

Indoor environment in three North European cities in relationship to atopy and respiratory symptoms

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Abstract

Background: In the European Community Respiratory Health Survey (ECRHS) I, the lowest prevalence of asthma and atopy was found in Reykjavík (Iceland) and Tartu (Estonia). The aim of this study was to compare home environments in Reykjavík and Tartu to a town with a higher prevalence of asthma and atopy (Uppsala, Sweden) in an attempt to identify factors in the indoor environment that could explain these differences.

Method: A random sample of 129 ECRHS II participants was included in this analysis at each of the three study centres. The subjects answered a questionnaire, blood was analysed for specific immunoglobulin E, a methacholine test was performed and home indoor measurements were taken.

Results: The prevalence of atopy was 11.9% in Reykjavík, 35.5% in Uppsala and 28.2% in Tartu ($P < 0.04$). The level of indoor cat allergen was significantly lower in Reykjavík compared with Uppsala ($P = 0.05$). No mite allergens were identified in the 41 homes investigated in Reykjavík, while this was the case in 16% and 72% of the households in Uppsala and Tartu, respectively ($P = 0.001$). A positive association was found between asthma symptoms and cat allergen levels [odds ratio 1.53 (95% confidence interval 1.04–2.24)], while the levels of viable moulds were significantly associated with increased bronchial responsiveness.

Conclusions: Indoor exposure to allergens, moulds and bacteria was lower in Reykjavík than in the Swedish and Estonian centres. This finding indicates that the lower prevalence of allergic sensitization in Reykjavík may partly be related to lower indoor allergen exposure.

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Key words

atopy – bacteria and mould – epidemiology – indoor allergens – respiratory symptoms

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Authorship

María I Gunnbjörnsdóttir analyzed data and wrote paper. Dan Norbäck designed the study, collected data and contributed important reagents. Eythor Björnsson performed the research and contributed important reagents. Argo Soon collected data. Deborah Jarvis designed the study and contributed important reagents. Rain Jõgi designed the study and collected data. David Gislason performed the research and contributed important reagents. Thorarinn Gislason performed research and contributed important reagents. Christer Janson designed the study, performed research and analyzed data.

Ethics

The study was approved by ethical committees in all centres

Conflict of interest

None of the authors have declared conflict of interest.

Introduction

The prevalence of asthma, atopy and bronchial hyper-responsiveness varies widely within Europe, as was confirmed by the European Community Respiratory Health Survey (ECRHS) I in the beginning of the 1990s (1, 2). A geographical variation was observed, with the highest prevalence in English-speaking countries and the lowest prevalence in the Mediterranean region and Eastern Europe (3).

ECRHS I demonstrated that in the countries located in the northernmost part of Europe, in the geographic area denoted as Scandinavia, the prevalence of asthma and atopy was quite similar within the countries. There was, however, a lower prevalence of asthma and atopy in Iceland and Estonia, countries that neighbour Scandinavia to the east and west (4). The lower prevalence of asthma and atopy in Estonia may have been expected, in that the country has been a part of the former USSR and geographically a part of Eastern Europe. Iceland, on the other hand, is historically a part of Western Europe and the population has adopted a thoroughly western lifestyle since the Second World War. A higher prevalence of asthma and atopy may thus perhaps also have been expected.

The reasons for these geographical differences are mostly unknown. A number of theories have however emerged in the last decades in attempts to explain both this variation and the worldwide rise in the prevalence of asthma and atopy. The hygiene hypothesis was first proposed by Strachan in 1989. It was suggested that infections in early childhood, transmitted by unhygienic contact with older siblings or acquired prenatally from a mother infected by contact with her children, might prevent the development of allergic diseases (5). It is, however, at the present date generally accepted that the hygiene hypothesis alone does not provide an adequate explanation for the observed increase in allergic disease (6). Changes in lifestyle, such as in food intake, exercise and smaller family size, have also been implicated as risk factors for asthma and allergy (7). In addition, indoor environment with exposure to potential allergens such as house dust mites (HDMs) and pets as well as other exposures such as non-viable microbial products from bacteria and moulds have all been suggested as a part of the explanation (8). A recent paper proposes that reduced allergen exposure is one of the underlying factors for the higher risk of immunoglobulin E (IgE)-mediated allergic disease in the population with an urbanised, westernised and affluent lifestyle (9).

The aim of this study was to compare indoor environment in three cities in Northern Europe that differ in the prevalence of asthma and atopy.

Method

The study design and population

The present study comprised subjects participating in the ECRHS I (10) and in ECRHS II (11) in Reykjavík (Iceland), Uppsala (Sweden) and Tartu (Estonia). Of 1238 subjects, 510 included in the random sample of ECRHS II participants had not moved house since the ECRHS I survey. Sixty of these subjects were subsequently randomly selected from each centre and invited to participate in the present study. A total of 129 subjects (42 in Reykjavík, 46 in Uppsala and 41 in Tartu; 72% overall) chose to accept this invitation (Fig. 1).

The subjects' homes were visited between March 2001 and January 2002 in Iceland, between February 2001 and December 2001 in Uppsala and between April 2001 and June 2002 in Tartu. Most home visits and indoor measures were performed during the winter months, early spring or late fall.

All subjects included in this study also participated in the ECRHS II Indoor study. We used data from that study in our analysis (mite and cat allergens), as well as data from the ECRHS II questionnaire (respiratory symptoms), blood samples (specific IgE) and results from the methacholine test. We combined this data with our additional indoor measurements.

Local ethics committees at each centre approved the study protocols.

The questionnaire

The ECRHS II main questionnaire was used as well as the ECRHS II Indoor protocol (11). For detail formation on exact formulation of all questions and protocols, we refer to the official ECRHS website: <http://www.ecrhs.org/>.

Respiratory symptoms

The following questions on respiratory symptoms were asked in the ECRHS II questionnaire and were used in this study: Have you had any of the following at any time in the last 12 months? (i) 'wheezing or whistling in your chest'; (ii) 'woken up with a feeling of tightness in your chest'; (iii) 'an attack of shortness of breath that came on during the day when you were at rest'; (iv) 'an attack of shortness of breath that came on

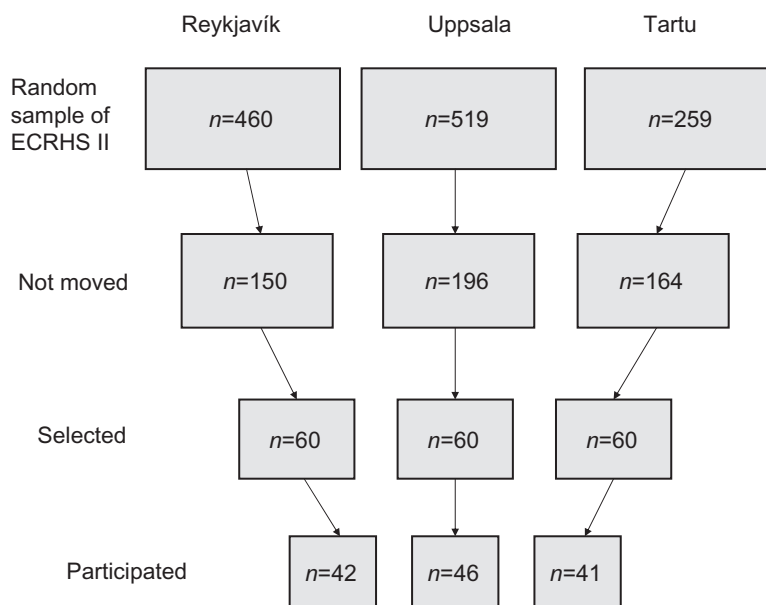


Figure 1. Study design. ECRHS, European Community Respiratory Health Survey.

following strenuous activity'; (v) 'been woken by an attack of shortness of breath'. To increase sensitivity, responses were combined into: 'daytime breathlessness' – a combination of questions three and four; 'nocturnal breathlessness' – a combination of questions two and five; 'asthma symptoms' – a combination of questions one to five. The variable 'current asthma' is the combination of a positive answer to the following questions: physician diagnosed asthma and having had asthma symptoms or an attack of asthma in the preceding 12 months (12).

Blood samples

Blood samples were collected in order to measure total IgE and specific IgE against cat, timothy, HDM (*Dermatophagoides pteronyssinus*) and *Cladosporium*, using the Pharmacia CAP System (Pharmacia Diagnostics, Uppsala, Sweden). Serum samples were stored at -20°C and then transferred to a centralised laboratory in London using the same method as in ECRHS I. Atopy was defined as specific IgE above 0.35 kU/L against one or more allergens.

Bronchial responsiveness

Bronchial responsiveness was assessed by methacholine provocation (Provocholine1, Methapharm Inc., Brantford, ON, Canada). The bronchial responsiveness to methacholine was presented as 'slope' using the following formula: $100/(\text{regression coefficient} + 10)$, where the regression coefficient was calculated by

regressing percentage fall in forced expiratory volume in 1 s on $\log_{10}$ (methacholine dose) (2). A lower slope value indicates a higher degree of bronchial responsiveness.

Home indoor measurements

Indoor measure included temperature, relative air humidity, airborne moulds and bacteria. Temperature and relative air humidity was measured with an Assman Psychrometer type SK-RHG (Sato Keiryoky Mfg. Co., Tokyo, Japan). Airborne micro-organisms were sampled on 25-mm nucleopore filters with a pore size of $0.4\ \mu\text{m}$ and a sampling rate of 2 L/min for 2.5 h. The nucleopore filters were stored in a refrigerator ($+4$ to $+10^{\circ}\text{C}$) after sampling, then sent by priority mail for analysis at Pegasus Lab AB, Uppsala, Sweden within 7 days. The total concentration of airborne moulds and bacteria, respectively, was determined by the collection of airborne micro-organisms on nucleopore filters method (13). Viable moulds and bacteria were determined by incubation on two different media. The detection limit for viable organisms was 30 colony-forming units per m^3 of air.

Dust sampling was carried out using ECRHS II Indoor protocol (14, 15). Dust was collected from the participants' beds using an Elektrolux Mondo (AB Elektrolux, Stockholm, Sweden) vacuum cleaner (1300 W) with an ALK dust collection device (ALK-Albelló A/S, Hørsholm, Denmark). The dust was analysed for major HDM allergens, *Dermatophagoides farinae* 1 (Der f 1) and *Dermatophagoides pteronyssinus*

1 (Der p 1) (16) and major cat allergen *Felis domesticu* 1 (Fel d 1) (17) using standard monoclonal antibody enzyme-linked immunosorbent assays. Allergen levels are expressed as microgram allergen per gram of dust ($\mu\text{g/g}$).

Other variables

Smoking history was assessed in the interview and the subjects were categorised in three groups: never smokers, ex-smokers or current smokers. Body mass index (BMI) in kg/m^2 was calculated from height and weight.

Statistics

Analysis was performed using Stata 8.0 (Stata Corporation, College Station, TX, USA). Chi-square test and unadjusted logistic regression were used for univariate analysis. Multivariate logistic regression was used to analyse the relationship between indoor air exposures and respiratory symptoms, and the results are presented as adjusted odds ratios (OR) with 95% confidence interval. Linear regression model was used to analyse the relationship between indoor air exposures and bronchial responsiveness (slope). All values were adjusted for age, gender, BMI and smoking in both models.

The distribution of cat (Fel d 1) and mite (Der f 1 and Der p 1) allergens were positively skewed, but logarithmic transformation normalised the distribution. The units of the regression coefficient (S) were that of the outcome variable, per change of 10^4 organism/ m^3 for total bacteria and mould and 10^3 for viable bacteria and mould. These values for change of exposure were selected to be in a similar order of magnitude to the measured values in the homes. Potential heterogeneity between centres was addressed by meta-analyses according to DerSimonian and Laird (18). A P value of <0.05 was regarded as statistically significant.

Results

A total of 129 subjects from Reykjavík ($n = 42$), Uppsala ($n = 46$) and Tartu ($n = 41$) accepted and were included in this analysis. The study design is presented in Fig. 1. Blood samples from 126 subjects were analysed for total and specific IgE, and methacholine test was performed on 101 subjects.

The characteristics of the population are presented in Table 1. The age of the participants was significantly lower in Tartu as the interval between ECRHS

I and II was shortest there. The prevalence of atopy was lowest in Reykjavík and highest in Uppsala. Almost 70% of the population in Tartu lives in apartments; this is twice as common as in the other two centres ($P = 0.009$). The prevalence of symptoms and atopy in this small sample were similar/different but compatible with the prevalence figures found in the sample as a whole and previously reported (1).

Results of the indoor air measurements are presented in Table 2. The amount of total and viable bacteria did not differ between the centres and the same applied to viable mould. Significantly higher levels of total mould were measured in Tartu when compared with Reykjavík and Uppsala. Reykjavík had the lowest level of cat allergen, and no HDM allergens were detected there. The mean indoor temperature was the same in Reykjavík and Uppsala and significantly higher than in Tartu. Indoor air humidity was highest in Uppsala and lowest in Reykjavík.

Viable moulds cultures were typed, and the results presented in Table 3. Significant differences were found in the measurable amount of viable *Aspergillus*, *Cladosporium* and *Penicillium* species, with low levels noted in Reykjavík.

The results of the multivariate logistic regression analysis are presented in Table 4. All values were adjusted to age, gender, BMI and smoking. In the total analysis (all centres included), a positive association was found between asthma symptoms and cat allergen exposure. When each centre is analysed, a weak association between total bacteria and nocturnal breathlessness was noted in Uppsala [OR 1.05 (1.01–1.10)]. In Reykjavík, wheeze was related to total mould [OR 1.22 (1.01–1.47)] and in Tartu, wheeze was related to cat allergen exposure [OR 2.90 (1.19–7.09)]. No centre heterogeneity was found regarding the associations between respiratory symptoms and indoor allergens or micro-organisms.

The association between indoor air exposure and bronchial responsiveness was calculated using a linear regression model, adjusted for age, gender, BMI and smoking. The results are presented in Fig. 2. Higher viable mould levels were significantly associated to higher bronchial responsiveness. No association was found between exposure and sensitisation except for a negative association between cat sensitisation and mite exposure (Table 5).

Discussion

In this cross-sectional study, the lowest level of indoor cat and mite allergens as well as bacteria and mould

Table 1. The characteristics of the study population 2001–2002

	Reykjavík <i>n</i> = 42	Uppsala <i>n</i> = 46	Tartu <i>n</i> = 41	<i>P</i> value
Female (%)	64.3	54.4	48.8	0.353
Age in years $\pm$ SD	47.9 (4.1)	46.6 (5.0)	41.3 (6.5)	0.001
BMI $\pm$ SD	25.3 (3.7)	24.4 (3.2)	26.3 (4.8)	0.097
Atopy, <i>n</i> (%)	5 (11.9)	16 (35.6)	11 (28.2)	0.036
BHR (slope)*	7.6	6.6	7.3	0.244
Smoking history (%)				0.092
Never smoked	30.9	39.1	50.1	
Ex-smoker	40.5	43.5	19.5	
Smoker	28.6	17.4	29.3	
Type of housing (%)				0.009
Detached	45.2	47.8	25.0	
Semi-detached	21.4	19.6	7.5	
Apartment	33.3	32.6	67.5	
Respiratory symptoms, <i>n</i> (%)				
Wheeze	11 (26.2)	13 (28.3)	10 (24.4)	0.919
Daytime breathlessness	4 (9.5)	9 (19.6)	12 (29.3)	0.075
Nocturnal breathlessness	3 (7.1)	5 (10.9)	5 (12.2)	0.728
Asthma symptoms	12 (28.6)	19 (41.3)	16 (39.0)	0.425
Current asthma	3 (7.1)	7 (15.2)	1 (2.4)	0.096
Pets, <i>n</i> (%)				
Cat keeping	5 (11.9)	14 (30.4)	7 (17.7)	0.080
Allergic sensitisation, <i>n</i> (%)				
Cat sensitised	2 (4.7)	10 (22.2)	4 (10.0)	0.229
HDM sensitised	0	3 (6.6)	8 (20.0)	0.147
Mould sensitised	0	2 (4.6)	1 (2.5)	0.210

*The bronchial responsiveness to methacholine was presented as 'slope' using the following formula: $100/(\text{regression coefficient} + 10)$, where the regression coefficient was calculated by regressing percentages fall in FEV1 on $\log_{10}$ (methacholine dose).

SD, standard deviation; BMI, body mass index; BHR, bronchial responsiveness; HDM, house dust mite; FEV1, forced expiratory volume in 1 s.

Table 2. Differences in indoor exposures presented as geometric means with 95% CI, means with range[†] or *n* (%)

	Reykjavík <i>n</i> = 42	Uppsala <i>n</i> = 46	Tartu <i>n</i> = 41	Total <i>n</i> = 129	<i>P</i> value*
Total bacteria ($10^3/\text{m}^3$)	13.3 (12.8–26.2)	19.5 (14.8–25.7)	16.9 (11.5–24.8)	16.4 (13.8–19.6)	0.125
Viable bacteria cfu/ m^3	136.9 (112.5–166.7)	242.5 (269.9–346.0)	306.5 (192.9–486.9)	216.9 (176.3–266.8)	0.127
Total mould ($10^3/\text{m}^3$)	11.4 (9.7–12.8)	12.36 (10.4–14.6)	14.3 (11.1–18.5)	12.5 (11.2–13.9)	0.027
Viable mould cfu/ m^3	111.2 (94.5–130.7)	230.7 (182.7–291.4)	298.4 (208.1–427.8)	197.4 (167.6–232.5)	0.099
Cat (Fel d 1) $\mu\text{g/g}$	0.48 (0.29–0.79)	1.77 (0.70–4.30)	1.55 (0.70–3.30)	1.10 (0.70–1.70)	0.029
HDM detected	0	7 (16.3)	29 (72.5)	36 (27.9)	<0.001
HDM > 2 $\mu\text{g/g}$	0	5 (10.9)	15 (36.6)	20 (15.5)	<0.001
HDM (Der p 1) $\mu\text{g/g}$	<0.05	0.06 (0.05–0.07)	0.28 (0.12–0.64)	0.09 (0.07–0.12)	0.118
HDM (Der f 1) $\mu\text{g/g}$	<0.05	0.09 (0.05–0.14)	0.44 (0.21–0.91)	0.122 (0.08–0.17)	0.074
Relative humidity (%) [†]	35.9 (21–56)	49.0 (27–76)	41.1 (23–68)	42.2 (21–76)	0.031
Temperature ($^{\circ}\text{C}$) [†]	21.5 (18.0–24.2)	21.5 (19.0–25.0)	20.2 (13.4–24.0)	21.0 (13.4–25.0)	0.006

*Analysed by ANOVA and chi-squared test.

[†]Means with range.

CI, confidence interval; cfu, colony-forming units; Fel d 1, *Felis domesticus* 1; HDM, house dust mite; Der p 1, *Dermatophagoides pteronyssinus* 1; Der f 1, *Dermatophagoides farinae* 1.

Table 3. Classification of viable indoor moulds at the centres, presented as total numbers and (%)

	Reykjavík (n = 42)	Uppsala (n = 46)	Tartu (n = 41)	P value
<i>Acremonium</i> sp.	0	2 (4.3)	0	0.160
<i>Alternaria</i> sp.	0	0	1 (2.4)	0.339
<i>Aureobasidium</i> sp.	1 (2.4)	1 (2.2)	0	0.621
<i>Aspergillus</i> sp.	1 (2.4)	3 (6.5)	8 (31.8)	0.020
<i>Cladosporium</i> sp.	0	16 (34.8)	6 (14.6)	0.001
<i>Dematia hyphomycetes</i> sp.	1 (2.9)	1 (2.2)	3 (7.3)	0.384
<i>Eurotium</i> sp.	0	1 (2.2)	3 (7.3)	0.142
Yeast sp.	1 (2.9)	2 (4.3)	2 (4.9)	0.823
<i>Paecilomyces</i> sp.	1 (2.9)	0	2 (4.9)	0.321
<i>Penicillium</i> sp.	7 (16.7)	17 (37.0)	23 (56.1)	0.001
<i>Pseudomonas</i> sp.	0	1 (2.17)	0	0.403
<i>Stachybotrys</i> sp.	1 (2.38)	0	0	0.352
<i>Streptomyces</i> sp.	1 (2.4)	2 (4.4)	2 (4.9)	0.819
<i>Trichoderma</i> sp.	0	0	1 (2.4)	0.343
<i>Wallemia</i> sp.	1 (2.4)	1 (2.2)	2 (4.9)	0.736
<i>Mucor</i> sp.	0	0	1 (2.4)	0.343
<i>Geotrichum</i> sp.	0	1 (2.2)	1 (2.4)	0.609
<i>Oidioden</i> sp.	0	0	3 (7.3)	0.037
<i>Chrysosporium</i> sp.	0	0	1 (2.4)	0.339

was found in Reykjavík, Iceland. In our study group, 11.9% of the study population in Reykjavík, 35.6% in Uppsala and 28.2% in Tartu were atopic. In the ECRHS I, the prevalence of atopy was 20% in Reykjavík, 32.3% in Uppsala and 19.1% in Tartu (1). In the ECRHS II, the prevalence of atopy was the same as in ECRHS I in Reykjavík and Tartu but somewhat lower in Uppsala (19). As our study group is a sample of 129 individuals selected from the main ECRHS II cohort, the prevalence of atopy in this group does not reflect any real change between the studies.

In this study, the lowest prevalence of cat ownership and the lowest level of indoor cat allergens were measured in Reykjavík. No HDM allergens were detected in the 41 dust samples gathered there. As a part of the

ECRHS II Indoor study, 197 homes in Reykjavík were investigated. Only two of the dust samples taken were found to be positive for HDM, but no actual HDM allergens were found (20). Studies measuring the level of indoor allergens in Sweden and Estonia have found similar levels of both cat and HDM allergens in the two countries, and the level of sensitisation to cat and HDM in children and young adults is also similar (21–23).

A recent study has demonstrated that exposure to HDM allergens resulting in sensitisations is non-linear, with the highest mite sensitisation rate at intermediate exposure levels (24). In our study, the exposure for HDM allergens was low in Uppsala but at the intermediate level in Tartu.

Table 4. Adjusted odds ratios for respiratory symptoms in relationship to indoor environment exposure

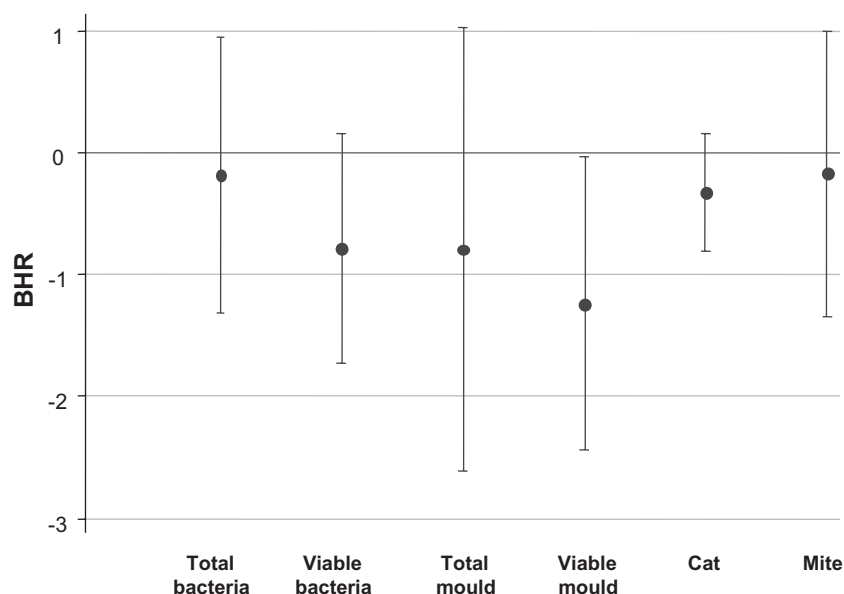
	Wheeze	Daytime breathlessness	Nocturnal breathlessness	Asthma symptoms
Total bacteria	1.07 (0.90–1.26)	0.97 (0.87–1.08)	1.24 (0.70–2.19)	1.06 (0.87–1.30)
Viable bacteria	0.98 (0.77–1.24)	1.10 (0.32–3.79)	1.12 (0.62–2.02)	0.98 (0.75–1.28)
Total mould	1.34 (0.43–4.21)	0.89 (0.36–2.23)	1.29 (0.86–1.93)	1.11 (0.49–2.50)
Viable mould	1.29 (0.78–2.13)	0.35 (0.08–1.66)	0.90 (0.53–1.54)	1.11 (0.81–1.51)
Cat allergen	1.42 (0.65–3.10)	1.43 (0.95–2.16)	1.15 (0.68–1.93)	1.53 (1.04–2.24)
HDM allergen	1.91 (0.07–49.56)	1.84 (0.34–9.73)	*	1.23 (0.31–4.82)

All values are adjusted for age, gender, BMI and smoking, and presented with 95% confidence interval. The odds ratio is calculated per change of 10^4 organism/m³ for total bacteria and mould, 10^3 /m³ for viable bacteria and mould and for logarithmic increase for cat and HDM allergens.

*No value.

BMI, body mass index; HDM, house dust mite.

Figure 2. Linear regression analysis on the relationship between indoor exposures (all centres) and bronchial responsiveness presented as slope. All values are adjusted for age, gender, body mass index and smoking, and presented with 95% confidence interval. The estimate is calculated per change of 10^3 organisms/ m^3 for viable bacteria and mould and per change of 10^4 organism/ m^3 for total bacteria and mould. Negative slope indicates increased bronchial responsiveness. BHR, bronchial responsiveness.



In the multivariate analysis, the strongest association was found between indoor cat exposure and all respiratory symptoms, but only the combined variable 'asthma symptoms' was significant. Removing cat-sensitised individuals from the analyses did not significantly change the association. HDM exposure was not a risk factor for respiratory symptoms in this study. There is, however, convincing evidence that HDM exposure increases the risk of HDM sensitivity, as well as the development of asthma in both children and adults (25–28), but that this dose–response relationship between allergen exposure and IgE sensitisation seems to be bell-shaped (24). Salo *et al.* found that increased allergen levels in the home were associated with asthma symptoms (OR 1.8) in allergic individuals (29).

Our study found that other indoor exposures such as bacteria and moulds were not risk factors for respiratory symptoms and that the same applies to physical factors such as indoor temperature and humidity. A Swedish study found higher levels of bacteria and moulds in the homes of subjects reporting at least one asthma-related symptom such as wheeze, breathlessness or chest tightness. After adjusting for possible confounders, it was noted that exposure to bacteria remained a risk factor for wheeze and asthma-related symptoms in that population (30). Schram-Bijkerk *et al.* measured allergens as well as endotoxins, $\beta(1,3)$ -glucans and fungal extracellular polysaccharides in the mattress of 402 children. It was found that in populations with high microbial agent levels and low sensi-

Table 5. Adjusted odds ratios for IgE-sensitisation (≥ 0.35 kU/L) in relationship to indoor environment exposures

	Cat	<i>Dermatophagoides pteronyssinus</i>	<i>Cladosporium</i>
Total bacteria	0.97 (0.89–1.07)	1.01 (0.95–1.06)	0.98 (0.76–1.26)
Viable bacteria	0.83 (0.46–1.49)	1.10 (0.94–1.28)	1.72 (0.42–7.12)
Total mould	0.72 (0.48–1.09)	0.86 (0.63–1.17)	0.45 (0.09–2.31)
Viable mould	0.75 (0.31–1.81)	0.56 (0.21–1.53)	0.54 (0.03–11.1)
Cat allergen	0.69 (0.44–1.07)	0.46 (0.22–0.98)	0.42 (0.11–1.73)
HDM allergen	1.26 (0.64–2.47)	0.95 (0.48–1.90)	*

All values are adjusted for age, gender, BMI and smoking, and presented with 95% confidence interval. The odds ratio is calculated per change of 10^4 organism/ m^3 for total bacteria and mould, 10^3 / m^3 for viable bacteria and mould and for logarithmic increase for cat and HDM allergens.

*No value.

IgE, immunoglobulin E; BMI, body mass index; HDM, house dust mite.

sation rates, the curve shifted down. This finding may explain – at least partially – the protective effect of living on a farm on mite sensitisation (24).

Significant differences were found in the amount of total mould between the centres and in the prevalence of some mould species. In the analysis of ECRHS I, the frequency of sensitisation to fungi was associated with severity of asthma (31). Other studies have reported an association between fungal sensitisation and severe asthma in children (32) and life-threatening asthma in adults (33). In Tartu, an association was found between indoor mould and wheeze, which corresponds with the fact that the highest values of total and viable mould were also found there. Researchers recently found that the prevalence of current symptomatic asthma increased with increasing *Alternaria* concentrations in US homes; higher levels of *Alternaria alternata* antigens increased the odds of having exhibited asthma symptoms in the past year (34). Using linear regression analysis, we found bronchial responsiveness being related to viable mould exposure. This is an interesting finding, as bronchial responsiveness is one of the main characteristics of asthma and an indirect sign of airway inflammation.

The indoor temperatures in Reykjavík and Uppsala were found to be the same and significantly higher than in Tartu. Reykjavík had the lowest indoor humidity. As mite and mould thrive in warm (>20°C) and humid (relative humidity >45%) environments, the relatively dry and warm indoor habitat in Iceland does not facilitate their growth. The Icelandic indoor climate does not, however, exclude mite growth. It is thus possible that mites are simply sparsely presented in Iceland when compared with other Scandinavian countries. Another factor is that heating costs are relatively low in Iceland and ventilation with open windows, even during the coldest winter months, is possible. This could be an important contributing factor, as good ventilation reduces indoor humidity while high humidity facilitates growth of mites, moulds and bacteria.

As our study is small and only a limited number of significant relationships were found, we view our results as a valuable baseline for future studies on indoor environment and respiratory health at the three centres. We did, nevertheless, find a relationship between indoor exposures to allergen. The level of IgE sensitisation at the centres was furthermore found to support the hypothesis that indoor allergen exposure is important for sensitisation and at least partly explains the difference found in the prevalence of atopy between the centres. In order to clarify the relationship between indoor allergen exposures and microbial agents in relationship to IgE sensitisation and respira-

tory symptoms, large prospective studies should be preferred to cross-sectional studies. The cost of such studies will, unfortunately, always be a limiting factor.

There are several limitations to the study and the most important ones should be noted. There is a selection (and non-participation) bias in four steps: ECRHS I and II, the ECRHS indoor study as well as in our study population. This might influence our results in that the population is no longer random, but the effect of this should affect the centres in the same way. Non-responder analysis was not preformed, but in other epidemiological studies younger male smokers tend to be under-represented. Other known important confounders such as age, gender, centre, smoking and socio-economic status were adjusted for in our analysis. Some unknown factor(s) operating unevenly at the centres might also influence our results. Outdoor air pollution could bias our results, but in general the particulate matter (PM) 2.5 levels are low in all three cities with the lowest level in Reykjavík (35). As outdoor air pollution may cause respiratory symptoms, it is reassuring to see no significant difference between centres regarding the prevalence of respiratory symptoms. Moulds mainly grow outdoors and their presence in indoor environment is usually a reflection of the outdoor levels. Most of the indoor measurements and sampling was therefore preformed during the winter months in order to reduce the effect of this phenomenon. A large number of statistical test were made and we can therefore not totally exclude that the few association between environmental factors and outcomes that were found may have been chance findings. The low number of participants decreases the power of the study in detecting small differences. This is best seen in the positive associations between cat allergen exposure and all respiratory symptoms, where only the combined variable asthma symptom became significant. A larger number of participants would be needed in order to increase the power of the study. In conclusion, indoor exposure to allergens, moulds and bacteria was lower in Reykjavík than in the Swedish and Estonian centres. This finding indicates that the low prevalence of allergic sensitisation in Reykjavík may partly be related to lower indoor allergen exposure.

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