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Family and Home Characteristics Correlate with Mold in Homes

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Abstract

Previously, we demonstrated that infants residing in homes with higher Environmental Relative Moldiness Index were at greater risk for developing asthma by age seven. The purpose of this analysis was to identify the family and home characteristics associated with higher moldiness index values in infants' homes at age one. Univariate linear regression of each characteristic determined that family factors associated with moldiness index were race and income. Home characteristics associated with the moldiness index values were: air conditioning, carpet, age of the home, season of home assessment, and house dust mite allergen. Parental history of asthma, use of dehumidifier, visible mold, dog and cat allergen levels were not associated with moldiness index. Results of multiple linear regression showed that older homes had 2.9 units higher moldiness index (95% confidence interval [CI] = 0.4, 5.4), whereas homes with central air conditioning had 2.5 units lower moldiness index (95% CI = -4.7, -0.4). In addition, higher dust mite allergen levels and carpeting were positively and negatively associated with higher moldiness index, respectively. Because older homes and lack of air conditioning were also correlated with race and lower income, whereas carpeting was associated with newer homes, the multivariate analyses suggests that lower overall socioeconomic position is associated with higher moldiness index values. This may lead to increased asthma risk in homes inhabited by susceptible, vulnerable population subgroups. Further, age of the home was a surrogate of income, race and carpeting in our population; thus the use of these factors should carefully be evaluated in future studies.

Keywords

mold; environmental relative moldiness index; air conditioning; age of the home; socioeconomic position

1. Introduction

Environmental exposures and family and home characteristics were monitored from infancy to the age of seven for a cohort of infants in the greater Cincinnati, Ohio. The study purpose

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was to investigate indoor and outdoor factor(s) linked to the development of asthma (Reponen et al., 2011; 2012). We have previously reported that infant exposure to high levels of mold as measured using the Environmental Relative Moldiness Index is associated with increased development of physician diagnosed asthma

The moldiness index methodology classifies mold species from settled dust into two groups. The Group 1 molds include 26 species associated with water-damaged homes. The Group 2 molds are commonly found in homes across the United States, even without water damage, and originate primarily from outdoors (Vesper et al., 2007). The moldiness index calculation takes the results from the concentrations (cells/mg dust) of each of 36 molds and mathematically converts these into a single number, as shown in Equation (Eq.) 1.

$$\text{Environmental Relative Moldiness Index} = \sum_{i=1}^{26} \log_{10}(s_{11}) - \sum_{j=1}^{10} \log_{10}(s_{21}) \quad \text{(Eq. 1)}$$

The concentration of each of the 26 Group 1 molds and 10 Group 2 molds are converted to a log and then separately summed arithmetically. The moldiness index scale for the U.S. was created from the analysis of dust samples from 1083 homes randomly selected during the 2006 Healthy Homes Survey (Vesper et al., 2007). The moldiness index scale ranges from about -10 to 20 with about 1% of homes have even higher moldiness index values.

The objective of this current analysis was to examine family and home characteristics associated with higher residential moldiness index values. By uncovering these factors, homes can be prioritized for remediation or other interventions.

2. Methods

Infants born in Cincinnati, Ohio and Northern Kentucky between 2001 and 2003 were recruited to the Cincinnati Childhood Allergy and Air Pollution Study using birth certificate data. Eligibility for the study required that at least one parent was atopic defined as having allergic symptoms and a positive reaction in a skin prick test, as previously described (LeMasters et al., 2006). The main focus of the overall birth cohort study was traffic exposure and therefore enrollment in the cohort also required living either near (<400 m) or far (>1500 m) from a major highway with greater than 1000 trucks, on average, daily (Ryan et al., 2007). The group of 288 subjects included in the current analysis was based on the availability of sufficient amount of dust to perform all of the analyses (at least 5 mg), a clinical examination at age seven, and complete family participant background information (Reponen et al., 2012). There were no significant differences among the distributions of parental asthma, sex, race and income between the 288 children in this sub-study analysis and the entire cohort of 617 children examined at age seven, but the asthma rate was lower in the entire age 7 cohort (Reponen et al., 2012). The study was approved by the Institutional Review Board of the University of Cincinnati, and parents signed an informed consent.

On-site home visits were performed by trained two-person teams when the infants were approximately eight months old. The home visit was conducted in order to collect floor dust samples and information on home characteristics including visible mold contamination, presence of air conditioning, dehumidifier, carpet and the age of home (Cho et al., 2006).

Methods and assays have been described for mold specific quantitative polymerase chain reaction analyses (Haugland et al., 2002; 2004). Briefly, the standard reaction assays contained 12.5 μl of "Universal Master Mix" 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) and 2.5 μl of DNA free water (Cepheid). A 5 μl volume of the DNA extract was added from the sample. All primer and probe sequences used in the assays as well as known species comprising the assay groups can be found online (US Environmental Protection Agency, 2012). Primers and probes were synthesized commercially (Applied Biosystems, Inc.).

The goal of the statistical analysis was to identify which family and home characteristics were most predictive of the moldiness index values. The associations between moldiness and each family and home characteristic including dust mite, dog and cat allergen levels in house dust, were first evaluated by simple linear regression. Variables that were associated with moldiness at the 15% level were considered for inclusion in a preliminary multiple linear regression model. The stepwise method for building the multivariate model was as follows. Variables were removed one at a time, beginning with the variable with the weakest association with the dependent variable. Contribution to model fit was assessed by (a) comparing Akaike Information Criterion (AIC) values of the models with and without the variable, and (b) evaluation of the change in regression coefficients of the remaining variables. If removal of a variable did not lower the AIC value, the variable was retained. The AIC approach provides a method for penalizing the log likelihood achieved by a given model for its complexity to obtain a more unbiased assessment of the model's worth (Harrell, 2001). If the AIC was lowered, then changes in the regression coefficients of the remaining variables were assessed. A change of more than 20% suggests that the excluded variable provides needed adjustment to the effect of the other variables, and the excluded variable was retained in the model. This process of deleting, refitting, and verifying continued until all important variables were included in the model. The statistical significance in the multivariate stepwise reduction process, as well as the univariate analyses and final multivariate analysis, were based on t-statistics of standardized effect sizes. Spearman correlation coefficients among predictor variables were calculated to assess associations among characteristics.

3. Results

Table 1 shows means and standard deviations of moldiness index with respect to infant, family and home characteristics at age one. The following were associated with higher moldiness index: African American race, winter season, living in a home with a measurable concentration of dust mite allergen, low family income (< $20,000 per year), and living in an older home (built before 1955). Homes with central air-conditioning and carpeting were associated with lower moldiness index. No evidence was found of an association between moldiness index and the following: parental asthma, dehumidifier in home, visual inspection estimates of mold contamination (categorized from a low of 0 to a high of 2), and dog and cat allergen levels (above/below limit of detection).

Characteristics which showed evidence of an association with moldiness index ($p < 0.15$) were included in a preliminary multiple regression model which was reduced to a final model which maximized the fit of the data after penalization for the number of parameters based on AIC values. Predicted changes in moldiness index and 95% confidence intervals (CI) for the final multiple regression model are shown in Table 2. Significant positive and negative associations with moldiness index were found for age of home (before 1955 versus after 1985) and central air-conditioning (yes versus no). Older homes had 2.9 units higher moldiness index (95% CI = 0.4, 5.4), whereas homes with central air conditioning had 2.5 units lower moldiness index (95% CI = -4.7, -0.4). Predicted changes for detectable dust mite allergen and home carpeting were 2.2 and -2.5, respectively. These, however, did not reach statistical significance.

Spearman correlations determined that the year that a home was built was positively correlated with family income, (correlation coefficient = 0.29; 95% confidence interval = 0.18, 0.39), presence of carpeting (0.34; 0.23, 0.44), and negatively correlated with being African American (-0.12; -0.23, -0.000005). In addition, air conditioning was positively correlated with family income (0.42; 0.32, 0.51) and negatively correlated with being African American (-0.34; -0.44, -0.23).

4. Discussion

Most studies of asthma have been cross-sectional or case-control with the potential for bias (Larsson et al., 2011). In addition, for the vast number of studies referenced in 2009 by the World Health Organization that evaluated mold and asthma morbidity/mortality, were focused on mold exposures and asthma exacerbations and not asthma incidence (WHO, 2009). Reponen et al. (2011; 2012) reported the first comprehensive evaluation of the association between indoor aeroallergen exposures during infancy and at age seven and the physician diagnosis of asthma at age seven. Among the studied indoor exposures, only the mold exposure in infancy, as described by higher moldiness index values, was predictive of asthma development at age seven (Reponen et al., 2011; 2012).

In the present analyses, we found that moldiness index values were positively associated with older homes and with lack of air conditioning. On the other hand, significant correlations were found between the studied home characteristics suggesting that age of the home and lack of air conditioning may be indicators of potentially deteriorated indoor air quality.

Older homes without air conditioning were more common among African American families. Race is commonly interpreted as a genetic predisposition for asthma susceptibility. Some studies suggest a genetic link between the incidence and prevalence of asthma and African American race (Smith et al., 2008; Flores et al., 2012), while others reported that life style and home environment may be the source of ethnic disparities (Sun and Sundell, 2011). Another explanation for the high prevalence of asthma among African Americans is that they are more likely to live in older urban homes in the U.S. (Aligne et al., 2000; Everhart et al., 2011). Families with lower income may have higher concentrations of indoor contaminants because poverty causes them to live in more deteriorating structures as those with higher income.

It has been estimated that as many as 50% of homes in the U.S. experience water-damage (Spengler et al., 1994; Mudarri and Fisk, 2007). Many low-income, urban communities live in sub-standard housing and also have higher rates of asthma compared to surrounding communities (Gruchalla et al., 2005; Simons et al., 2007). The Centers for Disease Control and Prevention recently reported that the asthma prevalence in the U.S. continues to increase (CDC, 2012) with the urban poor suffering disproportionately. Conversely, home characteristics of higher income families, such as the presence of air-conditioning and carpeting, were associated with lower moldiness index value in homes. Air conditioning may lead to reduced levels of moisture potentially reducing mold growth. Carpeting was not extensively used in U.S. homes before the 1960's, which is consistent with the results of our study. Therefore the borderline association of carpeting with lower moldiness index may be a function of the age of the home, with homes built before 1955 having higher moldiness index values.

There are some limitations to this study including the relatively small number of participants. It would have been helpful to include assessment of pesticides and other toxic materials as well as rodent allergen exposures.

In conclusion, it appears that lower overall socioeconomic position may lead to water-damaged, higher moldiness index homes which we have previously shown to be associated with the development of asthma. Further, age of home was a surrogate of income, race and carpeting in our population; thus the use of these factors should carefully be evaluated in future studies.

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Abbreviations

AIC	Akaike Information Criteria
CI	confidence interval

Highlights

- We demonstrated link between home environments that promote mold growth and asthma.
- We used Environmental Relative Moldiness Index to describe mold exposure.
- High Environmental Relative Moldiness Index was associated with older homes and lack of air conditioning.
- Overall lower socioeconomic position is associated with higher Environmental Relative Moldiness Index.

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Table 1

Mean values of Environmental Relative Moldiness Index (standard deviation) by infant, family and home characteristics for 288 subjects.

Infant, Family & Home Characteristics	Number of Homes	Environmental Relative Moldiness Index (Mean and standard deviation)
Parental Asthma		
Yes	134	2.9 (7.4)
No	154	2.7 (7.9)
Race *		
African American	66	4.5 (7.9)
Other	222	2.3 (7.5)
Season of Sampling *		
Spring	55	2.1 (6.4)
Summer	101	2.0 (7.6)
Fall	93	2.9 (8.6)
Winter	39	5.4 (6.3)
Income *		
<$20,000	51	5.6 (9.0)
$20-40,000	51	1.7 (6.5)
>$40,000	178	2.3 (7.4)
Air conditioning *		
Yes	221	2.0 (7.2)
No	67	5.4 (8.3)
Dehumidifier		
Yes	48	3.7 (8.5)
No	240	2.6 (7.4)
Carpet *		
Yes	226	2.1 (7.4)
No	63	5.2 (8.0)
Age of Home *		
Before 1955	115	4.9 (7.7)
1955-1985	104	2.1 (7.3)
After 1985	69	0.3 (7.1)
Mold Category-year 1		
0	134	1.9 (7.2)
1	130	3.6 (7.6)
2	23	3.6 (9.7)
Dog allergen		
>level of detection [a]	175	3.0(8.5)
≤level of detection	113	2.4(6.1)
Cat allergen		

Infant, Family & Home Characteristics	**Number of Homes**	**Environmental Relative Moldiness Index (Mean and standard deviation)**
>level of detection [b]	68	3.7(8.9)
≤level of detection	220	2.5(7.2)
Dust mite allergen *		
>level of detection [c]	47	4.3(7.3)
≤level of detection	241	2.5(7.7)

*Variables were included in preliminary multiple regression model

[a] Level of Detection = 10 μg/g dust

[b] Level of Detection = 8 μg/g dust

[c] Level of Detection = 2 μg/g dust

Table 2

Predicted change and ninety-five percent confidence interval (95% CI) for Environmental Relative Moldiness Index between categories of home characteristics obtained from multiple linear regression model for 288 subjects.

Home Characteristics	Predicted change in Environmental Relative Moldiness Index	(95% CI)
Central air-conditioning (yes vs. no)	-2.5	(-4.7, -0.4)
Carpet (yes vs. no)	-2.1	(-4.4, 0.1)
Age of home		
Before 1955	2.9	(0.4, 5.4)
1955-1985	0.6	(-1.8, 2.9)
After 1985	referent	
Dust mite allergen	2.2	(-0.1, 4.6)
(≥ vs. < Level of detection)		

Interpretation of predicted change: The predicted values of moldiness index were: 2.5 units lower for homes with versus without central air-conditioning; 2.1 units lower for homes with carpet versus without carpet; 2.9 units higher for homes built before 1955 and 0.6 units higher for homes built between 1955 and 1985 versus homes built after 1985; 2.2 units higher when dust mite allergen was above versus below level of detection.