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KEY WORDS

respiratory tract disease, cohort studies, indoor, mold, atopy, children

ABBREVIATIONS

IOM—Institute of Medicine

PASTURE—Protection Against Allergy Study in Rural Environments

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WHAT'S KNOWN ON THIS SUBJECT: Moisture and mold problems are associated with exacerbation of respiratory tract symptoms; but evidence on the possible association with development of new asthma and atopy is limited. Most previous studies were cross-sectional and based on self-reported exposure.

WHAT THIS STUDY ADDS: This birth-cohort study incorporated home visits, and results confirm that moisture damage or mold in the home increases the risk for early wheezing. Only moisture problems in the living areas of the home had health effects.

abstract

OBJECTIVES: Most previous studies on the association between moisture or mold problems in the home and respiratory symptoms in children were cross-sectional and based on self-reported exposure. The aim of this study was to evaluate the impact of objectively observed moisture damage and visible mold in the homes on early-life respiratory morbidity and atopic sensitization in a birth cohort.

METHODS: Building inspection was performed by building engineers in the homes of 396 children, and the children were followed up with questionnaires from birth to the age of 18 months. Specific immunoglobulin E levels were measured at the age of 1 year.

RESULTS: Doctor-diagnosed wheezing was associated with the severity of moisture damage in the kitchen and with visible mold in the main living area and especially in the bedroom of the child. The risk for parent-reported wheezing apart from cold increased with the severity of moisture damage in the kitchen. Moisture damage in the bathrooms or other interior spaces had no significant association with wheezing. No significant associations were observed for other end points, such as cough, or respiratory infections. There was a suggestion for an increased risk for sensitization to cat dander linked with moisture and mold exposure.

CONCLUSIONS: This birth-cohort study supports previous observations that moisture mold problems in the kitchen and in the main living area increase the risk for wheezing in early childhood. The results underline the importance of assessing separately the health effects of moisture and mold problems in different areas of the home. *Pediatrics* 2009;124:e329–e338

Several reviews[1–3] showed that moisture damage and mold growth in the building are significantly associated with cough, wheeze, and even asthma among children and adults. The Institute of Medicine (IOM)[4] concluded that there is sufficient evidence that moisture and mold problems are associated with upper and lower respiratory tract symptoms. In contrast, there is limited or suggestive evidence on the association with development of new asthma.[4] Few studies have suggested that moisture and mold problems may also increase the risk for sensitization to inhaled allergens.[5,6]

Recent studies on the association between moisture and mold problems in the homes and respiratory manifestations in children have mainly been cross-sectional, and the exposure assessment has been based on self-reports.[7–9] However, occupants' reports on dampness or mold growth are subjective[10] and may even be biased, creating an artificial association between home dampness and asthma.[11,12] Few studies have supplemented occupants' self-reports with measurements of fungal spores in indoor air and/or house dust samples.[5,13,14] There is only 1 earlier birth-cohort study with data on inspector-observed moisture damage in homes in early childhood.[15] We therefore established a birth-cohort study to evaluate the association of inspector-observed moisture damage and visible mold at home with occurrence of respiratory symptoms up to the age of 18 months and with atopic sensitization at the age of 1 year.

METHODS

Study Population

The study population consisted of a birth cohort, which has been prospectively followed up from the third trimester of pregnancy. Participants were recruited in 2 phases (Fig 1). The first half of the study population belongs to a European birth-cohort study (Protection Against Allergy Study in Rural Environments [PASTURE]), which has been conducted in rural areas of Austria, Finland, France, Germany, and Switzerland.[16] All pregnant women who lived on farms with livestock and an equal-sized random sample of nonfarming women who lived in nonurban areas were invited to join the study at 20 to 34 weeks of gestation in 4 hospitals in the Eastern and Middle Finland (Kuopio, Jyväskylä, Joensuu, and Iisalmi). The mothers were screened for the expected time of delivery, parents' occupation (farming), and home address by using information received from the maternal outpatient clinics. Criteria for inclusion in the study were maternal age of ≥18 years, singleton pregnancy, mother tongue Finnish, and no plans to move from the study area. Exclusion criteria were the delivery before 36 weeks of gestation, congenital abnormalities in the infants, and a failure to obtain cord blood samples.

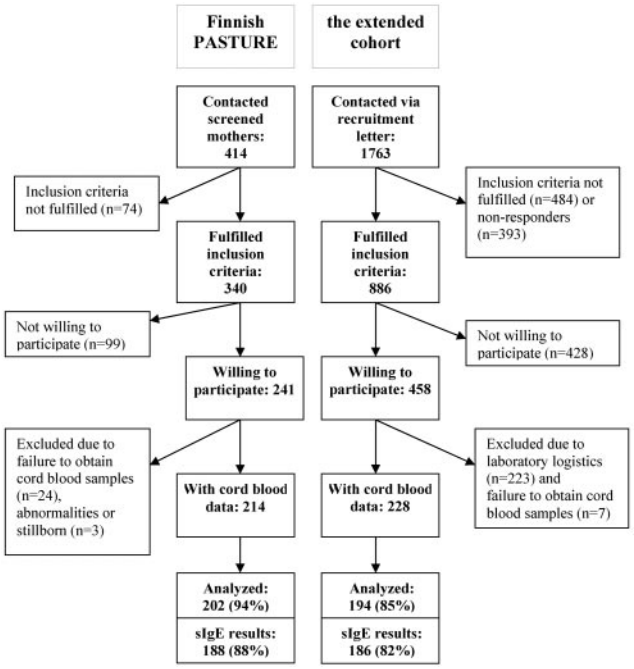

FIGURE 1
Flowchart of subject during recruitment and finally included in analyses: inclusions, exclusions, and refusals.

In the second half of the cohort (the extended cohort), all pregnant women with estimated delivery at Kuopio University Hospital between May 2004 and May 2005 were invited to the study at 32 weeks of gestation. There was no selection by the occupation or area of living; however, women who lived in apartments were excluded to make the building stock comparable between the 2 parts of the cohort. Because of logistic reasons, only women who delivered between Sunday afternoons and Thursday mornings were included. Otherwise, the inclusion and exclusion criteria were the same as described already. Each mother could take part in the study only once. All the children were born between September 2002 and May 2005.

Ultimately, 699 (57%) of the 1226 mothers who fulfilled the inclusion criteria were willing to participate in the study. Finally, cord blood samples were available from 442 mothers (Fig 1). These mothers, as compared with mothers fulfilling inclusion criteria but who

were not included in the study (N = 784), lived more often on a farm with livestock (28.1% vs. 14.2%) and had higher prevalence of maternal and/or paternal hay fever (42.1% vs 34.6%). The number of children, mother's educational level, and the prevalence of the maternal and/or paternal asthma and atopic eczema did not differ significantly between the groups. The study protocol was approved by the Research Ethics Committee, Hospital District of Northern Savo, Kuopio, Finland. A written informed consent was obtained from the parents of all participating children.

Follow-up

The first questionnaire was administered during the third trimester of pregnancy, and follow-up data were collected from the mothers by self-administered questionnaires when the children were 2, 12, and 18 months of age. In the Finnish PASTURE cohort, however, the 2-month data were obtained by interviews. The details of the questionnaires have been described elsewhere.[17] In brief, information was collected from respiratory symptoms and diseases, such as cough apart from cold, nocturnal cough apart from cold, any audible wheeze from the chest, audible wheeze apart from cold, otitis media, and acute laryngitis. Information on common cold with and without fever, as well as fever (≥38°C) with no respiratory symptoms was collected only at the age of 18 months. Doctor-diagnosed obstructive or asthmatic (wheezy) bronchitis was asked by using the question, "Has your child had an obstructive or asthmatic bronchitis diagnosed by a doctor?" Doctor-diagnosed asthma was asked by a corresponding question.

Venous blood samples at the age of 12 months were analyzed for specific immunoglobulin E to 19 common allergens, by using the Allergy Screen Test Panel for Atopy (Mediwiss Analytic, Moers, Germany).[18] The 13 inhaled allergens tested were 2 house dust mites (*Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*); 7 pollens (alder, birch, European hazel, grass pollen mixture, rye, mugwort, and plantain); cat, horse, and dog dander; and the mold *Alternaria alternata*. The 6 food allergens were hen egg, cow milk, peanut, hazelnut, carrot, and wheat. Atopic sensitization was defined as specific immunoglobulin E concentration of ≥0.35 kU/L.

Moisture Damage and Visible Mold in the Home

In the Finnish PASTURE cohort, either of 2 trained building engineers of our study group inspected the home for moisture damage and visible mold when the child was 2.0 months of age on average (SD: 0.3 months; range: 0.8–3.1 months). The inspectors had several years' experience in the use of a standard protocol.[19] In the extended cohort, only 1 of these same 2 building engineers inspected all of the homes when the child was 8.4 months of age on average (SD: 6.9 months; range: 1.1–25.0 months). Overall, home inspections were performed before the age of 6 months in 312 (79.5%) children.

The homes were inspected for the signs of moisture in the surfaces and the structures by using a predesigned checklist.[20] The information recorded during the home visit was focused on the whole house, and details of every individual damaged area were recorded and allocated in the analyses into 4 areas: kitchen, main living area, bathroom, and other areas. Main living area consisted of bedrooms, including the child's bedroom; living rooms; and main hallways connecting these rooms. Moisture damage was classified into 3 classes on the basis of a 6-point "need for repair" estimation scale[19] and the area of the damage: no damage, minor damage, and major damage. Classes 0 and 1 meant that the damage with no need for repair or only cosmetic repair; class 2 meant a repair of surface materials needed; class 3 meant a repair of structural components needed; and classes 4 and 5 meant more extensive repair needed. "No damage" was defined as need for repair classes 0 or 1. "Major damage" was defined in 3 different cases: (1) a need for repair class 2 with the area of damage ≥1 m^2, (2) a need for repair class 3 with the area of damage ≥0.1 m^2, or (3) a need for repair class 4 or 5. Other damage in the given area was classified as "minor damage".[20] During the home inspection, observed mold was also categorized separately in the 4 areas of the home into 3 classes: no mold, spots of mold, and visible mold. Because of the small numbers of homes with visible mold, the mold observations were categorized into 2 classes in the given area: any visible mold and no mold. Damage/mold odor in the whole house was defined as damage/mold odor when detected in any of the 4 areas.

Statistical Analyses

This analysis includes 396 children with complete data on home inspection, the questionnaire at the third trimester of pregnancy, follow-up questionnaires at the ages of 12 months and/or 18 months, and father's questionnaire. A venous blood sample at the age of 12 months was available for 374 (94%) children.

The questionnaire at the age of 12 months covered the period between 2 and 12 months, and the questionnaire at the age of 18 months covered the period between 12 and 18 months; therefore, a given symptom or disease was coded to be present at the age of 2 to 18 months when it was present in 1 or both of the 12- and 18-month ques-

tionnaires. The symptom or disease was coded as missing only when the data were missing in both 12- and 18-month questionnaires. Because most children had experienced at least 1 episode of common cold with or without fever between the ages of 12 and 18 months, these 2 outcomes were categorized into 2 classes: >1 vs ≤ 1 episode (fever) and >2 vs ≤ 2 episodes (no fever), respectively. Because of the small number of children with doctor-diagnosed asthma at <18 months, doctor-diagnosed obstructive or asthmatic bronchitis and asthma were combined into "doctor-diagnosed wheezing."

The data were analyzed by using SPSS 15.0 for Windows (SPSS, Inc, Chicago, IL). First, the associations between respiratory manifestations and moisture damage or mold in the home were tested with Pearson's χ^2 test and with Fisher's exact test. The risks were expressed as odds ratios and their 95% confidence intervals. Multivariate analyses were performed by logistic regression adjusted for gender, number of siblings (none, 1, and ≥ 2 siblings), maternal education (basic, middle, and academic), dog and/or cat ownership, maternal smoking (smoker but not during pregnancy; smoker also during pregnancy, which included all mothers who smoked at least the first weeks of pregnancy; and never smoked), maternal allergic diseases (asthma, atopic eczema and/or allergic rhinitis, and none), paternal allergic diseases, the cohort, and the place of residence (rural farm, rural nonfarm, and urban).

RESULTS

Weaker and mostly nonsignificant associations were observed for moisture damage or mold classification of the whole house (Table 1). The occurrence of doctor-diagnosed wheezing increased with the presence of moisture damage in the kitchen, showing a dose-response relationship, with the presence of visible mold in the main living area and in the child's bedroom. Parent-reported wheezing apart from cold was associated with moisture damage in the whole house, with visible mold in the kitchen and with moisture damage in the kitchen, again showing a dose-response relationship. Multivariate analyses in general confirmed these findings, except the association between visible mold in the kitchen and parent-reported wheezing apart from cold (Table 2).

There was a suggestion of an association between nocturnal cough apart from cold and major moisture damage in the kitchen or in the main living area (Table 1). Adjustment for covariates changed the estimates slightly (Table 2). The association with cough apart from cold was similar to nocturnal cough apart from cold but was slightly weaker (data not shown).

There was some evidence for associations between moisture or mold problems and respiratory infections. Adjustments had small effects on the estimates; therefore, only adjusted estimates are presented (Table 3). Common colds with and without fever tended to be inversely associated with the presence of visible mold in the kitchen. Otitis media tended to be associated with the presence of visible mold in the whole house.

In all, 355 (89.6%) children had lived in the same home since birth until the age of 18 months, and among them, home inspection was performed before the age of 6 months in 289 (81.4%) cases. In subgroup analyses that included only these 355 children or 289 children, the significant associations between moisture damage and doctor-diagnosed wheezing or parent-reported wheezing apart from cold as well remained significant (data not shown).

One third (32.3%) of the children were sensitized to at least 1 allergen at the age of 1 year, and 67 (16.9%) children were sensitized to cat. In univariate analyses, sensitization to cat was associated with several indicators of moisture problems, and the estimates were practically the same in the multivariate analyses (Table 4). The association between visible mold in the bathroom and sensitization to cat dander was independent of the presence of a cat and/or a dog indoors.

Eighteen (4.8%) children were sensitized to dog and 43 (10.9%) to cow milk. Only 5 (1.3%) children were sensitized to either of the 2 house dust mites. Prevalence of sensitizations to other allergens tested were $<4\%$ and therefore were not analyzed separately. There were no significant associations between sensitization to dog or to cow milk and moisture damage or visible mold in any of 4 areas of the home (data not shown). We found no effect modification for gender, maternal and paternal history of allergic diseases, cat ownership, dog ownership, and cat and/or dog ownership.

DISCUSSION

The main result of this birth-cohort study was that objectively documented moisture damage in the kitchen and the main living area of the house, where the child spends most of his or her time, was associated with both doctor-diagnosed wheezing and parent-reported wheezing apart from cold during the first 18 months of life. In addition, moisture and mold problems may be associated with atopic sensitization to cat dander, apparently independent from cat ownership.

On the basis of this study, the location of the moisture damage in the home is important. Significant associations with wheezing symptoms were seen mainly with moisture damage and mold in the kitchen and in the main living area, where the children are expected to spend most of their time. In

TABLE 1 Occurrence of Lower Respiratory Diseases or Symptoms According to Moisture and Mold Problems in Different Locations of the Home ($N = 396$)

Parameter		Doctor-Diagnosed Wheezing ($n = 45$)[a]		Parent-Reported Wheezing Apart From Cold ($n = 52$)[b]		Nocturnal Cough Apart From Cold ($n = 57$)[b]	
	N	*n* (%)	*P*	*n* (%)	*P*	*n* (%)	*P*
Moisture damage (whole house[c])			.31		.03		.75
No need for repair	33	1 (3.0)		1 (3.0)		3 (9.1)	
Cosmetic repair	80	8 (10.0)		6 (7.5)		11 (13.8)	
Repair of surface materials	150	17 (11.3)		20 (13.3)		22 (14.7)	
Major need for repair	133	19 (14.3)		25 (18.8)		21 (15.8)	
Mold odor indoors (whole house[c])			>.999		.10		.35
None	373	43 (11.5)		46 (12.3)		52 (13.9)	
Slight or obvious	23	2 (8.7)		6 (26.1)		5 (21.7)	
Mold indoors (whole house[c])			.74		.07		.71
None	246	26 (10.6)		27 (11.0)		34 (13.8)	
Only spots	62	7 (11.3)		7 (11.3)		8 (12.9)	
Visible mold	88	12 (13.6)		18 (20.5)		15 (17.0)	
Moisture damage in the kitchen			.01		<.001		.21
None	273	24 (8.8)		26 (9.5)		37 (13.6)	
Minor	101	15 (14.9)		18 (17.8)		14 (13.9)	
Major	22	6 (27.3)		8 (36.4)		6 (27.3)	
Mold in the kitchen			.94		.03		.89
None	336	38 (11.3)		39 (11.6)		48 (14.3)	
Any visible mold	60	7 (11.7)		13 (21.7)		9 (15.0)	
Moisture damage in the main living area			.22		.45		.04
None	268	28 (10.4)		34 (12.7)		34 (12.7)	
Minor	73	7 (9.6)		8 (11.0)		9 (12.3)	
Major	55	10 (18.2)		10 (18.2)		14 (25.5)	
Mold in the main living area			.03		>.999		.22
None	358	36 (10.1)		47 (13.1)		49 (13.7)	
Any visible mold	38	9 (23.7)		5 (13.2)		8 (21.1)	
Moisture damage in the child's bedroom			.57		.47		.32
No	337	37 (11.0)		46 (13.6)		51 (15.1)	
Yes	59	8 (13.6)		6 (10.2)		6 (10.2)	
Mold in the child's bedroom			.03		.45		.71
None	380	40 (10.5)		49 (12.9)		54 (14.2)	
Any visible mold	16	5 (31.3)		3 (18.8)		3 (18.8)	
Moisture damage in the bathroom			.99		.27		.71
None	148	17 (11.5)		16 (10.8)		22 (14.9)	
Minor	122	14 (11.5)		21 (17.2)		15 (12.3)	
Major	126	14 (11.1)		15 (11.9)		20 (15.9)	
Mold in the bathroom			.72		.85		.85
None	316	35 (11.1)		41 (13.0)		46 (14.6)	
Any visible mold	80	10 (12.5)		11 (13.8)		11 (13.8)	
Moisture damage in other interior spaces			.53		.17		.22
None	300	34 (11.3)		34 (11.3)		48 (16.0)	
Minor	22	4 (18.2)		4 (18.2)		3 (13.6)	
Major	74	7 (9.5)		14 (18.9)		6 (8.1)	
Mold in other interior spaces			.78		.20		.99
None	361	42 (11.6)		45 (12.5)		52 (14.4)	
Any visible mold	35	3 (8.6)		7 (20.0)		5 (14.3)	

P value for χ^2 test or Fisher's exact test.

[a] Doctor-diagnosed obstructive or asthmatic bronchitis and/or asthma in the age of 12 months and/or 18 months' follow-up.

[b] Parent-reported symptom in the age of 12 months and/or 18 months' follow-up.

[c] Damage/mold odor in the whole house means that damage/mold odor was detected in any of 4 areas.

contrast, only a few associations were observed with moisture problems in other parts of the house. These findings were also observed in our previous case-control study,[20] in which only moisture damage in the main living area was associated with early asthma. In that study, the home evaluations were performed by the same engineers by using the same protocol as in this study. The exposure in the kitchen may be especially important for children during the first year of life, because, at that age, children are usually taken care of at home (84% of the children in our

TABLE 2 Associations Between Lower Respiratory Diseases or Symptoms and Moisture and Mold Problems, Presented in Relation to the Location of the Damage or Mold Growth: Univariate and Multivariate Analyses

Parameter	Doctor-Diagnosed Wheezing[a]		Parent-Reported Wheezing Apart From Cold[b]		Nocturnal Cough Apart From Cold[b]	
	Unadjusted OR (95% CI)	aOR (95% CI)	Unadjusted OR (95% CI)	aOR (95% CI)	Unadjusted OR (95% CI)	aOR (95% CI)
Moisture damage (whole house[c])						
None or cosmetic repair	1.00	1.00	1.00	1.00	1.00	1.00
Repair of surface materials	1.48 (0.63–3.45)	1.68 (0.67–4.22)	2.33 (0.95–5.72)	1.90 (0.73–4.94)	1.22 (0.59–2.50)	1.14 (0.53–2.49)
Major need for repair	1.93 (0.83–4.45)	2.51 (0.98–6.44)	3.51 (1.45–8.45)	3.00 (1.15–7.84)	1.33 (0.64–2.75)	1.17 (0.52–2.64)
Mold odor indoors (whole house[c])						
None	1.00	1.00	1.00	1.00	1.00	1.00
Slight or obvious	0.73 (0.17–3.23)	0.66 (0.14–3.17)	2.51 (0.94–6.69)	2.78 (0.95–8.19)	1.72 (0.61–4.82)	1.33 (0.43–4.10)
Mold indoors (whole house[c])						
None	1.00	1.00	1.00	1.00	1.00	1.00
Only spots	1.08 (0.44–2.61)	0.99 (0.38–2.58)	1.03 (0.43–2.50)	0.81 (0.31–2.12)	0.92 (0.40–2.11)	0.74 (0.30–1.85)
Visible mold	1.34 (0.64–2.78)	1.39 (0.57–3.39)	2.09 (1.08–4.01)	1.98 (0.90–4.35)	1.28 (0.66–2.49)	1.13 (0.51–2.53)
Moisture damage in the kitchen						
None	1.00	1.00	1.00	1.00	1.00	1.00
Minor	1.81 (0.91–3.61)	2.13 (0.99–4.61)	2.06 (1.08–3.95)	2.04 (0.99–4.20)	1.03 (0.53–1.99)	0.91 (0.44–1.88)
Major	3.89 (1.39–10.87)	3.85 (1.16–12.76)	5.43 (2.08–14.15)	6.15 (2.01–18.82)	2.39 (0.88–6.50)	2.36 (0.72–7.79)
Mold in the kitchen						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.04 (0.44–2.44)	1.06 (0.41–2.71)	2.11 (1.05–4.24)	1.96 (0.89–4.31)	1.06 (0.49–2.29)	0.94 (0.40–2.21)
Moisture damage in the main living area						
None	1.00	1.00	1.00	1.00	1.00	1.00
Minor	0.91 (0.38–2.17)	0.80 (0.30–2.13)	0.85 (0.37–1.92)	0.69 (0.28–1.66)	0.97 (0.44–2.12)	0.97 (0.42–2.26)
Major	1.91 (0.87–4.19)	1.97 (0.79–4.93)	1.53 (0.71–3.32)	1.17 (0.48–2.85)	2.35 (1.16–4.76)	2.14 (0.94–4.86)
Mold in the main living area						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	2.78 (1.22–6.32)	3.92 (1.54–10.00)	1.00 (0.37–2.70)	1.22 (0.43–3.45)	1.68 (0.73–3.88)	1.73 (0.69–4.30)
Moisture damage in the child's bedroom						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	1.27 (0.56–2.89)	1.29 (0.50–3.32)	0.72 (0.29–1.76)	0.68 (0.26–1.80)	0.64 (0.26–1.55)	0.54 (0.20–1.43)
Mold in the child's bedroom						
No	1.00	1.00	1.00	1.00	1.00	1.00
Yes	3.86 (1.28–11.69)	5.22 (1.48–18.35)	1.56 (0.43–5.67)	1.92 (0.48–7.60)	1.39 (0.38–5.05)	1.17 (0.30–4.65)

All adjusted odds ratios (aORs) are controlled for gender, number of siblings, maternal education, cat and/or dog ownership, maternal smoking during pregnancy, maternal allergic diseases, paternal allergic disease, study cohort and the place of residence ($N = 387$). CI indicates confidence interval.

[a] Doctor-diagnosed obstructive or asthmatic bronchitis and/or asthma in the age of 12 months and/or 18 months' follow-up.

[b] Parent-reported symptom in the 12 months and/or 18 months' follow-up.

[c] Damage/mold odor in the whole house means that damage/mold odor was detected in any of 4 areas.

study) and spend a lot of time in the kitchen with their parents.

Moisture damage and visible mold were common in bathrooms in our study, but no associations with respiratory symptoms and diseases were observed. This may be attributable to the limited time spent in the bathroom daily, to the fact that bathrooms are well ventilated and have usually negative air pressure, or possibly to the potentially different characteristics of moisture and mold problems in the bathrooms. We also observed weaker associations when using variables that characterize the whole house instead of specific areas of the house. Taken together, these results underline the importance of separately assessing the health effects of moisture and mold problems in different locations of the home.

In this study, even more than half of the homes had moisture damage somewhere in their house. This figure is high, even higher than has been observed previously in Finland by objective assessments.[19] Our method to detect moisture damage is very sensitive, and the estimate for the whole house also includes attics and basements, provided that they were directly connected to the home living area. Also, this study excluded apartments and had a high proportion of farmers, who live in older and bigger houses than people on average.

Consistent with previous reviews,[1–4] we found that wheezing was associated with moisture damage in the home. The report of the IOM[4] concluded that there is sufficient evidence on the association between moisture or mold problems and exacerbations of lower respiratory tract symptoms,

TABLE 3 Associations Between Respiratory Infections and Moisture and Mold Problems, Presented in Relation to the Location of the Moisture Damage and Visible Mold: Multivariate Analyses

Parameter	Otitis ($n = 219$)[a]		Laryngitis ($n = 41$)[a]	Common Cold With Fever ($n = 129$)[b]		Common Cold Without Fever ($n = 100$)[c]		Fever (≥38.5°C) With No Respiratory Symptoms ($n = 97$)[d]	
	N	aOR (95% CI)	aOR (95% CI)	*N*	aOR (95% CI)	*N*	aOR (95% CI)	*N*	aOR (95% CI)
Moisture damage (whole house[e])									
None or cosmetic repair	111	1.00	1.00	103	1.00	103	1.00	104	1.00
Repair of surface materials	147	1.14 (0.66–1.95)	0.98 (0.44–2.21)	137	1.34 (0.76–2.35)	137	0.58 (0.32–1.06)	137	0.89 (0.48–1.63)
Major need for repair	129	0.85 (0.48–1.49)	0.73 (0.30–1.80)	116	1.30 (0.71–2.38)	112	0.57 (0.30–1.11)	115	1.06 (0.55–2.02)
Mold odor indoors (whole house[e])									
None	365	1.00	1.00	337	1.00	333	1.00	338	1.00
Slight or obvious	22	1.10 (0.44–2.77)	0.81 (0.17–3.72)	19	2.04 (0.78–5.35)	19	1.12 (0.40–3.16)	18	0.99 (0.33–2.98)
Mold indoors (whole house[e])									
None	241	1.00	1.00	226	1.00	223	1.00	227	1.00
Only spots	61	0.72 (0.39–1.32)	0.43 (0.14–1.35)	56	0.85 (0.44–1.62)	56	0.59 (0.28–1.21)	56	0.79 (0.39–1.64)
Visible mold	85	0.57 (0.32–1.02)	1.00 (0.40–2.54)	74	0.96 (0.51–1.80)	73	0.72 (0.35–1.46)	73	1.30 (0.66–2.58)
Moisture damage in the kitchen									
None	268	1.00	1.00	247	1.00	243	1.00	247	1.00
Minor	98	0.85 (0.51–1.41)	0.71 (0.31–1.65)	90	0.58 (0.33–1.02)	90	0.79 (0.43–1.43)	90	0.58 (0.31–1.09)
Major	21	1.04 (0.40–2.71)	0.37 (0.05–2.97)	19	0.77 (0.27–2.20)	19	0.49 (0.13–1.80)	19	0.48 (0.13–1.78)
Mold in the kitchen									
No	329	1.00	1.00	304	1.00	300	1.00	304	1.00
Yes	58	0.82 (0.44–1.51)	0.54 (0.17–1.68)	52	0.51 (0.25–1.06)	52	0.45 (0.20–0.99)	52	0.79 (0.37–1.69)
Moisture damage in the main living area									
None	263	1.00	1.00	242	1.00	238	1.00	242	1.00
Minor	70	0.98 (0.56–1.74)	0.61 (0.22–1.71)	62	0.87 (0.46–1.63)	62	0.77 (0.38–1.53)	62	0.48 (0.23–1.04)
Major	54	1.40 (0.73–2.67)	0.56 (0.18–1.76)	52	1.56 (0.80–3.02)	52	1.06 (0.51–2.19)	52	1.41 (0.70–2.85)
Mold in the main living area									
No	351	1.00	1.00	321	1.00	317	1.00	321	1.00
Yes	36	1.01 (0.48–2.13)	1.44 (0.49–4.25)	35	0.99 (0.46–2.14)	35	1.23 (0.54–2.78)	35	0.93 (0.40–2.16)
Moisture damage in the child's bedroom									
No	331	1.00	1.00	302	1.00	298	1.00	302	1.00
Yes	56	0.63 (0.34–1.16)	0.65 (0.21–2.03)	54	0.78 (0.40–1.51)	54	0.86 (0.42–1.78)	54	1.08 (0.54–2.16)
Mold in the child's bedroom									
No	372	1.00	1.00	341	1.00	337	1.00	341	1.00
Yes	15	2.20 (0.65–7.46)	1.18 (0.24–5.91)	15	1.18 (0.39–3.54)	15	1.77 (0.57–5.57)	15	1.86 (0.59–5.89)

All adjusted odds ratios (aORs) are controlled for gender, number of siblings, maternal education, cat and/or dog ownership, maternal smoking during pregnancy, maternal allergic diseases, paternal allergic disease, study cohort, and the place of residence. *N* = the total number of children in each category in multivariate analyses.

[a] Parent-reported infection in the 12 months and/or 18 months' follow-up ($N = 387$).

[b] Parent-reported common cold at the age of 12 to 18 months: >1 vs ≤1 episode ($N = 356$).

[c] Parent-reported common cold without fever at the age of 12 to 18 months: >2 vs ≤2 episodes ($N = 352$).

[d] Parent-reported fever (≥38.5°C) with no respiratory symptoms at the age of 12 to 18 months: ≥1 vs 0 ($N = 356$).

[e] Damage/mold odor in the whole house means that damage/mold odor was detected in any of 4 areas.

but for development of new lower respiratory tract illnesses, such as asthma, evidence was limited or suggestive. Since these reviews,[1–4] 2 studies have shown an association between early-life exposure to moisture and/or mold problems in the home and wheezing[21] or asthma onset,[20] as based on objective documentation of moisture and mold findings as in this study.

Some studies have suggested that mold problems may increase the risk for sensitization to inhaled allergens,[5,6] but there are also conflicting findings.[21] Certain fungal metabolites (eg, mycotoxins) seem to modify the immune system.[22,23] We found some evidence for an association between moisture and mold problems and sensitization to cat dander at the age of 1 year; however, the only significant association in adjusted analyses was with mold problems in the bathroom, where less time is spent daily and where the characterization of microbial growth and their emissions may be different from in main living areas. Additional research is needed to clarify the underlying mechanisms of this potential association.

The follow-up of this study was only up to age of 18 months, which is too short to reveal which children finally developed persistent asthma. In the first 3 years of life, approximately one third of all children wheeze during respiratory infection.[24] Of these, 40% have persistent wheezing up to age of 6 years, and approximately half of these wheezers become sensitized to inhaled allergens.[25] These sensitized wheezers of-

TABLE 4 Associations Between Sensitization to Cat Dander and Moisture and Mold Problems, Presented in Relation to the Location of the Damage or Mold Growth: Univariate ($N = 374$) and Multivariate Analyses ($N = 365$)

Parameter		Sensitization to Cat Dander		
	n	(%)	Unadjusted OR (95% CI)	aOR (95% CI)
Moisture damage in the kitchen				
None	254	(15.4)	1.00	1.00
Minor	99	(21.2)	1.48 (0.82–2.68)	1.33 (0.70–2.55)
Major	21	(33.3)	2.76 (1.05–7.27)	2.18 (0.72–6.64)
Mold in the kitchen				
None	316	(16.8)	1.00	1.00
Spots	58	(24.1)	1.58 (0.81–3.09)	1.64 (0.78–3.45)
Moisture damage in the main living area				
None	249	(16.1)	1.00	1.00
Minor	72	(22.2)	1.49 (0.78–2.86)	1.35 (0.67–2.72)
Major	53	(20.8)	1.37 (0.65–2.88)	0.99 (0.43–2.30)
Mold in the main living area				
No	336	(17.3)	1.00	1.00
Yes	38	(23.7)	1.49 (0.67–3.31)	1.44 (0.61–3.38)
Moisture damage in the child's bedroom				
No	316	(16.1)	1.00	1.00
Yes	58	(27.6)	1.98 (1.03–3.79)	1.81 (0.89–3.66)
Mold in the child's bedroom				
No	358	(17.3)	1.00	1.00
Yes	16	(31.3)	2.17 (0.73–6.47)	2.42 (0.74–7.91)
Moisture damage in the bathroom				
None	135	(14.1)	1.00	1.00
Minor	119	(16.0)	1.16 (0.58–2.31)	1.24 (0.59–2.57)
Major	120	(24.2)	1.95 (1.03–3.69)	1.98 (0.96–4.06)
Mold in the bathroom				
No	297	(15.5)	1.00	1.00
Yes	77	(27.3)	2.05 (1.13–3.70)	2.01 (1.04–3.89)

Sensitization to cat dander at the age of 1 year: specific immunoglobulin E ≥ 0.35 kU/L. All adjusted odds ratios (aORs) are controlled for gender, number of siblings, maternal education, cat and/or dog ownership, maternal smoking during pregnancy, maternal allergic diseases, paternal allergic disease, study cohort, and the place of residence.

ten developed chronic asthma.[25–27] In contrast, 90% of early wheezers without atopic sensitization stopped wheezing at school age and had normal lung function in adolescence[28]; however, long-term follow-ups have documented that early wheezers may develop asthma even after many nonsymptomatic years.[25] Thus, cough and wheezing in infancy may be the first signs of later asthma, especially when there are environmental factors that increase the asthma risk.

In this study, there were only occasional associations between moisture and/or mold problems and respiratory infections. This differs from the previous reviews,[1,3,4] which found sufficient evidence for this associations, and this association has since been replicated among children in 2 cross-sectional studies[29,30] and in a birth-cohort study.[15] Also unlike most previous reviews,[1–4] we did not find consistent association between moisture damage or mold growth and cough. The observed inverse association with otitis and common cold with and without fever and visible mold in the whole house or kitchen evidently was attributable to chance, because the other respective odds ratios in different areas of the home were near 1.

The major strength of this study is the objective home inspections by trained building engineers. In 2 previous reviews, in 6 of the 33[3] and in 8 of the 61[1] studies included were moisture and mold problems identified objectively. Although we have a prospective birth-cohort design, not all children lived in the same home all of their lives, and in one fifth of the homes, the home inspections were made after the age of 6 months. When these cases were excluded from the analysis, the conclusions did not change. The parents were informed about the results of the home inspections, which may have affected the reporting of respiratory symptoms by parents but have less or no effect on doctor-diagnosed wheezing and allergic sensitization. An additional limitation of this study is the absence of exposure assessment for specific bacteria or fungi.

CONCLUSIONS

The results of this birth-cohort study confirm previous findings[1–4] that moisture damage and visible mold in the home, especially in the kitchen and the main living area, increase the risk for wheezing in early childhood. There was also a suggestion for an association between mold problems and sensitization to cat dander. Our results are in line with previous observations that moisture and mold problems are associated with persistent asthma later in life, but this association and the mechanism need to be confirmed in future. The results underline the importance of separately assessing the health effects of moisture and mold problems in different locations of the home.

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Confirmed Moisture Damage at Home, Respiratory Symptoms and Atopy in Early Life: A Birth-Cohort Study

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