

Short communication

Increased prevalence of atopy among children exposed to mold in a school building

Background: The purpose of this study was to assess the occurrence of immunoglobulin E sensitization to common environmental allergens (atopy) and new allergic diseases among schoolchildren after starting school in a water-damaged school building. The staff and pupils of a Finnish elementary school with visible water damage and mold complained of respiratory and skin symptoms. The school building was examined and widespread moisture damage was found. A control school with no visible water damage was also examined. No indication of exceptional microbial growth was found in the samples taken from this school.

Methods: History of allergic diseases and the year of diagnosis were established by a questionnaire. IgE antibodies to the common environmental allergens were determined from randomly selected groups from both schools.

Results: Elevated IgE values were significantly more common among the exposed children, as was the occurrence of new allergic diseases after the children started at the school.

Conclusions: The odds ratios for the IgE values of the study groups indicated a possible relationship between exposure to microorganisms and IgE sensitization. Exposure to spores, toxins, and other metabolites of molds may have complex results with unknown immunogenic effects that may act as a nonspecific trigger for allergic sensitization leading to the development of atopy.

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Respiratory symptoms including wheezing (1–4), asthma (4, 5), and other respiratory diseases (6, 7) have been found to be associated with exposure to molds in water-damaged buildings. Atopy seems to be increasing in industrialized countries, possibly because of decreased infectious morbidity in childhood (8–10), but current discussion also indicates that the cause is multifactorial and still obscure. Little is known about the effects of water damage in schools on respiratory morbidity and allergy among schoolchildren, although it seems that the quality of school environments may cause asthmatic symptoms or airway inflammation (11, 12).

Our earlier study showed that exposure to molds in a school building was associated with an increased occurrence of respiratory symptoms and infections among the exposed children (13). The aim of this

study was to examine cross-sectionally the possibility of an association between immunoglobulin E (IgE) sensitization (atopy) or reported new allergic diseases and exposure to molds among children after they started school in a water-damaged school building.

Material and methods

Exposure

The staff and pupils of a Finnish elementary school (school E) with visible water damage and mold complained of respiratory and skin symptoms in 1994–5 (13).

In the spring of 1995, the building of school E was examined by the Tampere Regional Institute of Occupational Health. The examination revealed prolonged, marked, and widespread moisture damage on all three floors of the school, the most serious damage

being found on the ground floor, where visible mold and water on the floor were observed. Representative microbiologic samples of the air (Andersen 6-stage impactor) and building surfaces and materials were collected. Several species of microorganisms indicating moisture damage (*Penicillium*, *Aureobaculum*, *Cladosporium*, *Geotrichum*, and *Aspergillus*) were identified from the samples taken from all three floors. The most extensive growth was found in samples taken from the ground floor, especially from one classroom (class X), where also the growth of mycotoxin-producing molds (e.g., *Stachybotrys atra*) was found. Because it is not possible to assess the health risk in water-damaged buildings only on the basis of microbiologic grading, the results of both investigations (technical and microbiologic) were used to assess the extent and severity of the moisture damage and to draw reliable conclusions also for renovation purposes.

The same type of investigation was carried out in a control school (school C) situated about 5 km from school E. School C is a single-story building. No observation of moisture damage or any indication of exceptional microbial growth was found in the samples taken from this school.

The duration of the children's exposure in school E varied according to the number of school years. The children who started school in 1994 had had 1 year of exposure when the first questionnaire was answered, whereas the children in the sixth grade in 1994–5 had been exposed for 6 years. The average exposure of all the children in school E was 3 years. Children in class X were in the second grade in the 1994–5 school year, and their exposure by the end of the school year was 2 years. They had been in the same classroom on the ground floor both years.

School E was renovated in the summer of 1995, and a new investigation in the autumn of 1995 indicated that the renovation had been successful and exposure to microorganisms had ceased.

Subjects and methods

A questionnaire was sent in September 1995 to the parents of the schoolchildren (age range 7–12 years, in grades 1–6) ($n=397$) attending school E and also to the parents of the schoolchildren of the same age and same grades ($n=192$) who attended school C. Altogether, 92% (365) of the parents of the exposed children from school E and 92% (175) of the parents of the unexposed children from school C answered the questionnaire. The study populations are described in Table 1 (class X is described later in this section).

In May 1996, a second questionnaire was sent to the parents who answered the first questionnaire. Altogether, 303 in school E and 175 in school C responded. A history of allergic diseases (conjunctivitis, rhinitis, and asthma) among the children and their first-degree relatives and the year of diagnosis were inquired about. The question of reported allergic disease was as follows: "Has your child had allergic rhinitis, and, if so, when (what year) was it diagnosed?" The same type of question was asked for allergic conjunctivitis and asthma. A corresponding question for allergy in the family was asked so that only full siblings and biologic mothers and fathers were included in the comparison. The comparison of allergic diseases before and after the children started school, including the 1995–6 school year and the allergic diseases of relatives, was based on the answers given in the second questionnaire. The number of new allergies was determined from the data on children whose parents reported that an allergic disease had been diagnosed in any year later than the year their child had started school.

All the parents were asked for permission to take a blood sample from their child for testing. The children were selected randomly (fixed random sample) from those for whom permission was given so that each floor in school E, was equally represented. For school E, 12% of the parents refused, the percentage being under 10% for school C. Blood samples were drawn from 69 children (19%) in the exposed group and 50 children (29%) in the unexposed group.

After the responses to the first questionnaire and the patients' records were examined, respiratory symptoms and diseases were found to be markedly commoner among children in class X (11). Therefore, blood samples were also drawn for testing from 12 of the 14 children whose parents responded to the first questionnaire and who were not a part of the random sample (six children from class X) of the entire school. The parents of two children refused to let their children participate in the blood tests.

IgE antibodies to a mixture of 10 common environmental allergens (birch, timothy, mugwort, horse, cat, dog, *Dermatophagoides pteronyssinus*, *Cladosporium herbarum*, olive tree, and *Parietaria judaica*) were determined with a multi-RAST screening test (Phadiatop®, Pharmacia & Upjohn Diagnostics, Uppsala, Sweden) (14). The children with elevated IgE values (≥ 0.4) in the Phadiatop test were then tested specifically for eight of the 10 allergens used in the test and for three additional mold allergens (*Penicillium notatum*, *Aspergillus fumigatus*, and *Cephalosporium acremonium*) (RAST, Pharmacia & Upjohn Diagnostics, Uppsala, Sweden). Olive tree and *P. judaica*, used in the Phadiatop test, were excluded from this analysis because they do not exist in Finland.

Statistics

The statistical analysis was based on odds ratios (OR) and means supported by 95% confidence intervals (95% CI). The calculation was done with CIA software, as described by Gardner & Altman (15).

A logistic regression analysis was used to determine the significant risk factors for elevated IgE values. The independent variables were sex, pets at home, daily exposure to tobacco smoke, number of adults at home, number of children at home, apartment building (type of housing), recorded visits to a doctor, school, and reported allergy. The calculations were done with SPSS/Win (Version 9.0) software.

Results

IgE values

Elevated IgE values were found in the Phadiatop test for 40 (58%) of the exposed children and 17 (34%) of the unexposed children. There was a significant difference when the distribution of the elevated values in school E was compared with that of school C (Table 2).

The distribution of specific IgE allergens was later tested; 39% of the children in school E had antibodies to animal allergens (cat, horse, or dog), 68% to pollens, and 13% to house-dust mite. The corresponding percentages for the children in school C were 69%, 87%, and 19%, respectively.

In our study, there was only one positive IgE finding for molds in school E (*A. fumigatus*), and two children had positive IgE antibodies to molds in school C; one child to three molds (*C. herbarum*, *A. fumigatus*, and *C. acremonium*) and the other to two molds (*C. herbarum* and *A. fumigatus*). IgE tests were not available for all the molds found in the building (e.g., *Stachybotrys atra*).

Reported allergy

According to the questionnaire, 37% of the exposed and 39% of the unexposed children had a family history of allergy (parents or full siblings). Altogether,

Table 1. Characteristics of exposed and unexposed groups according to first questionnaire. Table includes only children whose parents answered both questionnaires

	Questionnaire			Randomized IgE group		
	School E	School C	Class X	Random school E	Random school C	Class X blood test
Number	303	175	18	69	50	18
Boys/girls	146/157	86/89	11/7	39/30	24/26	11/7
Age range (Sept. 1994) (years)	7–12	7–12	8–9	7–11	7–12	8–9
Average age (Sept. 1994) (years)	8.24	8.76	7.82	8.26	8.7	7.77
Pets at home (%)	57	62	44	54	52	22
Moisture damage at home (%)	8.9	9.6	9.1	2.8	12	5.5
Daily exposure to tobacco (%)	3.9	3.4	5.6	1.4	4	5.5
Children in families (mean)	2.1	3.3	1.9	1.8	3.48	1.9
Residence in apartment building (%)	30	0	17	30	0	16

School E: children of exposed school; school C: children of control school; class X: children of most exposed class in school E.

17% of the children (21% of the boys and 13% of the girls) in school E and 14% (14% of the boys and 13% of the girls) in school C reported current or previous allergic rhinitis, allergic conjunctivitis, or asthma (Table 3). Reported allergic diseases before school age were evenly distributed in the study groups; 7.9% in school E and 7.6% in school C. When only new allergic diseases after the children started school were compared, the occurrence in school E was higher than in school C.

Of the 20 children in school E and eight children in school C who reported allergies and underwent the Phadiatop test, 85% in school E and 87% in school C had elevated IgE values (atopy).

In the logistic regression analysis, the risk of having an elevated IgE value was 17 times higher for the children who had reported an allergic disease and three times higher for those going to school E. These were the only significant findings in the analysis.

Results in class X

Fifteen of the 18 children (83%) had elevated IgE antibodies (Table 2). The odds ratios of the elevated Phadiatop levels were significantly higher for class X than for school C and for the rest of school E. These findings suggested a relationship between different levels of exposure to microorganisms and IgE antibodies.

Altogether, 34% of the children in class X had a family history of allergy; 33% were currently experiencing or had previously experienced allergic rhinitis, allergic conjunctivitis, or asthma; and 11.1% had had allergic diseases before school age (Table 3). New allergic diseases after the children started school were commoner in class X than in the rest of school E or in school C. The difference was significant when class X was compared with school C, and almost significant (CI >90%) when class X was compared with the rest of school E.

Discussion

To our knowledge, this study is the first to report an association between exposure to molds in a water-damaged school and an increase in IgE sensitization (atopy) among schoolchildren. Exposure to molds in school as a consequence of exceptionally extensive water damage was confirmed by an examination of the technical structure of the building and microbiologic measurements (13). The study groups were comparable with regard to age, passive smoking, previous allergic diseases, and ownership of pets. However, the randomized subgroups for specific IgE measurements differed slightly with regard to confounders. According to the logistic regression analysis adjusted for the known confounders, the only variables affecting the IgE levels were reported allergic diseases and attendance in school E.

There was no indication of selection with regard to allergy in any of the study groups. A relationship between the number of siblings and atopy has been observed earlier, possibly because of more numerous infections in larger families (10, 16). Although there were more siblings among the unexposed children than among the exposed children, a controlled analysis of the confounders in the present study indicated that the number of siblings had no

Table 2. Comparison of randomized study groups according to children's allergen-specific IgE levels, when rated as negative (<0.4) or elevated

	IgE level		OR 95% CI
	Negative	Elevated	
School C	33	17	Reference
School E	29	40	2.68 (1.26–5.70)
Class X	3	15	9.71 (2.46–38.20)
Class X	3	15	1.42 (1.06–1.90)*

* Class X vs. rest of school E (class X not included in school E).

Table 3. Reported allergic diseases in study groups

Study groups	Total number of children	Reported allergies before starting school		OR (95% CI)	New occurrences after starting school		OR (95% CI)
		%	n		%	n	
School C	175	7.6	14	Reference	5.5	10	Reference
School E	303	7.9	24	0.99 (0.50–1.97)	9.2	28	1.61 (0.80–3.57)
Class X	18	11.1	2	1.44 (0.30–6.90)	22.2	4	5.05 (1.37–18.5)
Class X	18	11.1	2	1.49 (0.32–6.92)*	22.2	4	3.32 (0.99–11.1)*

* Class X vs rest of school E (class X not included in school E).

significant effect on the results. IgE screening with Phadiatop has been widely used in atopy screening, and its reliability has proved to be good (14).

When the first questionnaire was sent, the water damage in school E was obvious, and the parents were aware of it. This situation could have caused bias and could have weakened the comparability of the responses to the questionnaire between school E and school C. However, the reported respiratory infections did not differ from those in the patient records at the local health center (13). There was also a high correlation between reported allergic diseases and elevated IgE values among the children belonging to the randomized groups.

In epidemiologic studies, the occurrence of IgE-mediated allergy to molds has varied because of the lack of standardization of allergen extracts and because of differences in the study populations (14, 17–21). An increase in IgE antibodies to molds has been found among asthmatic children (18). In our study, there was only one positive IgE finding for molds in school E (*A. fumigatus*), and two children had positive IgE antibodies to molds in school C; one child to three molds (*C. herbarum*, *A. fumigatus*, and *C. acremonium*) and the other to two molds (*C. herbarum* and *A. fumigatus*). IgE tests were not available for all the molds found in the building (e.g., *Stachybotrus atra*). Our results support earlier observations and experience indicating that the health effects of water-damaged buildings are not caused by IgE-mediated allergy to microorganisms but probably by other mechanisms (22).

The children exposed to molds in school E had had, according to patient records, more respiratory infections during the school year than the unexposed children (13). This finding is similar to the results of studies on the health effects of water damage in residences (6, 7). There was a tendency toward a greater occurrence of allergic diseases among the exposed children during their school years (Table 3); that is, during the same time that exposure to

microorganisms caused by moisture damage took place. The occurrence of reported allergic diseases before school was equal in both groups. Children in class X, with heavier exposure, had a higher level of IgE and tended to have more new reported allergic diseases than the children from other classes of school E.

These findings suggest a potential relationship between exposure to molds and both the level of IgE sensitization to common environmental allergens (atopy) and the occurrence of new reported allergic diseases in children of water-damaged school buildings.

Our results indicate that the individual susceptibility of exposed subjects may be influenced by several factors associated with mold exposure; for example, inhaled mycotoxins or volatile organic compounds, which may, in some complex way, affect the immune response (22, 23–27).

Long-term exposure to spores, toxins, and other metabolites of molds may have complex properties with unknown immunogenic effects that may act as a nonspecific trigger for allergic sensitization (development of atopy). The potential immunogenic role of mycotoxins and other volatile organic compounds of molds on IgE sensitization should be investigated. The follow-up of the study groups after the renovation of the school building and the cessation of the mold exposure may give more information on the development of atopy and allergic diseases.

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