter	0.029**	0.013	0.023*	0.014
Unit built before 1960	0.048***	0.018	0.036**	0.018
Unit built 1960–79	0.032*	0.018	0.022	0.018
Unit built 1980–99	0.040**	0.019	0.034*	0.019
Crowded unit (more than 1 person per room)	0.006	0.025	-0.003	0.026
Multiunit building	-0.035**	0.018	-0.036**	0.018
In a metropolitan area	0.033*	0.019	0.036*	0.019
Household characteristics				
Household income at or below 200% of Census poverty	0.025	0.017	0.019	0.017
Household income 200–400% of Census poverty	0.008	0.014	0.008	0.014
Two children in unit	0.048***	0.012	0.048***	0.012
Three or more children in unit	0.081***	0.015	0.080***	0.015
Householder characteristics				
Householder has high school education or less	-0.005	0.014	-0.005	0.014
Householder is black, non-Hispanic	0.084***	0.022	0.083***	0.022
Householder is Hispanic	-0.036**	0.016	-0.031*	0.016
Householder is other, non-Hispanic	0.006	0.019	0.006	0.019
Householder is female	0.054***	0.013	0.052	0.012
Asthma triggers				
Exposure to smoke in the home at least monthly			0.039*	0.020
Exposure to musty smells in the home at least monthly			0.003	0.025
Exposure to mold in any room			0.067*	0.034
Exposure to leaks			0.039**	0.016
Evidence of roaches or rodents in the home at least monthly			0.024	0.022
Constant	0.42	0.024	0.034	0.024
Model R^2	0.03		0.03	

Source: Authors' analysis of the 2015 American Housing Survey.

Notes: SE = standard error. Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months.

* statistically significant at $p < 0.10$; ** statistically significant at $p < 0.05$; *** statistically significant at $p < 0.01$.

Other housing and householder characteristics were associated with a greater likelihood of reporting a school-age child with asthma, even after controlling for differential exposure to asthma triggers. Consistent with prior literature, households in a metropolitan area and households with a black, non-Hispanic householder were more likely to report a school-age child with asthma. In addition, older housing units were associated with higher asthma prevalence among school-age children.

Rental Housing Assistance, Triggers, and Asthma Prevalence

For the past 80 years, federal policies and programs have assisted in providing rental housing at lower costs to vulnerable households. The federal government supports approximately 5 million renter households through public housing, assisted multifamily housing, and vouchers (Center on Budget and Policy Priorities 2017). The public housing program provides around 1 million affordable units to low-income households, and the voucher program assists over 2.2 million households.

In this section, we focus on exposure to asthma triggers in the home among renters with household incomes at or below 200 percent of Census poverty (low-income renters) by receipt of rental assistance. We also compare childhood asthma prevalence between low-income renters with school-age children receiving housing assistance and low-income renters without housing assistance. Low-income renter households with school-age children that receive housing assistance are more likely to be exposed to some asthma triggers than other low-income renters, particularly smoke in the home at least monthly and mold in any room (table 7). Low-income renters with school-age children receiving vouchers were somewhat more likely than renters with school-age children in public housing to be exposed to mold in any room, but differences in the prevalence of other asthma triggers were not statistically significant between the two groups, potentially because of small sample size.

Childhood asthma prevalence is higher for low-income renters with school-age children who receive housing assistance compared with other renters across all the exposures to the asthma triggers measured here (table 8). Low-income renters with school-age children who receive housing assistance who identify exposure to smoke in the home at least monthly, musty smells in the home at least monthly, mold in any room, leaks, or evidence of pests in the home at least monthly are more likely to report having at least one school-age child with asthma compared with renters not receiving housing assistance who face the same housing quality issues. Sample sizes become low for these subsamples in some instances, so we do not report estimates for subgroups with fewer than 50 observations.

TABLE 7

Exposure to Asthma Triggers among Low-Income Renter Households with School-Age Children, by Rental Assistance Status and Type

	All low-income renters	Receiving assistance	Not receiving assistance	Voucher assistance	Public housing/ assisted multifamily
Asthma triggers					
Exposure to smoke in the home at least monthly	23.9%	32.8%	21.8%***	33.5%	31.8%
Exposure to musty smells in the home at least monthly	11.0%	11.5%	10.8%	12.7%	9.8%
Exposure to mold in any room	8.6%	11.4%	7.9%*	13.6%	8.5%#
Exposure to leaks	21.5%	24.8%	20.7%	23.0%	27.3%
Evidence of roaches or rodents in the home at least monthly	15.5%	18.0%	14.9%	19.6%	15.7%
Sample size	2,063	748	1,315	441	307

Source: Authors' analysis of the 2015 American Housing Survey.

Notes: Households with school-age children include households with children ages 5 to 17. Only households with incomes at or below 200 percent of Census poverty are included. All asthma triggers are measured over the past 12 months. Statistical tests compare receiving assistance versus not receiving assistance and voucher assistance versus public housing and assisted multifamily housing. * Estimate is significantly different from estimate for "Receiving assistance" at the 0.10 level. ** Estimate is significantly different from estimate for "Receiving assistance" at the 0.05 level. *** Estimate is significantly different from estimate for "Receiving assistance" at the 0.01 level. # Estimate is significantly different from estimate for "Voucher assistance" at the 0.05 level.

TABLE 8

Childhood Asthma Prevalence and Asthma Triggers among Low-Income Renter Households with School-Age Children, by Rental Assistance Status and Type

	Share of households with children who report a school-age child with asthma				
	All low-income renters	Assisted	Not assisted	Voucher assistance	Public housing/ assisted multifamily
Overall asthma prevalence	24.0%	34.7%	21.4%***	40.3%	27.0%##
Asthma triggers					
Exposure to smoke in the home at least monthly	26.5%	38.5%	22.1%***	40.2%	36.0%
Exposure to musty smells in the home at least monthly	28.9%	41.9%	25.6%*	45.0%	X
Exposure to mold in any room	31.9%	57.6%	22.8%***	59.6%	X
Exposure to leaks	29.0%	40.6%	25.7%**	42.0%	38.9%
Evidence of roaches or rodents in the home at least monthly	29.0%	46.2%	24.1%***	52.6%	X

Source: Authors' analysis of the 2015 American Housing Survey.
Notes: Households with school-age children include households with children ages 5 to 17. Only households with incomes at or below 200 percent of Census poverty are included. All asthma triggers are measured over the past 12 months. None of the differences between voucher assistance and public housing are significant at the 0.10 level. Statistical tests compare receiving assistance versus not receiving assistance and voucher assistance versus public housing and assisted multifamily housing. X indicates estimate is suppressed because there are fewer than 50 observations. ** Estimate is significantly different from estimate for "Receiving assistance" at the 0.05 level. *** Estimate is significantly different from estimate for "Receiving assistance" at the 0.01 level. ## Estimate is significantly different from estimate for "Voucher assistance" at the 0.05 level.

Low-income renters who receive housing assistance are more likely to report having a school-age child with asthma than other low-income renters. Receipt of housing assistance among low-income renters with school-age children is significantly associated with childhood asthma prevalence, even after controlling for housing characteristics, household characteristics, householder characteristics, and exposure to asthma triggers (table 9).

Although low-income renters with school-age children receiving housing assistance are more likely to be exposed to some asthma triggers in our study, including asthma triggers in our model did not eliminate estimated differences in childhood asthma rates by rental assistance status. None of the coefficients on the specific asthma triggers was statistically significant, and the magnitude of the association found between receipt of housing assistance and asthma prevalence was not sensitive to the inclusion of asthma triggers in the model.

Other householder characteristics were associated with a greater likelihood of reporting a school-age child with asthma among low-income renter households, even after controlling for differential exposure to asthma triggers and receipt of housing assistance. Consistent with prior

literature, low-income renter households with a black, non-Hispanic householder and those headed by a female were more likely to report a school-age child with asthma.

TABLE 9

Relationship between Childhood Asthma Prevalence and Housing and Householder Characteristics, among Low-Income Renter Households with Children

	Model 1: Without Asthma Triggers		Model 2: With Asthma Triggers	
	Coefficient	SE	Coefficient	SE
Housing characteristics				
Assisted renter	0.089***	0.032	0.086***	0.032
Unit built before 1960	0.025	0.042	0.016	0.042
Unit built 1960–79	-0.009	0.044	-0.017	0.045
Unit built 1980–99	0.056	0.049	0.052	0.049
Crowded unit (more than 1 person per room)	0.002	0.033	-0.009	0.033
Multiunit building	-0.046*	0.026	-0.047*	0.027
In a metropolitan area	0.019	0.033	0.021	0.033
Household characteristics				
Household income at or below 100% of Census poverty	0.033	0.023	0.031	0.023
Two children in unit	0.038	0.027	0.035	0.027
Three or more children in unit	0.074**	0.032	0.067**	0.031
Householder characteristics				
Householder has high school education or less	-0.020	0.024	-0.022	0.024
Householder is black, non-Hispanic	0.071*	0.037	0.071*	0.037
Householder is Hispanic	-0.028	0.029	-0.025	0.030
Householder is other, non-Hispanic	0.009	0.043	-0.001	0.045
Householder is female	0.058**	0.023	0.056**	0.023
Asthma triggers				
Exposure to smoke in the home at least monthly	N/A		0.006	0.030
Exposure to musty smells in the home at least monthly	N/A		0.031	0.044
Exposure to mold in any room	N/A		0.038	0.050
Exposure to leaks	N/A		0.027	0.029
Evidence of roaches or rodents in the home at least monthly	N/A		0.045	0.034
Constant	0.115**	0.049	0.109**	0.051
Model R^2	0.04		0.05	

Source: Authors' analysis of the 2015 American Housing Survey.

Notes: SE = standard error. Households with school-age children include households with children ages 5 to 17. Only households with incomes at or below 200 percent of Census poverty are included. All asthma triggers are measured over the past 12 months.

* statistically significant at $p < 0.10$; **statistically significant at $p < 0.05$; ***statistically significant at $p < 0.01$.

Asthma Triggers and Emergency Room Use

Overall, 20.8 percent of households with a school-age child with asthma reported that the youngest child with asthma had an ER or urgent care visit for their asthma in the past 12 months (table 12). This

rate was 30 percent for households with school-age children exposed to smoke in the home at least monthly.

Among households with a school-age child with asthma, households exposed to smoke at least monthly were more likely to report an ER or urgent care visit in the past 12 months than those not exposed to smoke (figure 2).

TABLE 12

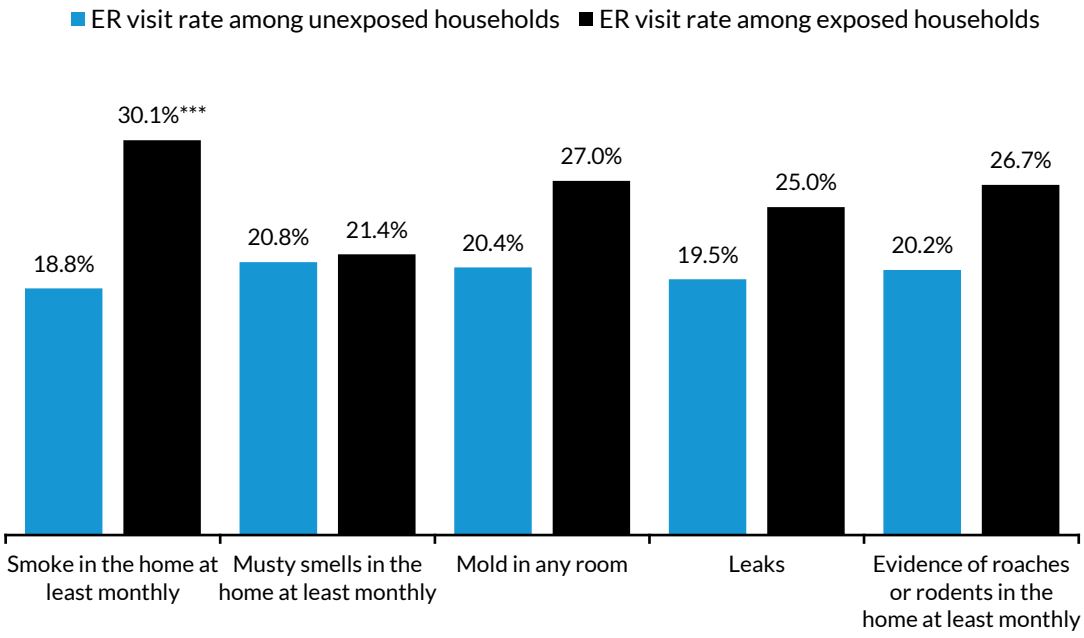
Asthma-Related Emergency Room and Urgent Care Visit Rates among Households with a School-Age Child with Asthma, by Exposure to Asthma Triggers

	Share with an emergency room visit for youngest child with asthma (%)
All	20.8
Asthma triggers	
Exposure to smoke in the home at least monthly	30.1
Exposure to musty smells in the home at least monthly	21.4
Exposure to mold in any room	27.0
Exposure to leaks	25.0
Evidence of roaches or rodents in the home at least monthly	26.7

Source: Authors' analysis of the 2015 American Housing Survey.
Notes: Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months.

FIGURE 2

Share of Households with a Child with Asthma Reporting an ER or Urgent Care Visit in the Past 12 Months, by Exposure to Asthma Triggers



Source: Authors' analysis of the 2015 American Housing Survey.

Notes: ER = emergency room. Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. *** Estimate is significantly different from estimate for households not exposed to the asthma trigger.

Exposure to smoke in the home at least monthly was associated with higher asthma-related ER and urgent care visit rates in the past year among households with school-age children with asthma, controlling for other household characteristics (table 13). Among the five asthma triggers we examined, only exposure to smoke in the home in the last month was significantly associated with a higher likelihood of an ER or urgent care visit.

Mold present in a bedroom was significantly associated with a pediatric ER visit for asthma among households with school-age children with asthma. When we re-estimate the model to include exposure to mold in any bedroom as an alternative asthma trigger, we find that exposure to mold present in a bedroom is associated with a higher likelihood of reporting an ER visit for the youngest child with asthma in the past 12 months, controlling for other household characteristics.

Other housing and householder characteristics were associated with a greater likelihood of reporting an ER or urgent care visit for a school-age child with asthma, even after controlling for differential exposure to asthma triggers. Households with school-age children living in crowded units and households headed by racial or ethnic minorities were more likely to report an ER or urgent care visit for the youngest child with asthma in the past 12 months. Research has shown that crowded housing is associated with an increased likelihood of experiencing respiratory conditions (Blake, Kellerson, and Simic 2007). In addition, racial and ethnic minorities are more likely to lack health insurance coverage (Cohen, Martinez, and Ward 2017), which is not captured in the AHS.

TABLE 13

Asthma-Related Emergency Room and Urgent Care Visits among Households with a School-Age Child with Asthma

	Model 1: Baseline		Model 2: With Mold in Any Room and Other Asthma Triggers		Model 3: With Mold in Bedroom and Other Asthma Triggers	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Housing characteristics						
Renter	-0.013	0.040	-0.016	0.039	-0.016	0.039
Unit built before 1960	0.015	0.044	0.000	0.044	-0.003	0.044
Unit built 1960–79	-0.001	0.044	-0.017	0.044	-0.020	0.044
Unit built 1980–99	-0.039	0.037	-0.048	0.038	-0.049	0.037
Crowded unit (more than 1 person per room)	0.102*	0.060	0.104*	0.058	0.097*	0.058
Multiunit building	0.007	0.040	-0.001	0.041	-0.006	0.041
In a metropolitan area	-0.059	0.050	-0.060	0.050	-0.055	0.050
Household characteristics						
Household income less than 200% of Census poverty	0.001	0.046	-0.008	0.046	-0.007	0.046
Household income 200–400% of Census poverty	-0.054	0.039	-0.064	0.040	-0.060	0.039
Two children in unit	0.002	0.036	0.000	0.036	-0.002	0.036
Three or more children in unit	0.005	0.038	0.001	0.038	0.000	0.038
Householder characteristics						
Householder has high school education or less	-0.015	0.033	-0.017	0.034	-0.018	0.034
Householder is black, non-Hispanic	0.192***	0.046	0.188***	0.046	0.183***	0.046
Householder is Hispanic	0.085**	0.037	0.093**	0.038	0.096**	0.038
Householder is other, non-Hispanic	0.101**	0.050	0.103**	0.049	0.100**	0.049
Householder is female	0.043	0.027	0.040	0.027	0.037	0.027
Asthma triggers						
Exposure to smoke in the home at least monthly	N/A		0.097**	0.039	0.099**	0.039
Exposure to musty smells in the home at least monthly	N/A		-0.027	0.039	-0.030	0.040
Exposure to mold in any room	N/A		0.005	0.052	N/A	
Exposure to mold in any bedroom	N/A		N/A		0.164*	0.094
Exposure to leaks	N/A		0.050	0.032	0.045	0.032
Evidence of roaches or rodents in the home at least monthly	N/A		-0.013	0.046	-0.014	0.045
Constant	0.190***	0.057	0.189***	0.060	0.186***	0.060
Model R^2	0.05		0.06		0.07	

Source: Authors' analysis of the 2015 American Housing Survey.

Notes: SE = standard error. Households with school-age children include households with children ages 5 to 17. All asthma triggers are measured over the past 12 months. * statistically significant at $p < 0.10$; ** statistically significant at $p < 0.05$; *** statistically significant at $p < 0.01$.

Sample sizes for this analysis were small (1,334 households), and the R^2 for our models indicate low explanatory power. Many factors affecting ER use, such as health insurance coverage and proximity to various types of care, cannot be measured using the AHS.

Conclusions, Emerging Practices, and Future Research

Given the burden of childhood asthma and associated health care costs, there are several key take-aways from our analysis in terms of what they tell us about asthma triggers in the home; how they affect owners, renters, and assisted renters differently; and the impacts they may have on emergency room and urgent care visits. Future research is needed to fill remaining gaps in data and knowledge about associations between asthma and triggers beyond what the 2015 American Housing Survey data can tell us.

Our results suggest that the presence of certain asthma triggers in the home, particularly smoke, mold, or leaks, are associated with higher childhood asthma rates and with more ER or urgent care visits among households with children who have asthma, even after controlling for such factors as householder demographics, housing age, and household income. Among only renter households, the presence of asthma triggers was not significantly associated with asthma prevalence, though sample sizes for that analysis were small. Renter households are more likely to have a child with asthma and are more likely to have asthma triggers present in the home, and higher renter asthma rates may be partially explained by the higher prevalence of asthma triggers in rented homes. Renters receiving rental housing assistance were more likely to have a child with asthma in the household, even after taking into account exposure to asthma triggers.

Current policies and programs may be missing certain asthma triggers. Many localities have building codes and inspections to protect residents' health and safety, but these are usually complaint-based systems focused on responding to immediate, physical threats to safety. Less visible but threatening hazards, such as smoke, mold, and leaks, can be overlooked and often require a different approach (de Leon and Schilling 2017). Even HUD's Housing Quality Standards, which are used to inspect units (usually owned by private landlords) for assisted renters with vouchers, do not include identifying the presence of mold, leaks, or smoke. Few programs and resources train code enforcement officers to look for more comprehensive problems or to help property owners—whether the properties are owner occupied or renter occupied—resolve these issues (ChangeLab Solutions 2015).

There are several emerging practices that address asthma triggers more directly, particularly for rental housing and assisted renters, that warrant further study and action. These include the following:

- *Proactive rental housing inspections*. Typically, these programs are adopted by a local government and require landlords to register their rental properties, submit to regular inspections, and

remediate any problems identified (ChangeLab Solutions 2014). These programs are implemented by local government for renters who may otherwise not complain because of fear of retaliation or eviction, because they are unaware of their rights, or because they lack other housing options. It is not clear whether rental housing inspections typically target asthma triggers such as mold or leaks. Although evidence suggests that such programs improve housing quality and reduce complaints, there is little research assessing impacts on health outcomes for renters to date (de Leon and Schilling 2017).

- *HUD housing quality inspections*. HUD requires regular housing quality inspections of its financed units and units leased by a household with a HUD voucher. Beginning in 2000, uniform physical condition standards were adopted and applied to all HUD-financed properties to standardize inspections across their portfolio. Although these standards improved the consistency and quality of inspections and reporting, they do not include identifying critical asthma triggers in the unit, such as mold, musty smells, leaks, and exposure to smoke (they do include pests) (HUD, n.d.). Given the higher exposure of assisted renters to such triggers in their homes, HUD could revise its inspection checklist to include the presence and required remediation of key asthma triggers.

- *Smoke-free policies*. Private landlords can implement smoke-free policies to reduce resident exposure to secondhand smoke by banning smoking within units, common spaces, buffer areas around outdoor areas, and entire properties (UCLA Center for Health Policy Research and ChangeLab Solutions 2015). Within public housing, the Boston Housing Authority was a leader in adopting a smoke-free housing policy (Scally, Waxman, and Gourevitch 2017), with 676 housing authorities following suit and implementing smoke-free policies in some of their properties in October 2016 (Helms, King, and Ashley 2017). In December 2016, HUD issued a final rule requiring all public housing authorities across the country to implement a smoke-free policy, followed by guidance for implementing the rule (HUD 2017).

- *Integrated pest management*. Integrated pest management focuses on using pesticide-free interventions to eliminate pests, and education on how to change behaviors to prevent future infestations. Maley, Taisey, and Koplinka-Loehr (2014) provide a resource for affordable housing owners and landlords with a step-by-step guide for implementing this strategy within their rental properties.

Asthma triggers within owner-occupied properties are also a problem but are harder to address on a systemic level. Childhood exposure to asthma triggers and reported asthma rates among owners

are still problematic, though less pronounced than the needs of renters found in this analysis. Because owners are responsible for improving and maintaining their property, they first need to be aware of the triggers. This may require education and awareness campaigns. Owners may also need access to additional resources to address asthma triggers. Many initiatives are under way to reduce the prevalence of asthma triggers in the home to reduce ER and hospital use, asthma symptoms, and missed school and work, but most of these initiatives focus on pests and mold. Our results suggest that integrating smoking cessation referrals for adults in the household could benefit these programs.

Other important factors influence asthma rates and emergency room and urgent care visits than the 2015 AHS data allow us to explore. Our study has several limitations and should not be interpreted as presenting a causal or comprehensive analysis of the effects of the determinants of asthma prevalence and related ER use among households with school-age children. We do not observe several environmental and genetic factors known to be associated with childhood asthma and asthma exacerbations, including outdoor air quality, family history of asthma, and genetic factors. In addition, we do not observe health insurance status, which could affect ER use and ability to control asthma through preventive medication. Finally, asthma rates vary substantially across the country, but our sample size was not sufficient to allow exploration of asthma prevalence in local areas.

Additional exploration, evaluation, and research would expand our understanding of the relationship between asthma triggers, tenure, receipt of housing assistance, childhood asthma prevalence, and visits to the ER or urgent care. But the 2015 AHS data help provide a snapshot of the issues and allows for evidence-based discussion and policy direction that could help reduce exposure to indoor asthma triggers among households with children.

Notes

1. "Most Recent Asthma State or Territory Data," Centers for Disease Control and Prevention, accessed September 8, 2017, https://www.cdc.gov/asthma/most_recent_data_states.htm#modalIdString_CDCTable_0.
2. "Most Recent Asthma Data," Centers for Disease Control and Prevention, accessed September 8, 2017, https://www.cdc.gov/asthma/most_recent_data.htm#modalIdString_CDCTable_1.
3. "Asthma-Related Missed School Days among Children Aged 5–17 Years," Centers for Disease Control and Prevention, accessed September 8, 2017, https://www.cdc.gov/asthma/asthma_stats/missing_days.htm.
4. "What Causes Asthma?" National Institutes of Health, National Heart, Lung, and Blood Institute, last updated August 4, 2014, https://www.nhlbi.nih.gov/health/health-topics/topics/asthma/causes.
5. "How Is Asthma Treated and Controlled?" National Institutes of Health, National Heart, Lung, and Blood Institute, last updated August 4, 2014, https://www.nhlbi.nih.gov/health/health-topics/topics/asthma/treatment.
6. See "How Is Asthma Treated and Controlled?" National Institutes of Health, National Heart, Lung, and Blood Institute, last updated August 4, 2014, https://www.nhlbi.nih.gov/health/health-topics/topics/asthma/treatment, and "Asthma: Home-Based Multitrigger, Multicomponent Environmental Interventions–Children and Adolescents with Asthma," The Community Guide, accessed September 8, 2017, https://www.thecommunityguide.org/findings/asthma-home-based-multi-trigger-multicomponent-environmental-interventions-children-and.
7. We also ran all models using logistic regression as robustness check. These models provided similar results to our linear probability models, so we present the linear probability models here for ease of interpretation.
8. "Most Recent Asthma State or Territory Data," Centers for Disease Control and Prevention, accessed September 8, 2017, https://www.cdc.gov/asthma/most_recent_data_states.htm#modalIdString_CDCTable_0.

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