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Use of Medicaid and housing data may help target areas of high asthma prevalence.

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Abstract

Objective: To determine if there was a significant difference between mold contamination and asthma prevalence in Detroit and non-Detroit Michigan homes, between newer and older homes, and if there is a correlation between mold contamination and measures of Medicaid use for asthma in the 25 Detroit zip codes.

Methods: Settled dust was collected from homes ($n = 113$) of Detroit asthmatic children and from a representative group of Michigan homes ($n = 43$). The mold contamination for each home was measured using the Environmental Relative Moldiness Index (ERMI) scale and the mean ERMI values in Detroit and non-Detroit homes were statistically compared. Michigan Medicaid data (13 measures related to asthma) in each of the 25 zip codes in Detroit were tested for correlation to ERMI values for homes in those zip codes.

Results: The mean ERMI value (14.5 ± 8.0) for Detroit asthmatic childrens' homes was significantly (Student's t -test, $p < 0.001$) greater than the mean ERMI value (2.1 ± 6.2) for the non-Detroit homes. Detroit homes > 60 years old had significantly ($p = 0.01$) greater mean ERMI values than Detroit homes < 60 years old (15.87 vs. 11.25). The percentage of children that underwent spirometry testing for their persistent asthma (based on Medicaid data) was significantly, positively correlated with the mean ERMI values of the homes in the 25 zip codes.

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Declaration of interest

The United States Environmental Protection Agency (US EPA) through its Office of Research and Development, collaborated in the research described here. Although this work was reviewed by EPA and approved for publication it may not necessarily reflect official EPA policy. Mention of trade names or commercial products does not constitute endorsement or recommendation by the EPA for use. Since MSQPCR technology is patented by the US EPA, the Agency has a financial interest in its commercial use.

Conclusions: Applying Medicaid-use data for spirometry testing and locating a city's older housing stock might help find foci of homes with high ERMI values.

Keywords

Detroit; mold; ERMI; zip code; *Aspergillus*; dust; home age

Introduction

The prevalence of asthma has nearly doubled in the United States (U.S.) since 1980 [1]. In 2014, approximately 24 million people in the U.S. had asthma: 17.7 million adults and 6.3 million children [2]. Urban communities that are socially and economically disadvantaged have a higher prevalence of asthma than the communities surrounding them [3,4]. Detroit, like many older U.S. cities with an aging housing stock, has a higher prevalence of asthma than is found statewide (11.3% vs. 9.7%, respectively, for children and 15.5% vs. 11%, respectively, for adults) [5]. Urban residency has been associated with increased prevalence of asthma in many U.S. cities [6, 7]. Some of the social reasons for the higher prevalence of asthma are the higher percentage of minority populations in the urban core, higher rates of poverty, greater stress, etc. [8–11]. In 2014, 8.4% of Black adults and 13.4% of Black children in the U.S. had “current asthma” [2]. In urban homes, many higher levels of environmental exposures, including cigarette smoke, air pollution, allergens (rodent, cockroach, and dust mite), mold etc. have been linked to asthma [12].

Mold contamination has been consistently associated with asthma [13, 14]. However, quantifying the relationship between mold contamination and asthma has been limited by the traditional methods of mold investigation like visual inspection and spore trap counts [15].

In order to more accurately quantify the relationship between mold exposure and asthma, US EPA researchers developed a DNA-based method for identifying and quantifying molds called mold specific quantitative PCR (MSQPCR) [16].

Medicaid data has been found to be useful in quantifying asthma prevalence at the county and state level [19]. We wanted to determine if Medicaid data could be used to localize asthma prevalence foci at the zip code, geographic level. Therefore, the goals of this study were to: 1) to determine if homes of asthmatic children in Detroit had greater ERMI values than non-Detroit homes in Michigan; 2) to determine the relationship between housing age and ERMI values; and 3) to determine if there was a correlation between various measures of Medicaid use for asthma within the different Detroit zip codes and the homes' ERMI values in those zip codes.

Methods

Data Source

This current study was part of the Near-Road Exposures and Effects of Urban Air Pollutants Study (NEXUS) (20). The NEXUS was designed to evaluate exposures in urban Detroit, including air pollution and mold contamination that might influence asthma prevalence and

health-care use. Recruitment and study protocols utilized written informed consent and followed ethical guidelines approved by the University of Michigan Institutional Review Board and our community-based partners. The homes of the recruited families were located in 25 Detroit/Wayne County zip codes (Figure 1). Asthmatic children, ages 6 to 14 years, and their families were recruited and a cohort of 113 completed this part of the study.

A comparison group of Michigan homes ($n = 43$) came from the Department of Housing and Urban Development (HUD) American Healthy Homes Survey (AHHS), described previously [17] Vesper SJ, McKinstry C, Haugland RA, Wymer L, Ashley P, Cox D, et al. Development of an environmental relative moldiness index for homes in the U.S. *J Occup Environ Med* 2007;49:987–90. In the AHHS, a nationally representative sample of homes was selected by HUD to describe housing conditions in the US. The homes selected in the AHHS for Michigan were from Flint ($n = 11$), Lansing ($n = 15$) and Tuscola County ($n = 17$). The AHHS was reviewed for human subject involvement by the Westat Institutional Review Board and a Confidentiality Certificate protecting the identity of the survey respondents issued by the National Institute of Environmental Health Sciences.

Dust sample collection

The dust samples were collected from the Detroit homes between October 2010 and April 2012. (The study was significantly delayed and slowed because of logistical problems and difficulties encountered in recruitment and retention of families.) The AHHS samples ($n = 43$) were collected in 2006. Settled floor dust samples were collected by vacuuming a 2 m² area for 5 minutes in the living room and then the bedroom with a MiTest sampler (Indoor Biotechnologies, Charlottesville, VA). The dust was returned to the laboratory and then sieved through a 300- μ pore size nylon mesh (Gilson Company, Inc., Lewis Center, OH) and shipped frozen on ice packs overnight to the analytical laboratory and maintained frozen at -20°C until analyzed.

Mold analysis and ERMI calculation

Five mg of each sieved-dust sample was extracted and the DNA purified using the DNA-EZ kit (GeneRite, Monmouth Junction, NJ) [21]. Each of the 36 ERMI molds was quantified by mold specific quantitative PCR (MSQPCR) assays, as previously described [16]. Briefly, standard curves were generated for each of the 36 molds based on microscopically counted spore stocks. Assay mixes were prepared for each of the 36 species and tested before use with a previously validated extract of each spore stock. The standard MSQPCR assays contained 12.5 μl of “Universal Master Mix” (Applied Biosystems Inc., Foster City, CA), 1 μl of a mixture of forward and reverse primers at 25 μM each, 2.5 μl of a 400 nM TaqMan probe (Applied Biosystems Inc.), 2.5 μl of 2 mg/ml fraction V bovine serum albumin (Sigma Chemical, St. Louis, MO) and 2.5 μl of DNA free water (Cepheid, Sunnyvale, CA). To this mix was added 5 μl of the DNA extract from the sample. All primer and probe sequences used in the assay are available [22]. The mold contamination or ERMI value in each home was then calculated, as described next.

The calculation of the ERMI value classifies mold species from settled dust into two groups. Group 1 includes 26 species related to water damage, while Group 2 species are commonly

found in homes across the United States, even without water damage, and come primarily from outdoors. The ERMI calculation takes the results from the concentrations (cells/mg dust) of each of 36 molds and mathematically converts these into a single number, shown in Equation (1).

$$ERMI = \sum_{i=1}^{26} \log_{10}(s_{1i}) - \sum_{j=1}^{10} \log_{10}(s_{2j})$$

The concentration of each of the 26 Group 1 molds is converted to a log and then the “Sum of the Logs of the Group 1” (SLG1) molds is determined (s_1). Similarly, the concentration of each of the 10 Group 2 molds are converted to a log and then the “Sum of the Logs of the Group 2” (SLG2) molds is determined (s_2). The arithmetic difference (SLG1-SLG2) is the ERMI value for the home [17].

Medicaid data for asthma related health services by zip code

The number of homes sampled in each of the 25 Detroit/Wayne County zip codes are shown in Figure 1. Children were defined as those 17 years of age and enrolled in the Medicaid program 11 or 12 months of the calendar year and with no other insurance. The asthma-related health services used in 2010 (the year the NEXUS recruitment began) for children living in these 25 zip codes were quantified from 13 measures of Medicaid administrative claims data [23]. The thirteen measures were based on counts of health services that are taken directly from Medicaid claims data. These thirteen measures were: Persistent Asthma (%) (defined as: (1) 4 asthma medication dispensing events OR (2) 1 emergency department visits for asthma OR (3) 1 hospitalization for asthma OR (4) 4 outpatient visits for asthma and 2 asthma medication dispensing events; Emergency Department Rate Per 10,000; Hospitalizations per 10,000; Had 2+ Outpatient visits (%); Had 1+ Emergency Department Visits (%); Had 2+ Emergency Department Visits (%); Emergency Department Reliance for Primary Care (%); Had 1+ Hospitalizations (%); Short-Acting Beta Agonists (SABA) Overuse (%); Had 1+ Inhaled Corticosteroid (%); Had 1+ Long Term Control (%); Had 2+ Oral Corticosteroid (%); and Had Spirometry for Persistent Asthma. These 13 measures were then tested for correlation with the mean ERMI value in the homes sampled in each zip code.

Statistical analysis

The statistical differences between the ERMI values in Detroit homes versus the AHHS homes was determined using Student's *t*-test. The correlation between ERMI values and the age of the Detroit homes was based on the Spearman rho correlation test. The statistical analysis of the differences in concentrations in the dust samples of individual mold species between Detroit homes 60 years of age compared to > 60 years was evaluated by the Mann-Whitney U-test and corrections for multiple comparisons made using the Holms-Bonferroni test. The correlation between ERMI values and the 13 measures of asthma prevalence, as defined in the 2010 Medicaid data, was based on the Spearman rho correlation test. Analyses were performed in SAS version 9.3 (SAS Institute, Cary NC) and R version 2.14 (R Foundation for Statistical Computing, Vienna, Austria).

Results

The mean ERMI value (14.5 ± 8.0) for Detroit asthmatic childrens' homes was significantly (Student's *t*-test, $p < 0.001$) greater than the mean ERMI value (2.1 ± 6.2) for the non-Detroit homes in Michigan. The mean age of the Detroit homes was 65.3 ± 29.9 years of age. The ERMI values and homes' age were significantly positively correlated (Spearman rho $R = 0.27$; $p = 0.004$), i.e. the oldest homes have the highest levels of mold contamination.

The Detroit homes were divided into those older and younger than 60 years of age. Homes 60 years old had a significantly ($p = 0.01$) lower average ERMI value (11.25) compared to homes > 60 years old (15.87) (Table 1). In addition, a comparison of the concentrations of the 36 ERMI molds in homes 60 years old compared to homes > 60 years were made (Table 2). Each of the 36 ERMI molds was detected in these homes but only the average population of *Aspergillus ochraceus* was significantly greater ($p < 0.001$) in the homes > 60 years of age compared to those homes 60 years

Discussion

In this study, the Figure 2 Figure 3 mean ERMI values of the homes of asthmatic children in the 25 Detroit zip codes were significantly correlated with the Medicaid data for the percentage of children that had spirometry testing for their persistent asthma. Also, Detroit asthmatic children were found to be living in homes with a higher mean ERMI value than non-Detroit homes in Michigan. The Detroit homes in our study were also significantly older than housing in the rest of the state. The average age of a home in Detroit is 74 years but the overall average age in Michigan is only about 60 years [24]. Even in Detroit itself, homes older than 60 years of age had significantly higher ERMI values than Detroit homes younger than 60 years of age.

Numerous reviews of the scientific literature have concluded that there is an association between mold exposures and asthma [25–27]. Mold growth in homes can be the result of water-damage from leaks, flooding, high humidity, etc. For example, as homes age, the integrity of the infrastructure (roof, windows, and plumbing) tends to deteriorate. This aging might lead to water leaks resulting to mold growth. In Cincinnati, Ohio, homes older than 60 years of age had higher average ERMI values than newer homes [28]. Infants living in those homes with high ERMI values (> 5.2) were more than twice as likely to develop asthma by age 7 [29]. But it wasn't higher concentrations of all mold that were associated with asthma development in that prospective study but infant exposures to higher concentrations of *Aspergillus ochraceus*, *A. unguis* and *Penicillium variable* [30]

In Detroit homes older than 60 years, *Aspergillus ochraceus* was significantly more common than in newer homes. Therefore, *Aspergillus ochraceus* concentrations may be a possible indicator for water-damage in older homes.

It may not be just cities with older housing that have a higher prevalence of asthma but also states with the oldest housing stock. The relationship between the average age of the housing stock in each of the 50 U.S. states and the prevalence of asthma in each state was compared

using on-line CDC and HUD maps [31, 32]. There was a significant correlation (Spearman correlation 0.38, $p = 0.005$) between the mean prevalence of asthma and the mean age of the state's housing stock. The higher prevalence of asthma in the US states (Figure 2) generally corresponds with the states with the oldest housing stock (Figure 3).

Our study has many limitations including the small number of study homes assessed, especially the small number of non-Detroit homes sampled. Because of the small number of non-Detroit homes, the extension of our interpretation to include all non-Detroit homes in Michigan is problematic. However, the non-Detroit homes were selected by HUD in the AHHS to be representative of Michigan, so this generalization is reasonable.

We also acknowledge that there was an extended time between the sampling of the non-Detroit homes and the Detroit homes. Problems with funding logistics, family recruitment and retention created the delays. However, changes in the conditions of homes do not generally occur quickly, except in situations like floods and tornadoes. Therefore, we believe that for most of the homes, the time delay was not a major issue.

Another limitation to the study was the unequal number of homes tested in each of the zip codes and this may have limited our ability to detect significant correlations with other measures of Medicaid use for asthma. Yet, we did find that the Medicaid data for “percentage that underwent spirometry testing for their persistent asthma” was significantly correlated with the mean ERMI values of the homes at the zip code level. One reason for this significant correlation might be the importance that the National Asthma Education and Prevention Program (NAEPP) Expert Panel Report placed on spirometry testing in the initial diagnosis of asthma and at least once per year thereafter for ongoing management [33, 34].

Of course, there are many possible reasons that a higher percentage of asthmatic children are found in Detroit. This study has suggested that the homes in Detroit have greater levels of mold contamination than homes in other parts of the state. Even if this is true, higher ERMI values may only be an indicator of other critical exposures that were not measured and which may be the real problem, e.g., air pollution, allergens, etc. [35].

Conclusions

Applying Medicaid-use data for spirometry testing and locating a city's older housing stock might help find foci of homes with high ERMI values. Although causation cannot be proven, a high ERMI value may be a useful predictor for a greater risk of asthma.

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Figure 1.
Location of each zip code followed by the number of homes sampled in each Detroit/Wayne County zip code. Each zip code begins with 48 followed by the three digits shown.

Figure 3.
Age of housing in the states in the US (32).

Table 1

Mean age of homes in years and standard deviation (SD) and the statistical difference in mean Environmental Relative Moldiness Index values (and SD) for homes in Detroit, Michigan that are ≤ 60 (n=27) versus > 60 years of age (n=86).

Home age	Age mean	SD	ERMI mean	SD	T-test p value
≤ 60	32.6	22.1	11.25	8.1	0.01
>60	82.4	15.6	15.87	7.8	

Table 2

Average concentration of each of the 36 Environmental Relative Moldiness Index molds in the homes compared to > 60 years of age. 60

Mold	Age of Home	Age of Home	Mann-Whitney U
Group 1	60 years	> 60 years	P value
	cells/ mg dust	cells/ mg dust	
<i>Aspergillus flavus</i>	11	6	0.603
<i>Aspergillus fumigatus</i>	15	15	0.646
<i>Aspergillus niger</i>	1172	1108	0.019
<i>Aspergillus ochraceus</i>	55	802	<0.001
<i>Aspergillus penicillioides</i>	205	196	0.984
<i>Aspergillus restrictus</i>	29	73	0.002
<i>Aspergillus sclerotiorum</i>	32	27	0.085
<i>Aspergillus sydowii</i>	96	77	0.834
<i>Aspergillus unguis</i>	25	187	0.147
<i>Aspergillus versicolor</i>	74	188	0.049
<i>Aureobasidium pullulans</i>	16112	28258	0.121
<i>Chaetomium globosum</i>	24	130	0.116
<i>Cladosporium sphaerospermum</i>	81	99	0.131
<i>Eurotium amstelodami</i>	370	576	0.069
<i>Paecilomyces variotii</i>	142	29	0.051
<i>Penicillium brevicompactum</i>	50	133	0.026
<i>Penicillium corylophilum</i>	22	29	0.036
<i>Penicillium crustosum</i>	987	106	0.379
<i>Penicillium purpurogenum</i>	15	42	0.008
<i>Penicillium spinulosum</i>	2	1	0.928
<i>Penicillium variabile</i>	87	15	0.465
<i>Scopulariopsis breviaulis</i>	14	241	0.084
<i>Scopulariopsis chartarum</i>	15	51	0.019
<i>Stachybotrys chartarum</i>	24	54	0.060
<i>Trichoderma viride</i>	40	46	0.509
<i>Wallemia sebi</i>	5501	8500	0.080
Group 2			
<i>Acremonium strictum</i>	6	8	0.590
<i>Alternaria alternata</i>	1255	763	0.418
<i>Aspergillus ustus</i>	15	37	0.087
<i>Cladosporium cladosporioides 1</i>	8218	5983	0.756
<i>Cladosporium cladosporioides 2</i>	79	92	0.552
<i>Cladosporium herbarum</i>	1198	843	0.029
<i>Epicoccum nigrum</i>	2204	1551	0.204
<i>Mucor amphibiorum</i>	1229	1227	0.204
<i>Penicillium chrysogenum</i>	684	399	0.826

Mold	Age of Home	Age of Home	Mann-Whitney U
<i>Rhizopus stolonifer</i>	11	42	0.278

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Table 3

Correlation (Spearman rho) between mean Environmental Relative Moldiness Index value in the homes of each of the 25 zip codes sampled and the thirteen measures of asthma prevalence in those zip codes based on 2010 Medicaid data.

Measure of Asthma Prevalence	Spearman	P-value
1. Persistent Asthma (%)	−0.002	0.99
2. Emergency Department Rate Per 10,000	0.000	1.00
3. Hospitalizations Per 10,000	−0.071	0.75
4. Had 2+ Outpatient Visits (%)	0.094	0.66
5. Had 1+ Emergency Department Visits (%)	0.142	0.50
6. Had 2+ Emergency Departments (%)	0.052	0.81
7. Emergency Department Reliance for Primary Care (%)	−0.042	0.84
8. Had 1+ Hospitalizations (%)	−0.052	0.81
9. SABA Overuse (%)	0.138	0.51
10. Had 1+ Inhaled corticosteroid (%)	0.009	0.97
11. Had 1+ Long Term Control (%)	−0.049	0.82
12. Had 2+ Oral Corticosteroid (%)	0.075	0.72
13. Had Spirometry for Persistent Asthma (%)	0.430	0.04