Environmental Research 124 (2013) 67–70

Contents lists available at SciVerse ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Short Communication

Family and home characteristics correlate with mold in homes

Tiina Reponen [a,*], Linda Levin [a], Shu Zheng [a], Stephen Vesper [b], Patrick Ryan [a,c], Sergey A. Grinshpun [a], Grace LeMasters [a]

[a] University of Cincinnati, Department of Environmental Health, Cincinnati, OH, USA
[b] United States Environmental Protection Agency, Cincinnati, OH, USA
[c] Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

ARTICLE INFO

Article history:
Received 18 October 2012
Received in revised form
17 April 2013
Accepted 23 April 2013
Available online 14 May 2013

Keywords:
Mold
Environmental relative moldiness index
Air conditioning
Age of the home
Socioeconomic position

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.

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 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 Eq. (1).

$$\text{Environmental Relative Moldiness Index} = \sum_{i=1}^{26} \log_{10}(s_{1i}) - \sum_{j=1}^{10} \log_{10}(s_{2j}) \quad (1)$$

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

Abbreviations: AIC, akaike information criteria; CI, confidence interval.

* Corresponding author. Fax: +1 513 558 2263.
E-mail addresses: tiina.reponen@uc.edu, reponeta@ucmail.uc.edu (T. Reponen).

0013-9351/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.envres.2013.04.003

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.

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.

Spearman correlations determined that the year that a home was built was positively correlated with family income, (correlation coefficient = 0.29; 95% CI = 0.18, 0.39), presence of carpeting (0.34; 95% CI: 0.23, 0.44), and negatively correlated with being African American (−0.12; 95% CI: −0.23, −0.000005). In addition,

Table 1
Mean values of Environmental Relative Moldiness Index (standard deviation) by infant, family and home characteristics for 288 subjects.

Infant, family and 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		
> 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.