

Occupational exposure and sensitization to fungi among museum workers

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Background	Museum employees are exposed to fungi and storage mites in the workplace.
Aim	To evaluate the prevalence and risk factors of sensitization to moulds, as well as clinical symptoms associated with allergy in museum workers.
Methods	A total of 103 employees of the Polish National Museum (NM) in Warsaw, potentially exposed to fungi during their work, were assessed using a questionnaire and skin prick tests to common allergens and fungal extracts. The level of total and serum-specific IgE to moulds was evaluated, and spirometry was performed in all subjects. Mycological analysis of the workplace was also performed.
Result	<i>Penicillium</i> , <i>Aspergillus</i> , <i>Cladosporium</i> , <i>Alternaria</i> , <i>Trichoderma</i> , <i>Acremonium</i> and <i>Paecilomyces</i> were the most frequent species isolated from investigated exhibits of NM. Thirty per cent of museum employees were sensitized to at least one of the fungal allergens. Logistic regression analysis revealed that duration of occupational exposure lasting >5 years, family history of atopy, presence of a cat at home, sinusitis, allergic rhinitis and a history of frequent respiratory infections were risk factors for the development of sensitization to fungi in this working group.
Conclusions	This study suggests an important role of fungi as occupational allergens for museum workers. The prevalence of allergic symptoms among employees of NM was relatively high. Further studies are necessary to elucidate the importance of particular fungal species in the development of occupational allergy.
Key words	Moulds; museum workers; risk factors.

Introduction

Museum employees are exposed to various fungi, $\beta(1,3)$ -glucans, fungal volatile organic compounds and storage mites in the workplace. Fungi are spore-bearing organisms which may develop on museum objects and may cause serious damage to wood, paper, leather, textile and woollen objects [1,2]. Occupational mould allergy has not been widely reported in the literature. The allergic manifestations induced by fungi are more widely recognized and include asthma, rhinitis, allergic sinusitis, allergic bronchopulmonary mycoses and hypersensitivity pneumonitis [3]. In the European Union, the issue of the protection of workers from risks related to exposure

to biological agents at work is regulated by Directive 2000/54/EC [4].

Only a few cases of occupational allergy among museum workers have been reported. Sheldon and Johnston [5] were the first to publish on rhinitis and asthma due to insect exposure in museum personnel. In 1986, Kolmodin-Hedman *et al.* [6] described a case of organic dust toxic syndrome induced by *Aspergillus versicolor* and *Penicillium verrucosum* exposure.

The aim of the study was to evaluate the prevalence and risk factors for sensitization to fungi and to investigate allergic symptoms in Polish museum employees.

Methods

Subjects were employees at the National Museum (NW) in Warsaw employed as conservators, custodians, store-room workers or laboratory workers. Conservators mainly clean, consolidate and repair museum objects potentially working with exhibits contaminated by microorganisms. Custodians prepare exhibitions, principally

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being involved in manual handling of exhibits leading to temporary contact with contaminated objects. Laboratory workers have direct contact with the contaminated exhibits while they carry out microbiological analysis on exhibits. Storeroom workers perform assistant jobs and they have regular contact with potentially microbiologically contaminated objects.

The Regional Bioethical Committee approved the study protocol. All the participants gave their informed consent to participate in the study.

Subjects completed a questionnaire that was an adapted version of the International Union against Tuberculosis and Lung Disease questionnaire [7]. Questions asked included a history of respiratory and skin symptoms, personal and family history of atopy, tobacco smoking status, exposure to pet allergens at home, housing conditions and residence area and history of exposure to fungi.

Skin prick tests (SPTs) were performed on the forearm with a standard, commercially available battery of common allergens including tree and grass pollens, *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, *Acarus siro*, *Thyrophagus putrescentiae*, *Lepidoglyphus destructor* and *Euroglyphus manei*; feathers and fungal series *Alternaria tenuis*, *Aspergillus fumigatus*, *Botrytis cinerea*, *Candida albicans*, *Trichophyton mentagrophytes*, *C. herbarum*, *Fusarium moniliforme*, *Helminthosporium halodes*, *Mucor mucedo*, *Penicillium notatum*, *Pullularia pullulans*, *Rhizopus nigricans*, *Serpula lacrymans*, *Curvularia lunata*, *Phoma betae*, *Neurospora sitophila*, *Alternaria* sp., *Aspergillus* mix, *Cladosporium* sp., *Penicillium* mix, *Levures melanges* and *Charbons cerealiers* (Allergopharma, Reinbek, Germany). The negative control was a diluted allergen and the positive control was a 1 mg/ml histamine dihydrochloride solution (Allergopharma). The largest wheal diameter was assessed after 15 min. A wheal diameter of ≥ 3 mm and equal to or greater than half of that formed by histamine was defined as positive, indicating sensitization. Subjects were told to avoid antihistamines or antidepressants for at least 72 h prior to testing.

Blood was taken and total serum IgE was evaluated. Total IgE level >100 kU/l was considered as elevated. Specific IgE antibodies to fungi [*P. notatum*, *C. herbarum*, *A. fumigatus*, *C. albicans*, *Alternaria alternata*, *H. halodes* (mx2), *R. nigricans* (m11), *Trichoderma viride* (m15), *Mucor racemosus* (m4), *B. cinerea* (m7) and *Chaetomium globosum* (Rm208)] were measured. IgE levels >0.35 kU/l were regarded as positive.

Spirometry was performed in all subjects.

Mycological analysis was performed by the Microbiological Laboratory of the NM in Warsaw. It included a qualitative assessment of fungi present on the museum exhibits. Fungal samples were collected from contaminated exhibits using aseptic filter tissue papers strips. The isolated fungi were classified by species on the basis of species identification keys. Quantitative assessment of moulds was not performed.

Sensitization to fungi was defined as at least one positive result of SPT to fungal allergens or positivity of specific fungal serum IgE assay.

To identify the risk factors of sensitization to fungi, odds ratios and their 95% confidence intervals were calculated to a number of possible associated features. The factors found to be significant in the univariate analysis were included into the logistic regression model (Statistica'99). A significance value for the *P* value was set at 0.05.

Results

Species isolated from investigated exhibits included *Penicillium* sp. (*P. verrucosum*, *P. expansum*, *P. notatum*), *Aspergillus* sp. (*A. fumigatus*, *A. niger*, *A. flavus*, *A. nidulans*), *Cladosporium* sp., *Alternaria* sp. (*A. alternata*, *A. chartarum*, *A. tenuissima*, *A. consortiale*), *T. viride*, *Paecilomyces variotii*, *Eurotium* sp., *Chaetomium candidum*, *Saccharomyces* sp., *Acremonium* sp., *Mucor* sp., *Rhizopus* sp., *Botrytis* sp., *Verticillium* sp. and yeasts.

Out of a group of 150 workers, 103 volunteered to participate in the study (23 males and 80 females). Workers not involved refused to participate because of a lack of time or were absent from work at the time of the study. The mean age of subjects was 43.7 years. The mean duration of occupational exposure to fungi was 13.4 (± 8.9) years. The baseline characteristics are summarized in Table 1.

A total of 88 (85%) subjects reported one or more allergic symptoms. Of these, 71 (69%) reported rhinitis, 72 (70%) reported conjunctivitis and 59 (57%) reported skin symptoms. A total of 31 (30%) subjects reported developing symptoms during work with objects potentially contaminated with fungi. The prevalence of all symptoms was higher among fungi-sensitized subjects (Table 2).

The results of SPT and to allergen-specific serum IgE are presented in Table 3. A total of 48% of subjects had at least one positive SPT response to common allergens. In the total study population, the most frequent allergens yielding positive results SPT were *D. farinae* (27%), *D. pteronyssinus* (23%) and grass pollens (24%). Thirty per cent of museum employees were sensitized to at least one of the fungal allergens, most frequently to *Cladosporium* (13%), *Penicillium* (11%), *Alternaria* and *Aspergillus* (9%).

The mean baseline spirometric values in the study population did not show any significant variations. A mild decrease in pulmonary function was demonstrated in only three subjects.

Factors associated with fungal allergy are presented in Table 4. The logistic regression analysis revealed that duration of occupational exposure lasting >5 years, family history of atopy, presence of a cat at home, sinusitis, allergic rhinitis and the history of frequent respiratory infections were significant risk factors for the development of sensitization to fungi.

Table 1. Characteristics of the study population—103 museum workers

	All group, N = 103 (%)	Subjects sensitized to moulds, n = 31 (%)	Subjects not sensitized to moulds, n = 72 (%)
Age (mean $\pm$ SD) (years)	44 $\pm$ 11	47 $\pm$ 8	42 $\pm$ 11
Sex: male/female	23/80 (22/78)	5/26 (16/84)	18/54 (25/75)
Smoking status—active smokers	15 (15)	4 (13)	11 (15)
Ex-smokers	43 (42)	13 (42)	30 (42)
Passive smokers	23 (22)	7 (23)	16 (22)
Family history of atopy	34 (33)	16 (52)	18 (25)
Pets at home	51 (50)	22 (71)	29 (40)
Dog	28 (27)	8 (26)	20 (28)
Cat	20 (19)	12 (39)	8 (11)
Presence of visible moulds at home	9 (9)	3 (10)	6 (8)
Duration of occupational exposure (mean $\pm$ SD) (years)	17 $\pm$ 11	21 $\pm$ 9	16 $\pm$ 12
Duration of occupational exposure > 5 years	82 (80)	30 (97)	52 (72)

Table 2. The prevalence of reported potential atopic symptoms among museum workers (N = 103)

Reported symptoms	All group, N = 103 (%)	Subjects sensitized to moulds, n = 31 (%)	Subjects not sensitized to moulds, n = 72 (%)
At least one allergic symptom	88 (85)	31 (100)	57 (79)
Cough	32 (31)	13 (42)	19 (26)
Dyspnoea	35 (34)	14 (45)	21 (29)
Wheezing	17 (17)	6 (19)	11 (15)
Rhinitis	71 (69)	23 (74)	48 (67)
Conjunctivitis	72 (70)	24 (77)	48 (67)
Skin symptoms	59 (57)	21 (68)	38 (53)

Discussion

The results of the mycological assessment showed that the majority of species isolated from investigated exhibits of the NM belonged to fungal species that are important causes of allergic diseases [1,3].

In our study, 85% of examined subjects reported at least one symptom of allergy. Thirty per cent of workers reported symptoms that occurred during work with objects contaminated with fungi. In a previous study, ~17% of office workers reported respiratory symptoms associated with exposure to mite allergen or detectable airborne *Alternaria* allergens at work [8]. The higher rate of reported symptoms than of sensitization in our study may be due to non-allergic mechanisms inducing respiratory symptoms. The role of β -glucans or spore-borne mycotoxins in such cases has been postulated [9]. It is also possible that allergic symptoms were over-reported. Strachan [10] observed a discrepancy between questionnaire and clinical findings. It has been suggested that gathering information about self-reported symptoms and fungal exposure in the same questionnaire may lead to over-reporting of symptoms among the symptomatic subjects and under-reporting among the symptom-free individuals [11].

Forty-eight per cent of the study population had a positive SPT to common allergens, whereas the prevalence of atopy in the general population was 30–40% [12–14]. Moreover, in our group, allergy to fungi was found in 30% of subjects compared to 2–10% of the general population [11,15]. *C. cerealiers*, *L. melanges*, *Cladosporium* and *Penicillium* were found to be the most frequent sensitizers in museum workers, whereas *Alternaria*, *Cladosporium* and *Candida* are the most common in general population [16,17]. The prevalence of *Alternaria* sp. reactivity observed in this study (9%) was similar to that reported by others [17]. Basidiomycete sensitization was observed in >14% of museum workers. Basidiospore extracts are generally not included in routine skin testing; however, several studies have showed levels of sensitivity comparable to fungi typically used in skin test panels [18]. Lehrer *et al.* [19] found 25% of atopic subjects and 9% of non-atopic subjects reacted to at least one basidiomycete extract.

In our study, a higher prevalence of SPT reactivity (30%) than the presence of serum-specific IgE to moulds (4.9%) was found. Mari *et al.* [16] have previously reported discrepancies between SPT results and IgE assays. Perzanowski *et al.* [20] found a similar sensitivity of these two methods for *Alternaria* allergens. Differences between SPT and IgE results are possibly related to poor or insufficient standardization of fungal extracts and cross-reactivity among different fungal species. The quality of fungal allergen preparations might have had a significant effect on the specificity and sensitivity of SPTs [21].

In the present study, a significant correlation between duration of occupational exposure >5 years, family history of atopy, presence of a cat at home, sinusitis, allergic rhinitis, history of frequent respiratory infections and hypersensitivity to fungi was found. Length of exposure was a highly significant association in cases of occupational allergy to fungal enzymes [22]. Atopy is regarded as a predisposing factor of mould allergy [23, 24].

A limitation of the present study is that the findings are limited to the employees of the NM in Warsaw. Further

Table 3. The results of SPT to common, mould and fungal allergens and evaluation of total and specific IgE level among museum workers (N = 103)

Positive SPT to	All group, N = 103 (%)	Subjects sensitized to moulds, n = 31 (%)	Subjects not sensitized to moulds, n = 72 (%)
At least one common allergen	50 (49)	23 (74)	27 (38)
Feathers	2 (2)	1 (3)	1 (1)
Grass pollens	25 (24)	12 (39)	13 (18)
Trees pollens I ^a	18 (18)	9 (29)	9 (13)
Trees pollens II ^b	19 (18)	10 (32)	9 (13)
Weeds	16 (16)	8 (26)	8 (11)
<i>Dermatophagoides farinae</i>	28 (27)	13 (42)	15 (21)
<i>Dermatophagoides pteronyssinus</i>	24 (23)	9 (29)	15 (21)
<i>Acarus siro</i>	10 (10)	4 (13)	6 (8)
<i>Thyrophagus putrescentiae</i>	13 (13)	7 (23)	6 (8)
<i>Lepidoglyphus destructor</i>	9 (9)	5 (16)	4 (6)
<i>Euroglyphus manei</i>	14 (14)	10 (32)	4 (6)
At least one fungal allergen	31 (30)	31 (100)	0
<i>Alternaria tenuis</i>	8 (8)	8 (26)	0
<i>Aspergillus fumigatus</i>	6 (6)	6 (19)	0
<i>Botrytis cinerea</i>	2 (2)	2 (7)	0
<i>Trichophyton mentagrophytes</i>	6 (6)	6 (19)	0
<i>Cladosporium herbarum</i>	6 (6)	6 (19)	0
<i>Fusarium moniliforme</i>	6 (6)	6 (19)	0
<i>Helminthosporium halodes</i>	3 (3)	3 (10)	0
<i>Mucor mucedo</i>	7 (7)	7 (23)	0
<i>Penicillium notatum</i>	9 (9)	9 (29)	0
<i>Pullularia pullulans</i>	7 (7)	7 (23)	0
<i>Rhizopus nigricans</i>	9 (9)	9 (29)	0
<i>Phoma betae</i>	5 (5)	5 (16)	0
<i>Alternaria</i> sp.	9 (9)	9 (29)	0
<i>Aspergillus</i> mix	9 (9)	9 (29)	0
<i>Cladosporium</i> sp.	13 (13)	13 (42)	0
<i>Penicillium</i> mix	11 (11)	11 (36)	0
Basidiomycetes and yeasts			
<i>Candida albicans</i>	6 (6)	6 (19)	0
<i>Levures melanges</i>	12 (12)	12 (39)	0
<i>Curvularia lunata</i>	3 (3)	3 (10)	0
<i>Neurospora sitophila</i>	5 (5)	5 (16)	0
<i>Serpula lacrymans</i>	2 (2)	2 (7)	0
<i>Charbons cerealiens</i>	14 (14)	14 (45)	0
Total IgE level kU/l (mean $\pm$ SD) (minimum, maximum)	95 $\pm$ 142 (1, 875)	113 $\pm$ 129 (4, 466)	86 $\pm$ 147 (1, 875)
IgE > 100 kU/l	22 (21)	9 (29)	13 (18)
Presence of asIgE to			
mx2 ^c	5 (5)	5 (16)	0
m11 (<i>R. nigricans</i>)	0	0	0
m15 (<i>Trichoderma viride</i>)	0	0	0
m4 (<i>Mucor racemosus</i>)	0	0	0
m7 (<i>B. cinerea</i>)	1 (1)	1 (3)	0
Rm208 (<i>Chaetomium globosum</i>)	0	0	0

^aAlder, hazel, poplar, elm, willow.^bBird, beech, oak, plane.^cmx2—*P. notatum*, *C. herbarum*, *A. fumigatus*, *C. albicans*, *Alternaria alternata*, *H. halodes*.

studies are necessary to elucidate the importance of particular fungal species in the development of occupational allergy. Furthermore, our study was cross-sectional in nature. Cross-sectional studies provide limited information and cannot establish causation, and this is a potential weakness of our study.

This study suggests an important role for fungi as occupational allergens in museum workers. The prevalence of allergic symptoms among employees of the NM is relatively high and frequently related to specific sensitization. Especially difficult is establishing the cause-effect relationship between occupational exposure and fungal

Table 4. Results of logistic regression analysis of the risk factors of sensitization to fungal allergens among museum workers

Analysed risk factors	OR (95% CI)
Occupational exposure > 5 years	14.7 (1.22–178)*
Sinusitis	4.7 (1.19–19.0)*
Allergic rhinitis	8.3 (1.86–37.0)**
Respiratory infections at least one for 6 months	4.3 (1.07–17.0)*
Family history of atopy	4.48 (1.07–18.7)*
Presence of a cat at home	6.86 (1.45–32.4)*
Positive SPT to <i>Dermatophagoides farinae</i>	0.61 (0.11–3.53)
<i>Euroglyphus manei</i>	6.99 (0.77–63)

Variables found to be significant in the univariate analysis were included in the regression model; * $P < 0.05$, ** $P < 0.01$.

allergy disease. In the case of allergens present both in workplace settings and in the home environment, the essential thing is to evaluate the role of occupational exposure in allergy development. If a significant causative link can be established, subjects at risk may require health surveillance alongside exposure reduction. Avoidance or reduction of exposure may be crucial in limitation of development of mould allergy.

Key points

- Thirty per cent of museum employees were sensitized to at least one of the fungal allergens.
- The prevalence of allergic symptoms among employees of the NM was relatively high and frequently related to specific sensitization.
- Duration of occupational exposure lasting >5 years, family history of atopy, presence of a cat at home, sinusitis, allergic rhinitis and a history of frequent respiratory infections are risk factors for the development of sensitization to fungi in museum workers.

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Conflicts of interest

None declared.

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