

Can we trust cross-sectional studies when studying the risk of moisture-related problems indoor for asthma in children?

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Most studies studying dampness as a risk factor for asthma are of a cross-sectional design. The aim of this study was to investigate if the association between moisture-related problems indoor and asthma found in cross-sectional questionnaire data can be confirmed in longitudinal analyses. The Dampness in Building and Health (DBH) study started in 2000 in Värmland, Sweden, with a baseline questionnaire to all children aged 1–5 y ($n = 14,077$) and five years later a follow-up questionnaire was distributed to children aged 6–8 y ($n = 7,509$). Moisture-related problems that were associated with asthma in cross-sectional analysis decreased or disappeared in the longitudinal analysis. However, the association between reports of moldy odor in the homes at baseline and incident asthma remained and became stronger. Our results suggest that cross-sectional data showing associations between moisture-related problems in homes and asthma in children partly can be explained by reporting bias.

Keywords: moisture problems; asthma/allergy; cross-sectional study; longitudinal study; bias

Introduction

Moisture-related problems and dampness in buildings are frequently reported globally. There are, however, large differences in frequency between different countries and regions. In tropical climate the frequency of mold or water damages have been reported to be 23–79% (Li and Hsu 1996; Li et al. 1997) while in colder climates, like in Scandinavia, the rate of such problems have been reported in the range of 4–25%. Smell and bad odor are more frequently reported in buildings in cold climate (Andrae et al. 1988; Forsberg et al. 1997; Smedje et al. 1997).

Reviews have concluded that living or working in a building with reported moisture problems is associated with a wide range of respiratory health effects (Bornehag et al. 2001, 2004a; Sundell 2004; World Health Organization [WHO] 2009). A meta-analysis of the health effects associated with mold and dampness reported an odds ratio of 1.56 (95% CI 1.30–1.86) for current asthma (Fisk et al.

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2007). However, there is limited knowledge regarding biological mechanisms explaining the reported associations although some hypothesis has been proposed.

Most studies on the association between indoor dampness and respiratory effects are of a cross-sectional design. This may limit the possibility for establishing temporality between exposure and health outcome and increase the risk for reporting bias. Reporting bias occurs when the same person reports both exposure and health effects as in the case of questionnaire studies and when there is a public awareness of the problem. In such a situation there is risk for a systematic over-reporting of moisture problems in diseased subjects when compared with healthy ones and/or a risk for over reporting of symptoms in subjects living in problem buildings when compared with people living in buildings without such problems (Bornehag et al. 2001; Fisk et al. 2007). Such reporting bias does not occur to the same extent in longitudinal studies.

In 2000 the Dampness in Buildings and Health (DBH) study started with a baseline cross-sectional questionnaire study of more than 14,000 children aged 1–5 years. From that study we have earlier reported strong associations between reports of dampness indoor and asthma (Bornehag et al. 2005). We have now conducted a 5-year follow-up study of the baseline investigation meaning that we now can examine the relationship between reported dampness problems and the incidence of asthma in these children at follow-up. The main aim with the current study is therefore to investigate if the association between moisture-related problems indoor and asthma found in our cross-sectional data can be confirmed in a longitudinal analysis.

Method

The DBH-study started in 2000 in the county of Värmland, Sweden, with a baseline questionnaire to the parents of all children in the age of 1–5 years ($n=14,077$), focusing on asthma and allergic symptoms and indoor environmental factors in these children's homes. Data from 10,851 children were achieved corresponding to a response rate of 79%. This population was included in the cross-sectional analysis in the year 2000. These 10,851 children lived in 8,918 homes since they had siblings also participating in the study. In the follow-up questionnaire study five years later, the three youngest year cohorts from the baseline study were invited ($n=7,509$), now 6–8 years of age. There were 5,483 responses from children corresponding to a response rate of 73%. Of these, 4,779 children participated in both the baseline and follow-up study and therefore constituted the study population in the longitudinal analyses. This follow-up population reflects the baseline population well in relation to sex, allergic symptoms in family, type of building and smoking in family.

Questionnaire

The child's and parent's health status was assessed by using the same questions as used in the International Study of Asthma and Allergies in Childhood (ISAAC) (Pearce et al. 1993; Larsson et al. 2008). The questionnaire included 84 questions on, e.g., type of building (single family house, multi family house), flooring materials in the bedrooms (PVC, wood, linoleum, stone, wall-to-wall carpet) and different lifestyle factors. Further details regarding the questions and the questionnaire, see elsewhere (Bornehag et al. 2004b; Larsson et al. 2008). We have calculated moisture indices at three different points in time: Moisture problems at baseline (2000) as

described in Bornehag et al. (2005), moisture problems in the child's birth residence where data were collected in the baseline questionnaire, and moisture problems at follow-up (2005).

The following moisture indices were used at baseline:

- Water leakage: "Have you had flooding or other types of water damages in the child's and/or parent's bedroom and/or in kitchen and/or bathroom?" (No such indices vs. yes at least one indices during the past 12 month, yes at least one earlier).
- Floor moisture: "Is there loosening, bubbling or discoloured flooring material in the child's and/or parent's bedroom and/or in the bathroom?" and/or "Is there miscoloured plastic cork or parquet in the dwelling?" (No such indices vs. Yes at least one)
- Visible dampness: "Is there visible mold on the floor, wall or roof in the parent's and/or child's bedroom?" and/or "Is there visible damp stains on the floor, wall or roof in the parent's and/or child's bedroom?" (No such indices vs. Yes at least one)
- Condensation on window: "Is there condensation on the inside of the windows during winter time in the parent's and/or child's bedroom?" (No condensation vs. Yes, less than 5 cm, Yes, more than 5 cm).
- Moldy odor: "Have you perceived moldy odor in your dwelling during the last three months?" and/or "Have you perceived earthy odor in your dwelling during the last three months?" (No odor vs. Yes, sometimes; Yes, often)

At baseline, there were also retrospective questions about moisture-related problems in the child's birth residence (BR). However, these questions were not specific for rooms; the parents could only answer "yes at least one problem vs. no such problems".

- Water leakage^{BR}: "Was there flooding or other types of water damages in the child's birth residence?"
- Floor moisture^{BR}: "Was there loosening, bubbling or miscoloured floor carpets in the child's birth residence?" and/or "Was there discoloured plastic cork or parquet in the child's birth residence?"
- Visible dampness^{BR}: "Was there visible mold or damp stains on the floor, wall or roof in the child's birth residence?"
- Condensation on window^{BR}: "Was there condensation on the inside of the window during winter time in the child's birth residence?"
- Moldy odor^{BR}: "Did you perceive moldy odor in the dwelling in the child's birth residence?" and/or "Did you perceive earthy odor in your dwelling in the child's birth residence?"

In the follow-up questionnaire (year 2005) only visible dampness and condensation on windows could be calculated.

Statistical analyses

The distribution of different moisture indices at baseline was calculated for 8,918 homes. Estimating the associations between moisture-related problems and asthma

in children were conducted in two ways. Firstly, analyses for prevalent asthma were made in the cross-sectional baseline data from year 2000 including 10,851 children. Even though many analyses of the baseline dataset can be found in Bornehag et al. (2005) we have chosen to include these data in the current paper due to more expanded analyses. Secondly, analyses for incident asthma were performed for children participating in the baseline and the follow-up questionnaire, 4,779 children.

The incidence of asthma during the five-year period was estimated by excluding children with doctor-diagnosed asthma and/or wheezing symptoms at baseline and calculating the incidence rate of those children who reported to have doctor-diagnosed asthma in the follow-up questionnaire 2005. A more detailed description is described elsewhere (Larsson et al. 2008).

Associations between moisture indices and prevalent and incident asthma were estimated using a univariate logistic regression model. In order to control for possible confounders, multivariate logistic regression models were used. The multivariate analyses were adjusted for age, sex, allergic symptoms in the family and type of dwelling, based in previous findings (Bornehag et al. 2005; Larsson et al. 2008). In separate analyses, adjustments were also made for factors that were associated with moldy odor. In order to further investigate potential confounding factors the association between perceptions of moldy odor and prevalence/incidence of asthma was studied in subgroups with regards to allergic symptoms in the family, smoking in family, building characteristics and age of the child (Supplementary Table 1, available online).

In Supplementary Table 2 (available online), we combined some variables to investigate the joint effect of having PVC-flooring in the child's or parent's bedroom and to have reported moldy/earthy odor (index name: PVC/Odor), with the definition of odor as described above. We compared the risk of having asthma in four exposure categories: No PVC-flooring and no moldy odor (reference category), no PVC-flooring but moldy odor, PVC-flooring but no moldy odor, and both PVC-flooring and moldy odor. Another combined index was constructed between type of flooring in the children's or parent's bedroom and moldy odor (index name:

Table 1. The distribution of different dampness indices in 8,918 homes of 10,851 children.

	Baseline questionnaire	
	<i>n</i> = 8,918	
	<i>n</i>	%
Dampness indices in the home year 2000		
Water leakage	1588	17.8
Floor moisture	737	8.3
Visible dampness	130	1.5
Condensation on window	1274	14.3
Moldy odor	385	4.3
Dampness indices in the birth residence		
Water leakage ^{BR}	617	6.9
Floor moisture ^{BR}	582	6.5
Visible dampness ^{BR}	641	7.2
Condensation on window ^{BR}	2879	32.3
Moldy odor ^{BR}	563	6.3

^{BR} = birth residence.

Table 2. Crude and adjusted association between dampness indices at baseline (year 2000) and prevalence of asthma in cross-sectional analyses ($n = 10,851$) as well as incidence asthma in longitudinal analyses ($n = 4,779$).

Dampness indices at baseline		Prevalence of doctor-diagnosed asthma, 2000				Incidence of doctor-diagnosed asthma, 2005			
		n^1	n	%	Adjusted OR 95% CI ²	n^1	n	%	Adjusted OR 95% CI ²
Water leakage	No	7670	391	5.1	1.0	2557	78	3.1	1.0
	Yes	1909	123	6.4	1.20 (0.97–1.48)	606	18	3.0	0.93 (0.55–1.57)
Floor moisture	No	9465	496	5.2	1.0	3127	90	2.9	1.0
	Yes	865	62	7.2	1.34 (1.01–1.77)	267	10	3.7	1.25 (0.64–2.45)
Visible dampness	No	10287	548	5.3	1.0	3395	104	3.1	1.0
	Yes	163	14	8.6	1.69 (0.96–2.96)	47	2	4.3	1.49 (0.35–6.30)
Condensation on window	No	8477	433	5.1	1.0	2779	86	3.1	1.0
	Yes	1561	106	6.8	1.34 (1.07–1.67)	518	8	1.5	0.48 (0.23–1.00)
Moldy odor	No	9862	517	5.2	1.0	3280	91	2.8	1.0
	Yes	453	34	7.5	1.41 (0.98–2.03)	129	10	7.8	2.99 (1.50–5.94)

¹Number of children in analysis; ²Adjusted for age, sex, allergic symptoms in family, smoking in family.

Odor/flooring). We compared the odds ratios (OR) of asthma in four exposure categories: No odor and any type of flooring (reference category), odor and wood flooring, odor and linoleum flooring, and odor and PVC-flooring.

The associations were considered to be statistically significant when the P -value was below 0.05. Statistical analyses were carried out using SPSS for Windows (version 18.0).

Results

In the baseline study, where the children were 1–5 years, 5.4% had doctor-diagnosed asthma and in the follow-up study five years later the asthma prevalence was 8.7%. The most frequent moisture problem in the baseline investigation was water leakage followed by condensation on window (Table 1). Reports of moisture in the birth residence were most common for condensation on window (32.3%), with other moisture problems varied between 6.3–7.2%. In the follow-up study condensation on window was reported for 11.0% of the current homes and visible dampness was only reported for 0.3%. Almost 36% of the children at age 1–3 years did not live in their birth residence, but had moved.

In the cross-sectional data at baseline four moisture indices were focused on: Water leakage, floor moisture, moldy odor and condensation on window. All these indices were significantly associated with an increased risk of doctor-diagnosed asthma in crude analysis. In adjusted analysis, the significance of the association remained for floor moisture and condensation on window. This result has been published elsewhere (Bornehag et al. 2005). Cross-sectional data in year 2005, showed the same associations between condensation on window, visible dampness

and doctor-diagnosed asthma as in the baseline data, however, not significant due to a smaller sample size (data not shown).

The association between moisture problems (i.e., water leakage, floor moisture, visible dampness, and condensation on window) and doctor-diagnosed asthma – that was found in the cross-sectional analyses – decreased or disappeared in the longitudinal analyses of incident asthma (Table 2). However, the association between a perception of moldy odor in the home at baseline and incident doctor-diagnosed asthma became stronger in longitudinal analyses. There is also an indication of a linear-by-linear association between odor reports and incident asthma ($p=0.01$). Reports of “moldy odor sometimes” increased the OR to 2.21 (95% confidence interval (CI): 0.94, 5.24) and reports of “moldy odor often” increased the OR to 11.44 (95% CI: 3.50, 37.36) compared with “no moldy odor” (data not shown).

Moisture problems in the birth residence – where data were collected in the baseline questionnaire – were associated with asthma at baseline (Table 3). Significant associations were found for water leakage^{BR}, floor moisture^{BR}, visible dampness^{BR}, condensation on window^{BR} and moldy odor^{BR} with ORs in the range of 1.4–2.1. However, in longitudinal analyses all associations between asthma and reported moisture problems at birth disappeared.

In order to investigate potential confounding factors for the association between perceptions of moldy odor at baseline and prevalence/incidence of asthma in the child, the data has been stratified into sub groups (Supplementary Table 1, available online). Reports of a moldy odor, both at baseline and in the birth residence, were associated with both the prevalence and the incidence of asthma in families with

Table 3. Crude and adjusted association between dampness indices in the birth residence^(BR) and the prevalence of asthma in cross-sectional analyses ($n=10,851$) and the incidence of asthma in longitudinal analyses ($n=4,779$).

Dampness indices in the birth residence		Prevalence of doctor-diagnosed asthma, 2000				Incidence of doctor-diagnosed asthma, 2005			
		n^1	n	%	Adjusted OR 95% CI ²	n^1	n	%	Adjusted OR 95% CI ²
Water leakage ^{BR}	No	9355	476	5.1	1.0	3121	91	2.9	1.0
	Yes	738	63	8.5	1.67 (1.27–2.21)	201	5	2.5	0.87 (0.35–2.18)
Floor moisture ^{BR}	No	9531	483	5.1	1.0	3130	94	3.0	1.0
	Yes	686	66	9.6	1.88 (1.42–2.47)	211	5	2.4	0.75 (0.30–1.87)
Visible dampness ^{BR}	No	9503	479	5.0	1.0	3144	95	3.0	1.0
	Yes	755	71	9.4	1.83 (1.40–2.39)	233	6	2.6	0.84 (0.36–1.94)
Condensation on window ^{BR}	No	6550	312	4.8	1.0	2160	70	3.2	1.0
	Yes	3451	232	6.7	1.41 (1.18–1.69)	1122	26	2.3	0.70 (0.44–1.11)
Moldy odor ^{BR}	No	9618	485	5.0	1.0	3197	95	3.0	1.0
	Yes	671	72	10.7	2.10 (1.61–2.74)	179	5	2.8	0.95 (0.38–2.38)

¹Number of children in analysis; ²Adjusted for age, sex, allergic symptoms in family, smoking in family.

allergic symptoms while such associations could not be found in non-allergic families. However, allergic families did not report more moldy odor, neither in the baseline or birth residence compared with non-allergic families (3.9 vs. 3.8%). Furthermore, moldy odor reports were significantly associated with both prevalence and incidence of asthma in non-smoking families while the associations were slightly lower and non-significant in smoking households. Regarding type of flooring material in the child's bedroom, perception of moldy odor at baseline was found to be a stronger risk factor for incident asthma in homes with PVC-flooring compared with homes equipped with wood or other types of flooring materials. In the parent's bedroom, moldy odor increased the risk for incident asthma in homes with PVC-flooring as well as other types of materials, however, not for homes with wooden floor.

In order to avoid confounding problems we analyzed the association between a moldy odor at baseline and different building and behavioral related factors. Moldy odor was significantly associated with a flat roof of the building, a multi family house, if the family had rebuilt the home due to dampness or moisture problem. Also smoking was associated with moldy odor as well as less cleaning of the child's bedroom. When adjusting for these variables separately in the multivariate model, the significant associations between a moldy odor at baseline and incident asthma remained (data not shown).

When analyzing the importance of moldy odor at different point in time for incident asthma, i.e., if the family had reported no moldy odor at birth residence and no moldy odor at baseline; moldy odor only at birth residence; moldy odor only at baseline and; moldy odor at both birth residence and baseline, no associations could be found that early life exposure to moldy odor was more associated to incident asthma. These analyses have very small sample size due to only 10 children with incident asthma that have reported moldy odor, which limits the interpretation of data.

When reports of a moldy odor were combined with different types of flooring material it was found that moldy odor in combination with PVC-flooring increased the risk for both prevalent and incident asthma (Supplementary Table 2, available online).

Discussion

In Sweden there is a common opinion that moisture problem in homes is related to respiratory symptoms such as asthma. In cross-sectional questionnaire studies, families with symptomatic children might be more prone to report moisture damages in their dwelling due to their opinion about these associations and families with signs of dampness in the home may systematically over-report symptoms of the children (Bornehag et al. 2001; Fisk et al. 2007). This could be one reason why we generally find strong associations between reports of visible dampness and asthma among children in our cross-sectional study compared to the longitudinal data on incidence asthma.

Most studies that show that moisture-related problems indoor are associated with respiratory health effects are of a cross-sectional design (Verhoeff et al. 1995; Aberg et al. 1996; Nafstad et al. 1998; Rönmark et al. 1998; Bornehag et al. 2001, 2004a, 2005; Simoni et al. 2005). The first phase of the DBH-study, with a cross-sectional design, also showed that moisture problems were associated with several

allergic symptoms. Visible dampness showed the strongest association to asthma, followed by water leakage and condensation on windows (Bornehag et al. 2005). In the current longitudinal analysis these associations decreased or disappeared. However, reports of a moldy odor in the home remained significantly associated with incident asthma in the longitudinal analyses.

There are a limited number of longitudinal studies that have focused on moisture-related problems indoor and the association to incident wheezing and/or incident asthma among children. The Swedish BAMSE-study showed that parental reports of a damp home environment when the child was two months old increased the risk for incident wheezing and asthma two years later. They defined dampness as at least one of following indicators: Odor (smell), visible signs of mold, water damage inside construction, and persistent windowpane condensation in dwellings with double glazing (Wickman et al. 2003). This is a rather wide definition of dampness, which makes it difficult to distinguish which specific dampness problems could be of importance for development of asthma and wheezing. In a Finnish birth-cohort study, Karvonen et al. (2009) investigated different moisture-related problems when the child was six month old. They used two different indices in the study; “any visible mold in kitchen, main living area, and bathroom or other areas” and “moldy odor anywhere in the dwelling” was observed by inspectors. Visible mold at the age of six months was associated with doctor-diagnosed wheezing and parental-reported wheezing in the child at the age of 18 months. However, they did not find that moldy odor significantly increased the risk for incident doctor-diagnosed wheezing, but moldy odor was associated to parental reported wheezing (aOR 2.78; 95% CI: 0.95, 8.19). Jaakkola et al. (1993) found in cross-sectional analyses in a Finnish population-based questionnaire study of children aged 1–6 years that visible mold, moisture, water damage and moldy odor anywhere in the dwelling were all significantly associated with wheezing in separate analyses. In the longitudinal analyses six years later there were no association between visible mold, moisture or water damage at baseline (1–6 years of age) and incident asthma. However, the only dampness indicator that was significant was moldy odor with an increased risk of developing asthma (Jaakkola et al. 1993, 2005). This means that the results by Karvonen et al. (2009) and Jaakkola et al. (2005) are in accordance with our finding that moldy odor could be of importance for development of asthma in the child.

We have earlier reported that moldy odor could be of interest for allergic symptoms in children. In the second step in the DBH-study, a nested case-control study where trained inspectors visited 390 dwellings, we could not find that moldy odor in the dwelling in general increased the risk for asthma in the children. However, we found that children living in dwellings with inspector-observed moldy odors along the skirting board were reporting to have more doctor-diagnosed asthma than children from homes without such odor (Hagerhed-Engman et al. 2009). Our interpretation was that moldy odor along the skirting board perhaps could be seen as an indication of moisture-related problems inside the building structure. Our data showed further that the combination of PVC-flooring in the bedroom and reported moldy odor increased the risk of asthma in cross-sectional analyses, and the association became stronger in the longitudinal analysis. The reason for this result could be that hidden moisture problems in the construction, in interaction with different building material, probably could emit odor and increase the risk for asthma.

However, the picture regarding the risk with a moldy odor for asthma in children is not consistent in our data. When analyzing the association between a moldy odor in the birth residence and asthma, there was an association in cross-sectional data which disappeared in the longitudinal analyses. We do not have any explanation for this difference in associations; however, one complicating factor is that the frequencies of odor problems did differ between the homes at baseline and at birth and that one third had moved to another house. In general, there were higher frequencies of moisture problems reported for the birth residence compared with such problems reported from the current dwelling at baseline. A possible explanation for this could be that moisture-related problems at baseline was reported in the parent's or the child's bedroom while moisture-related problems in the birth residence were reported from anywhere in the home. Almost 65% of parents that reported moldy odor in the birth residence reported also moldy odor at baseline.

Our analysis showed that the association between moldy odor and incident asthma was mainly found for families with allergic parents and/or siblings. Such a result indicates that there can be a reporting bias even in a longitudinal study. Families with asthma and allergy problems (where the index child is without symptoms) may systematically report more odor problems due to the fact that they know that such problems are associated with allergic problems in other family members. Furthermore, we know that allergic symptoms in the family are strong risk factors for development of allergies in a child. However, we found that reports of moldy odor in the home was about the same for allergic and non-allergic families at baseline (3.9 vs. 3.8%) meaning that there is no obvious risk that reporting bias can explain the association between moldy odor at baseline and incident asthma.

Our study showed that children in non-smoking families developed more asthma if they also reported a moldy odor while this association was not seen in smoking families. As shown in the DBH-study, smoking was not a risk factor for incident asthma (Larsson et al. 2008), which could be due to the fact that Swedish parents are well informed about the risk of exposing the children for tobacco smoke, meaning that they do not smoke close to the child. Another explanation for not finding an association between odor and incident asthma in smoking families could be that these adults might be less sensitive to and report less odor, as smokers may have an impaired ability to sense smell (Vennemann et al. 2008).

One of the weaknesses of the present study is that asthma that was developed during the early life period (the first year of life for the youngest children and the first three years for the oldest children) has not been considered since the diseased children were excluded at baseline. When stratifying for age there was power problems, due to small number of cases within every age group. This means that we have not investigated the importance of moisture problems for development of asthma during infancy.

We have shown that reports of moldy odor in homes might be seen as a risk factor for developing asthma in children, but the results are not absolutely consistent. However, even if odor problems in the home are related to the development of asthma in children we have to realize that such exposures can explain very little of the incident asthma since moldy odor were reported from less than 4% of the homes and the attributable fraction can be estimated to about 6%. This means that elimination of the exposure (moldy odor) will reduce the number of incident asthma during the five-year period from 100 to about 94 children.

Significant associations between parental-reported dampness in the dwelling and parental-reported asthma in children was found in cross-sectional data while the associations disappeared or decreased in longitudinal data. However, a significant association between moldy odor reports in the home at baseline and incident asthma was found in the longitudinal analyses but moldy odor reports from the birth residence were surprisingly not a risk factor for incident asthma. Our result suggests that cross-sectional associations between self-reported moisture-related problems in homes and asthma in children at least in part can be explained by reporting bias. This means that cross-sectional data from questionnaire studies have to be interpreted with caution.

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Supplementary material available online

Supplementary Tables 1 and 2.

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