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Indoor viable dust-bound microfungi in relation to residential characteristics, living habits, and symptoms in atopic and control children

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Floor dust was collected in the wintertime from the homes of 61 children sensitized to house dust mites, 57 children with sensitization to other aeroallergens, and 57 nonatopic control children. The dust was cultivated and microfungal growth was identified microscopically. Indoor humidity was measured, and condensation on windowpanes was registered during 1 winter week. Housing and sociodemographic and symptom data were obtained by a questionnaire. Penicillium, Alternaria, and Cladosporium were the three most common microfungi. The mean total number of colony-forming units per 30 mg of dust was significantly lower in the homes of the two atopic groups than in homes of the control group, which may be a result of allergen-sanitation measures. High colony-forming unit counts appeared to be related to damp housing. Weak associations were found between the occurrence of viable fungi in dust and allergic symptoms among the house dust mite-sensitized children. However, no consistent association between viable mold growth and sensitization to molds was observed. The health implications of indoor fungal exposure still remain unclear. (J ALLERGY CLIN IMMUNOL 1992;89:752-9.)

Key words: Microfungi, floor dust, indoor climate, building characteristics, living habits, atopy

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Allergic symptoms worsen in patients with atopic sensitization to fungi when outdoor spore exposure is high in summer and autumn.¹⁻⁶ The indoor occurrence of spores largely reflects that of the outdoor air,^{1, 7-10} but dampness and damp building materials may provide suitable conditions for indoor fungal growth.¹¹⁻¹⁴ The contribution of such growth to atopic sensitization and for the precipitation of allergic symptoms is mainly unknown.

Epidemiologic studies from many western countries, such as the United Kingdom and Scandinavia, indicate an increase of the prevalence of atopic diseases.¹⁵⁻¹⁸ Outdoor, as well as indoor, environmental influences are believed to be possible causes.^{19, 20} Inadequate ventilation, which in temperate regions can be a consequence of energy saving, may contribute to increased indoor humidity and HDM infestation.²¹ A damp indoor climate also possibly affects indoor fungal growth, and the degree of dust mite infestation has been reported to correlate with the occurrence of microfungi in dust.²²

In a previous study,²¹ we studied exposure to HDM in relation to residential characteristics and allergic sensitization. The aim of this study was to examine viable fungi in house dust in relation to residential features, living habits, and allergic and irritant symptoms in the same groups of atopic and control children.

MATERIAL AND METHODS

Subjects

Children, aged 3 to 17 years, attending the outpatient clinic of St. Göran's Children's Hospital, Stockholm, during January 1986 to September 1987, with a diagnosis of BA, AR, or atopic eczema were included. The children under study and the methods of dust collection are described in detail in a previous article.²¹ The children exhibited at least one positive reaction at a single SPT with a panel of common aeroallergens: *Dermatophagoides pteronyssinus*, *D. farinae*, *Cladosporium herbarum*, *Alternaria alternata*, birch, timothy, dog, and cat. Precoated SPT lancets (Pharmacia AB, Uppsala, Sweden) were used, and wheal reactions were related to reactions of histamine hydrochloride-containing lancets corresponding to 100,000 BU/ml of aqueous solution in principle, as suggested in the Nordic Guidelines.²³ A wheal at least half the size of the wheal of the histamine control was regarded as positive.

Sixty-four HDM-SPT-positive children constituted an HDM-sensitized group and 63 children sensitized to other airborne allergens constituted an atopic group. All children were selected consecutively from a total of 555 children with positive SPT results during the observation period. A third group, the control group, included 58 children without a history of atopic diseases, who lived in the neighborhood of children in the HDM-sensitized group.

All children lived within an area of approximately 450

Abbreviations used

SPT:	Skin prick test
AIH:	Absolute indoor humidity
HDM:	House dust mite
BA:	Bronchial asthma
AR:	Allergic rhinitis
cfu:	Colony-forming unit
OR:	Odds ratio
CI:	Confidence interval

km² in the northwestern part of Stockholm. The children's mean age was 10 years, and boys were more common in the HDM-sensitized and atopic groups (64%) than in the control group (48%).

Dust sampling and fungal identification

At the end of February and beginning of March 1988, livingroom floor dust was collected for detection of microfungi.²⁴ The average outdoor temperature had been below freezing temperature for 3 months before sampling, and the ground was covered with snow to 70% to 80% during this period (Dagsten A. Personal communication. Swedish Meteorological and Hydrological Institute). Three square meters of the livingroom floor was vacuumed by the parents for 1 minute with their own vacuum cleaner carrying a nozzle with a filter paper.²⁴ The weight of collected dust was not affected by age and type of vacuum cleaner.²¹ The floor dust containing filters were enclosed in plastic boxes and kept at room temperature for less than a fortnight until cultivated. Thirty milligrams of unsieved dust from each sample was incubated on V₈ agar (vegetable juice, Campbell Soup, Ltd.) plates for 1 week at 26°C. To eliminate bacterial growth, penicillin and streptomycin were added. Fungal growth was quantified as cfus per 30 mg of dust and identified microscopically.²⁵ Dust samples were not obtained from three, six, and one family of the HDM-sensitized, atopic, and control groups, respectively.

Questionnaire

Questionnaires were delivered to the families in April 1988. The questions focused on indoor environmental conditions, such as type and construction of the present residence, carpeted area, use of air-cleaning device, type of ventilation, and housing restoration. A total household vapor-producing activity index was estimated from the use of humidifiers, aquariums in the house, the amount of water used to maintain indoor plants, hours of laundry per week, and wet mopping. The index also included hours of shower and tub bathing and cooking daily. Special emphasis was placed on indications of dampness, such as presence of visible mold spots, damp patches, and condensed water on double-paned glass windows. Questionnaires were obtained from 175 (95%) of the included families, leaving for analyses 61, 57, and 57 children in the HDM-sensitized, atopic, and control groups, respectively.

Residential humidity and temperature measurements

Calibrated synthetic thermohygrometers (Feingarärbau K. Fischer GmbH, Drebach, Germany) were delivered to the families. Daily readings of relative indoor humidity and temperature were performed by the parents who also registered the occurrence of condensation on windowpanes in the living room and their child's bedroom. This observance was done in the second or third week of March 1988. The average outdoor temperature during this period was -3.5°C . The results of relative indoor humidity were transformed to AIH with a Mollier diagram. For technical reasons, the measurements failed in eight homes of the HDM-sensitized and in nine homes of the atopic and control groups, respectively.

Statistical analyses

Comparisons between the various exposure groups were expressed as ORs with 95% CI according to the method of Cornfield.²⁶ If the 95% CI does not include 1.0, the results are statistically significant at $p < 0.05$. In addition, tests for trend were performed according to the method proposed by Mantel.²⁷ The comparisons of mold counts between the groups were performed with Wilcoxon's two-sample test with two-tailed p values. Spearman's rank-correlation coefficient was used to determine the relationships between cfu and vapor-producing activity index and cfu and mite-allergen content in the control group.

RESULTS

Thirty-one fungal genera were identified (Table I). *Penicillium* was the most frequently occurring genus that also demonstrated the highest cfus, followed by *Alternaria* and *Cladosporium*. Twenty genera were found in $<25\%$ of the dust samples with a mean cfu count of 0.5/30 gm of dust or less. No dust sample contained >12 fungal genera, and all but one sample contained viable fungal spores. *Penicillium*, *Cladosporium*, different yeasts, *Alternaria*, and *Aspergillus* spp comprised 78% of the total cfu count. The different mold species were evenly distributed among the three groups of children with the exception of *Aspergillus* and *Rhodotorula*. Thirty-two of 61 dust samples of the HDM-sensitized group harbored *Aspergillus* spp compared to 19/57 in the atopic and 18/57 in the control group, corresponding to $\text{OR} = 2.2$ (CI, 1.0 to 5.0) and $\text{OR} = 2.4$ (CI, 1.1 to 5.4), respectively. The yeast, *Rhodotorula*, was found in higher proportion in the dust of homes of the HDM-sensitized group (35/61) compared with that of the atopic group (19/57), $\text{OR} = 2.7$ (CI, 1.2 to 6.1), but not with that of the control group, $\text{OR} = 1.1$ (CI, 0.5 to 2.3).

There was a skewed distribution of cfu counts with an overall median and mean mold count of 30 and 40.5 cfu, respectively. The total microfungus content of the dust of the control group was significantly

higher than that of the combined HDM-sensitized and atopic groups, $p = 0.02$ (Fig. 1). There were several indications of sanitation measures in the homes, particularly in the homes of the two atopic groups. An air-cleaning device was used in seven homes of the HDM-sensitized and in one home of the control group. The mean total cfu of dust from the homes with an air-cleaning device was 24.2 compared with 41.4 ($p = 0.04$) in homes without such equipment. Wall-to-wall carpets were found in 45% of the homes of the control group compared with 36% of the homes of the two atopic groups, but the total cfu count was only marginally affected by the presence of such carpets. Parental indoor smoking was reported in 35% of the homes of the control group compared with 28% of the homes of the HDM-sensitized and atopic groups combined. Cats and dogs were less prevalent in the two atopic groups than in the control group, 7% and 47%, respectively ($\text{OR} = 0.1$; CI, 0.0 to 0.2). However, the reported cleaning habits did not differ between the atopic groups and the control group.

The occurrence of microfungus growth in floor dust in relation to residential characteristics and living habits was analyzed separately in the control group to avoid influences of allergen sanitation (Table II). Shower bathing and reported windowpane condensation in the winter were more prevalent in the homes exhibiting dust samples with >35 cfu (median) than in homes with ≤ 35 cfu. Furthermore, AIH, HDM-allergen content in mattress dust, occurrence of humid patches, visible mold growth, or vapor-producing activity index did not correlate with the total cfu count.

In all 175 homes, condensation on windowpanes during the week of registration was found to be more prevalent (27/35) in homes with AIH >5.6 gm/kg (median) compared with homes with AIH ≤ 5.6 gm/kg (48/114), $\text{OR} = 4.6$ (CI, 1.8 to 12.8). These observations were also consistent for window condensation reported in the questionnaire 2 months later, $\text{OR} = 2.5$ (CI, 1.2 to 5.3). Observation of window vapor for detection of AIH >5.5 gm/kg exhibited a sensitivity of 71% (53/75) and a specificity of 51% (38/74), and at AIH ≥ 7 gm/kg, a sensitivity of 75% (15/20) with specificity of 43% (55/129). Furthermore, the homes of the HDM-sensitized group revealed higher average AIH compared with homes of the atopic group, trend based, $p = 0.05$, but not in comparison with that of the control group, $p = 0.84$ (data not presented).

Some construction characteristics of buildings were found to be associated with the occurrence of certain mold genera. Thus, growth of *Alternaria alternata* was more prevalent in dust samples from homes with, than in homes without, additional mineral-wool ther-

TABLE I. Viable fungal genera identified in dust samples of 175 homes of allergic and control children in Stockholm, Sweden

Fungal genera and subspecies	% Of dust samples with identified colonies	Mean cfu/30 mg dust	Upper range cfu/30 mg dust
<i>Penicillium</i> spp	89	13.5	100
<i>A. alternata</i>	70	3.4	75
<i>Cladosporium</i> spp	61	5.1	50
<i>Mycelia sterilia</i>	53	1.5	8
<i>Rhodotorula rubra</i>	49	3.5	100
Yeasts minus <i>Rhodotorula</i>	47	4.1	150
<i>Mucor spinosus</i> , <i>M. racemosus</i>	44	1.2	8
<i>Aspergillus</i> spp	39	1.5	25
<i>Trichosporon pullulans</i>	37	1.9	20
<i>Chaetomium globosum</i>	34	0.9	10
<i>Rhizopus nigricans</i>	25	0.6	5
<i>Trichoderma viride</i>	20	0.4	5
<i>Phoma</i> spp	19	0.3	6
<i>Aureobasidium pullulans</i>	16	0.3	5
<i>Fusarium</i> spp	9	0.2	4
<i>Scopulariopsis brevicaulis</i> + spp	8	0.5	30
<i>Verticillium</i> spp	8	0.2	5
<i>Ulocladium botrytis</i>	5	0.2	10
<i>Paecilomyces variotti</i> spp	5	0.1	12
<i>Acremoniella atra</i>	3	<0.1	5
<i>Oedocephalum</i> sp	3	<0.1	5
<i>Stachybotrys atra</i>	2	<0.1	5
<i>Botrytis cinerea</i>	2	<0.1	4
<i>Chrysosporium</i> sp	2	<0.1	6
<i>Acremonium atra</i>	2	<0.1	5
<i>Acrospeira mirabilis</i>	1	<0.1	3
<i>Epicoccum nigrum</i>	1	<0.1	2
<i>Arthrinium phacospermum</i>	1	<0.1	1
<i>Absidia</i> sp	1	<0.1	1
<i>Sordaria timicola</i>	1	<0.1	3
<i>Curvularia</i> sp	1	<0.1	2

mal insulation ($p = 0.002$). *Aspergillus niger* was more common in detached houses compared with that of apartments and in homes with, as compared with homes without, wall-to-wall carpets ($p = 0.01$ and $p = 0.02$, respectively). Furthermore, growth of *Cladosporium* spp was more often found in homes with a concrete-slab basement compared with that of other basements ($p = 0.007$).

Thirty percent of the HDM-sensitized-group children exhibited at least a 2+ reaction to *Cladosporium herbarum* and 16% for *Alternaria alternata* compared with 17% and 4% in the atopic group, respectively, $p = 0.09$ and $p = 0.01$ (data not presented). However, no significant relationships were found between the occurrence of viable fungi in the dust and SPT to these mold genera.

In the HDM-sensitized group of children, there was

a relationship between growth of *Alternaria* and/or *Cladosporium* spp in the dust samples and history of atopic eczema and AR, respectively (Table III). However, these findings were not confirmed in the atopic group. No significant relationships were found between total cfu or number of identified fungal genera and any of the atopic diseases, pneumonia, bronchitis, or otitis, among the children of the two atopic groups.

Damp housing has been reported to be related to asthma. Among all atopic children, 23 of 76 with BA had lived in homes with mold patches on walls compared with five of 37 children in homes without children with asthma (OR = 2.8; CI, 0.9 to 9.3). SPT positivity to any of the two molds, *Alternaria alternata* or *Cladosporium herbarum*, was found to be a strong risk factor for asthma (OR = 4.1; CI, 1.2 to 15.3). No relation was found between humidity

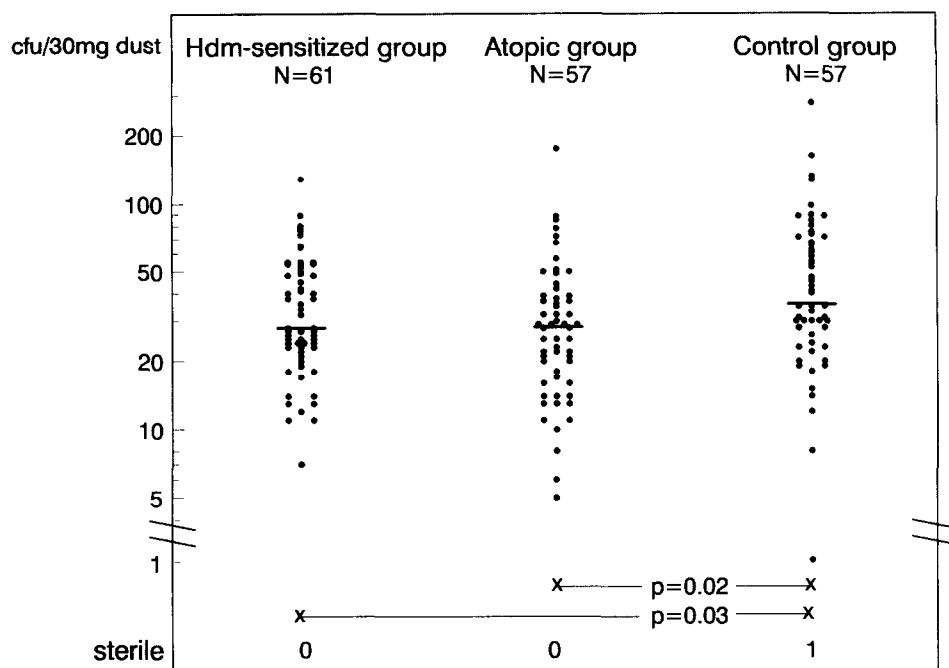


FIG. 1. Distribution of total fungal cfus in dust samples of the 175 homes of atopic and control children from Stockholm, Sweden. Horizontal lines, median cfu counts of 27.5, 28, and 35, in HDM-sensitized, atopic, and control group, respectively. Total cfu count of homes of control group was significantly higher than for the two atopic groups ($p = 0.023$).

TABLE II. Indoor dust-bound fungal counts in relation to residential characteristics and living habits of 57 children in a control group

	Total cfu counts/30 mg of dust			
	>35 (N = 28)	≤35 (N = 29)	OR	95%
Living habits				
Furred pets ≥1	15	12	1.6	0.5-5.3
Indoor smoking	12	8	2.0	0.6-6.9
Vacuuming <1/wk	7	6	1.3	0.3-5.4
Shower bathing >0.5 hr/day	17	9	3.4	1.0-12.0
Tub bathing >0.5 hr/day	2	7	0.2	0.0-1.5
Residential characteristics				
Wall-to-wall carpets	14	12	1.4	0.4-4.6
Mold patches	4	5	0.8	0.1-4.0
Humidity patches	13	9	1.9	0.6-6.5
AIH average, >5.6 gm/kg*	10	13	0.8	0.2-3.0
Window vapor I*	9	6	2.3	0.6-9.7
Window vapor II†	20	13	3.1	0.9-10.8
Mattress-mite allergen‡	10	5	2.6	0.7-11.6

*Results obtained during registration week; homes of nine children missing for technical reasons, six with total cfu >35 and three with total cfu ≤35, respectively.

†Questionnaire answers 2 months after registration week.

‡The sum of the major HDM allergen of the three *Dermatophagoides* sp (≥25 ng/gm of dust) assayed with ELISA technique.²¹

patches on walls, condensation on windowpanes, or AIH and asthmatic symptoms.

About 20% of the children, both in the HDM-sensitized and atopic groups, had suffered from false

group while they were living in their present residence, but only 7% in the control group, OR = 3.3 (CI, 1.0 to 13.7). In the HDM-sensitized group, which exhibited the higher average AIH than the atopic group, a

TABLE III. Association between occurrence of dust-bound fungi and atopic disease in the HDM-sensitized and atopic group of children

Health effect	Exposure variable	HDM-sensitized group (N = 59*)				Atopic group (N = 54*)			
		Pos outcome	Neg outcome	OR	CI	Pos outcome	Neg outcome	OR	CI
BA	Genera sum	30/48	5/11	2.0	0.4-9.1	11/28	11/26	0.9	0.3-3.0
	≥35 cfu								
	<i>Alternaria</i>	35/48	7/11	1.5	0.3-7.4	18/28	17/26	1.0	0.3-3.4
Atopic eczema	<i>Cladosporium</i>	26/48	9/11	0.3	0.0-1.5	19/28	13/26	2.1	0.6-7.4
	Genera sum	14/29	21/30	0.4	0.1-1.3	12/29	10/25	1.1	0.3-3.6
	≥35 cfu								
	<i>Alternaria</i>	25/29	17/30	4.8	1.2-21.1	20/29	15/25	1.5	0.4-5.3
	<i>Cladosporium</i>	15/29	10/30	2.1	0.7-7.1	17/29	15/25	0.9	0.3-3.2
AR	Genera sum	20/35	15/24	0.8	0.2-2.6	12/38	10/16	0.3	0.1-1.1
	≥35 cfu								
	<i>Alternaria</i>	24/35	18/24	0.7	0.2-2.7	16/38	10/16	1.1	0.3-4.5
	<i>Cladosporium</i>	25/35	10/24	3.5	1.0-12.2	22/38	10/16	0.8	0.2-3.1

Pos, Positive; neg, negative.

*Five children of two atopic groups were excluded in analysis because of habitation for less than 2 years in the present residence or to SPTs performed within 1 year after moving into the present home.

strong association was found between history of false croup and occurrence of condensation on windowpanes during the registration week (9/11 compared with 6/41; OR = 26.2; CI, 3.7 to 238) as well as wintertime window condensation reported in the questionnaire (trend-based *p* value, 0.03). An association was also found between history of false croup and high average AIH; trend-based *p* value, 0.07. Such relationships were, however, not found in the atopic group.

DISCUSSION

In the present study, the dust samples were collected in the winter during a period of subfreezing outdoor temperature with the ground extensively covered by snow, and thus, direct contribution from outdoor spores was minimized. These data are likely to be representative of indoor fungal growth and not of influx from outdoors, as during summer and in warmer climatic regions. This is a major prerequisite for the study and the attempt to correlate indoor fungal exposure to other indoor environmental factors and symptoms of atopic children. Furthermore, we chose a simple sampling technique, vacuuming of floor dust, which is less influenced by indoor activities and air turbulence and represents more of a long-term pattern than indoor air sampling.^{7, 28, 29} Since the study was conducted in a limited urban area, possible geographic and climatologic influences were reduced.³⁰ *Penicillium* spp were the most prevalent among the fungal genera, as described in studies from Denmark and Michigan.^{11, 12}

When the study was designed, we hypothesized that indoor fungal growth is amplified in the humid climate of the homes of children with atopic sensitization to HDMs. Instead, we found considerably less dust-bound fungi in the homes of the atopic children. Since advice about allergy sanitation is an important part of clinical practice, the most likely explanation is that fungal-spore contamination is reduced by intense house cleaning by the parents of children with atopic diseases. The failure to demonstrate this difference between the two atopic groups and the control group in reported cleaning habits can be explained by too low sensitivity of the questionnaire, which did not take into account more frequent cleaning than once weekly and the intensity of the cleaning. The finding that homes with air cleaners exhibited the lowest degree of fungal-spore content reinforces our interpretation. This finding is also supported by the studies of Kozak et al.³⁰ and Banerjee et al.¹⁰ who found low indoor mold contamination in homes with high degree of dust-control compliance. Furthermore, it should be noted that there were less frequent keeping of pets, use of wall-to-wall carpeting, and parental smoking in the two atopic groups that also indicate allergen-sanitation measures, even if these findings do not necessarily have implications for the general cleaning habits.

A relationship between damp housing and increased occurrence of dust-bound microfungi was discernible in the homes of the control group in which condensation on windowpanes and shower-bathing habits were found to be associated with the indoor spore

count. Such results have also been reported in other studies.^{13, 31} The homes of the HDM-sensitized group also exhibited more "humid-home" characteristics than homes of the atopic group, such as more frequent condensation on windowpanes, additional thermal insulation with mineral wool, and presence of HDM allergen in mattress dust.²¹ These findings may indicate that our original hypothesis is correct but concealed by allergen-sanitation measures undertaken as a consequence of the childrens' atopic diseases.

There were no consistent relationships between indoor growth of various fungi and the spectrum of atopic diseases among the children. Positive SPT to molds was, however, more common among the HDM-sensitized children than among the atopic children, a difference that reached statistical significance only for *Alternaria alternata*. Fungal sensitization is known to be associated with BA,^{6, 32, 33} and previously, we have reported that asthma was considerably more prevalent among the mite-sensitized children than among children with atopic sensitization to other airborne allergens.²¹ This difference could partially be ascribed to the high frequency of SPT positivity to molds and to mite-allergen exposure as well. Since the HDM-sensitized group also demonstrated other signs of tight homes, that is, mold patches, and exhibited higher mean AIH than the homes of the other groups, we hypothesized that dampness and insufficiently ventilated residences could contribute to a more asthmogenic indoor climate.

False croup is not only associated with viral infection, but also with allergy and airway hyperreactivity.³⁴ An association between false croup and outdoor air pollution has been reported, but the results of epidemiologic studies are conflicting.³⁵ In our study, we found an association between signs of indoor dampness and false croup in the HDM-sensitized group. Hypothetically, indoor climate conditions associated with dampness may not only promote inflammation in the airways, atopic sensitization, and disease, but also manifestations, such as false croup. The children of the HDM-sensitized group lived more often in homes with additional insulation than children in the atopic group; however, no relationship was found between "tight" housing and history of false croup.

We conclude that the lower mold counts of the homes of children with atopic disease may have been influenced by allergen-sanitation measures. In the control group, a relationship was found between high mold count and indications of damp housing. The strongest risk factor for asthma was found to be sensitization to molds. Among the HDM-sensitized children, damp housing was associated with a history of

false croup. The health implications of the occurrence of viable microfungi in floor dust remain unclear.

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Latex-specific proteins causing immediate-type cutaneous, nasal, bronchial, and systemic reactions

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*We examined 70 patients reporting hypersensitivity reactions caused by latex articles. All patients suffered from urticaria, 36 from rhinitis, 31 from conjunctivitis, 22 from dyspnea, and 17 from systemic reactions, and four patients developed severe systemic complications during surgery. By means of inhalative challenge tests with powdered latex gloves, it could be demonstrated that the glove powder (cornstarch) obviously functions as a carrier for latex allergens, which then become airborne. Five of 18 patients undergoing such challenge tests demonstrated a significant increase of specific airway resistance; 17, acute rhinitis and/or conjunctivitis; and two, a systemic reaction. Sixty-two percent of the patients demonstrated specific IgE antibodies to natural latex, 58% to an irradiatively cross-linked, so-called, "hypoallergenic" latex preparation, and 46% to commercial-latex RAST disks (Pharmacia). No specific antibodies to cornstarch or a mixture of rubber chemicals were found. A good correlation (82%) exists between latex IgE RAST and latex skin prick test, as revealed in a subgroup of 45 subjects. By means of sodium dodecyl sulfate-polyacrylamide gel electrophoresis, the latex allergen appears to be a mixture of proteins in a molecular weight range from 10 to 67 kd. (*J ALLERGY CLIN IMMUNOL* 1992;89:759-68.)*

Key words: Latex, rubber gloves, glove powder, latex asthma, immediate-type hypersensitivity, specific IgE antibodies, PAGE, immunoblot, inhalative provocation test

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