

Home dampness and respiratory health status in European children

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Summary

Background Living in a damp home has been associated with impaired respiratory health in previous studies, but objective data on lung function variability and atopy have been lacking from most studies.

Objectives Data collected in the winter of 1993–1994 in the framework of the PEACE study (Pollution Effects on Asthmatic Children in Europe) were used to study the association between home dampness and Peak Flow (PEF) variability, frequency of respiratory symptoms and relief medication use during the period of observation.

Methods Children were selected with a screening questionnaire on the basis of positive answers to questions on symptoms of asthma and chronic cough. Children were instructed to perform PEF measurements with Miniwright PEF meters twice daily over a period of 2 months. Parents kept diaries on respiratory symptoms and medication use of their children. Data on demographic and housing characteristics were derived from a parent-administered questionnaire. As indicators for home dampness reported moisture stains and moulds were used. Children were tested for atopy with skin-prick tests. Data from 1614 children from 13 centres in 10 different countries were available for analysis. Linear regression models and prevalence rate ratios were used to investigate the association between home dampness and PEF variability and the period prevalence of cough, phlegm, lower and upper respiratory symptoms and bronchodilator use.

Results In atopic children, PEF variability was positively related to self-reported moulds but not to moisture stains. The period prevalence of cough and upper respiratory symptoms was significantly higher in children living in houses with reported moulds, compared with 'dry' homes.

Conclusions These results show that self-reported moulds in homes are associated with objective as well as subjective markers of airway lability in European children with chronic respiratory symptoms.

Keywords: PEF, respiratory symptoms, home dampness moulds, children

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Introduction

In the last decade, there has been an increasing interest in the relation between home dampness and the prevalence and severity of respiratory symptoms. Most studies have been

conducted on children under 12 years of age and focused on chronic respiratory symptoms and lung function. Spengler *et al.* [1] found in a study of 9–11-year-old children in 24 North American communities that chronic respiratory symptoms (bronchitic, asthmatic and lower respiratory) were significantly associated with reported home dampness and presence of moulds. In a cross-sectional study of pre-school children in Finland, Jaakkola *et al.* [2] found that persistent cough, wheezing, phlegm and nasal symptoms

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were positively associated with the presence of moisture and visible moulds. In this study asthma was not found to be associated with home dampness. Dekker *et al.* [3] reported that in a survey of more than 17 000 Canadian school-children, asthma diagnosed by a physician was significantly associated with living in damp homes. In a population of Dutch children 6–12 years of age, Dijkstra *et al.* [4] found a significant association between home dampness and respiratory symptoms (especially cough) but no association with pulmonary function. In a cohort study of 8–12-year-old children in six US cities, Brunekreef *et al.* [5] concluded that there was a consistent and strong association between reported dampness in the home and childhood respiratory symptoms. They found only a weak, insignificant relationship between home dampness and pulmonary function. Several other studies [6–13] have reported similar findings.

As most findings reported to date were based on questionnaire reports of home dampness and symptoms, it is possible that to some extent reporting bias is responsible. However, in a recent case-control study that used objective assessment of atopy (by measuring IgE) and exposure (by measuring dust mite allergen levels), Verhoeff *et al.* [14] showed that the association between home dampness and respiratory symptoms appeared to be mediated by allergy to dust mites and moulds.

Other studies have shown that the level of exposure to dust mite allergen in the home is associated with peak flow variability and medication use in asthmatic patients [15–18]. No studies have been reported so far that have evaluated the relationship between home dampness and morbidity in children with chronic respiratory symptoms. The present paper addresses this issue by investigating the association between home dampness and lung function variability, symptom exacerbations and relief medication use, measured over a period of 2 months in children with chronic respiratory symptoms. Our null hypothesis was that reports of home dampness are not associated with lung function variability, symptom prevalence and medication use, the alternative hypothesis being that living in a damp home increases PEF variability as well as the period prevalence of respiratory symptoms and relief medication use. The data were collected in the framework of a study on acute respiratory health effects of air pollution among children with chronic respiratory symptoms, the PEACE study (Pollution Effects on Asthmatic Children in Europe).

Materials and methods

The PEACE study was designed to study the relationship between short-term changes in air pollution and lung function, respiratory symptoms and medication use [19]. It is a collection of panel studies that were conducted in the winter of 1993/1994 in 14 different locations in Europe. Data were

also collected about a number of indicators for indoor air quality.

Study locations

Fourteen study centres participated in the PEACE study [19]: Amsterdam (The Netherlands), Kuopio (Finland), Oslo (Norway), Berlin and Hettstedt (Germany), Pisa (Italy), Athens (Greece), Cracow and Katowice (Poland), Prague and Teplice (Czech Republic), Budapest (Hungary), Umeå and Malmö (Sweden). In each centre, there were two panels of children with chronic respiratory symptoms: an urban and a suburban or rural panel. As the analysis in this paper is not concerned with urban-rural differences, results from the two panels were pooled for each study centre.

Study population

Children were selected by a parent-administered screening questionnaire. The criteria for selection were: reporting of recent wheeze (apart from colds), recent attacks of shortness of breath with wheezing, recent dry cough (apart from colds) and/or doctor diagnosed asthma, ever in life. Data were available from 2267 children. For this study the data were used from the children with valid data on peak flow measurements and respiratory symptoms on more than 60% of the days. Children with missing data in the detailed questionnaire (see below) were also left out. The data from Hettstedt were different with respect to the methods used to study atopy, for which reason Hettstedt was excluded from the study. With this selection the study population consisted of 1614 children (71%). The excluded children did not differ with respect to age, gender, atopy, PEF variability, prevalence of symptoms, medication use or dampness reports.

Detailed questionnaire and diary

A detailed questionnaire was used to collect information about demographic and housing characteristics and the education of the parents. This questionnaire contained questions about observed moisture stains and moulds during the last 2 years, use of a gas range or gas oven, use of unvented heaters and unvented gas fired water heaters, main source of heating, presence of pets with fur or feathers, smoking in the living quarters, age of the house, the number of years of full time education of the parents, etc.

For at least 2 months, a parent completed a diary for the child on morning and evening PEF, the presence of respiratory symptoms and use of medication for respiratory symptoms. The symptoms included were: cough, phlegm, runny/stuffy nose, woken up with breathing problems, shortness of breath, wheeze, attacks of shortness of breath with wheeze,

fever, eye irritation and sore throat. The periods of observation differed slightly from centre to centre, but all were within the winter months (December – March) of the 1993–94 winter.

PEF measurements

PEF measurements were done in the morning after getting up and in the evening before going to bed. The measurements were done in a standing position and prior to medication use. On every occasion the PEF measurement was performed three times. All three readings were noted in the diary. For analysis the highest of the three readings was used. All centres used the Miniwright Peak Flow meter (Clement Clarke International Ltd, Essex, UK).

Skin-prick tests

Skin-prick tests were done using the ALK skin prick test solutions (ALK Laboratories, Horsholm, Denmark). The allergens tested in all centres were birch (*Betula verrucosa*), timothy grass (*Phleum pratense*), cat fur (*Felis catus*) and house dust mite (*Dermatophagoides pteronyssinus*). Histamine hydrochloride (10 mg/mL) and glycerol (50%) were used as the positive and negative control, respectively. In addition, two local allergens were tested in each centre. They were: dog epithelial dander and *Cladosporium herbarum* in Amsterdam, Oslo, Umeå and Malmö, dog epithelial dander and mugwort pollen in Kuopio, *Alternaria alternata* and *Plantago lanceolata* in Berlin, *Alternaria alternata* and ragweed in Budapest, *Alternaria alternata* and *Parietaria officinalis* in Pisa, Olive and *Parietaria officinalis* in Athens, grass mix pollens (*Alopecurus pratensis*, *Dactylis glomerata*, *Festuca pratensis*, *Lolium perenne*, *Phleum pratense*) and dog epithelial dander in Cracow and Katowice and grass mix pollens and mould mix (*Aspergillus fumigatus*, *Cladosporium herbarum*, *Penicillium notatum*, *Botrytis cinerea*) in Prague and Teplice. Reactions were read 15 min after the application of the allergens by outlining the circumferences of all resulting weals on the skin. A mean weal diameter of more than 2 mm was regarded as a positive result. If there was no reaction to the positive control or a reaction more than 1 mm to the negative control, the results were excluded from the analyses.

Statistical analyses

For statistical analyses the statistical package SAS/STAT version 6.09 was used [20]. The daily PEF measurements and diary data were aggregated such that variables were calculated which expressed for each individual the PEF variability or the occurrence of respiratory symptoms and medication use during the measurement period.

For the analyses of the PEF data, four variables were calculated for each child:

- *The mean daily variation of PEF (PEF variation)*; defined as the average of the daily variation over the study period:

$$\text{daily variation} = \frac{|\text{morningPEF} - \text{eveningPEF}|}{(\text{morningPEF} + \text{eveningPEF})/2} \times 100\%.$$

- *The coefficient of variation of the morning PEF*; defined as:

$$\text{cvmo} = \frac{(\text{SD of morning PEF values})}{(\text{mean of the morning PEF values})} \times 100\%.$$

- *The coefficient of variation of the evening PEF*; defined as:

$$\text{cveve} = \frac{(\text{SD of evening PEF values})}{(\text{mean of the evening PEF values})} \times 100\%.$$

The coefficient of variation describes the day-to-day variation in PEF.

- *The minimal morning PEF variation*; defined as the minimal morning PEF expressed as percentage of the maximum PEF reading achieved at any time during the whole period of study [21]. This variable describes the maximum airway lability during the period of study.

In the analyses of respiratory symptoms for each child four variables were used. From these four variables two were combinations of several symptoms. For each child the percentage of symptom-days (PSD) was calculated, which in interpretation is comparable to an individual period prevalence rate.

- *The PSD of cough*; defined as the number of days that a child reported cough divided by the number of non-missing days in the diary;
- *The PSD of phlegm*; defined as the number of days that a child reported phlegm divided by the number of non-missing days in the diary;
- *The PSD of lower respiratory symptoms*; defined as the number of days that a child reported shortness of breath and/or wheeze and/or attacks with shortness of breath with wheeze and/or waking up with breathing problems divided by the number of non-missing days in the diary.
- *The PSD of upper respiratory symptoms*; defined as the number of days that a child reported runny or stuffed nose and/or sore throat divided by the number of non-missing days in the diary.

Furthermore the PSD of the use of bronchodilators was studied. It was defined as the number of days that a child reported the use of bronchodilators divided by the number of non-missing days in the diary.

For the assessment of home dampness reports by parents of moisture stains and moulds in the last 2 years were used. Possible confounding factors that were studied were: study centre, gender, smoking in the living quarters, crowding,

pets, age of the residence, having one's own bedroom, main source of heating, the use of gas range or gas oven for cooking, the use of an unvented gas fired water heater, the use of unvented space heaters, and the number of years of full time education of the father and mother. From these factors, crowding, use of gas for cooking, unvented space heaters and unvented gas fired water heaters conceivably increase home dampness, so that adjusting for them might be equivalent to over-adjusting the association of interest. Therefore these factors were used in a stratified analysis. The correlation between the possible confounding factors and reports of moisture stains or moulds was generally low (Pearson's $r < 0.2$).

The health outcome variables were not normally distributed except for the minimal morning PEF variation. The mean daily variation of PEF and the CV of the morning and evening PEF were log-normally distributed. To normalize the residuals these analyses were done with log-transformed variables and linear regression models. With the minimal morning PEF variation untransformed linear regression models were used. The results of these analyses are expressed as variability ratios defined as the variability in PEF in the exposed group divided by the variability in PEF in the unexposed group.

The distributions of the percentage of symptom days (PSD) of cough, phlegm, lower respiratory symptoms, upper respiratory symptoms and bronchodilator use were a combination of binary and log normal distributions. The analyses of these variables were done in two steps.

1 Analyses of binary variables expressing the absence (PSD = 0) or presence (PSD > 0) of symptoms of cough, phlegm, lower and upper respiratory symptoms over the study period or the absence (PSD = 0) or presence (PSD > 0) of bronchodilator use over the study period. This was done by calculating prevalence rate ratios [22,23], using Cox's proportional hazards model [24], as modified by Breslow [25] with the SAS PHREG procedure. These analyses describe the association between the reporting of symptoms and bronchodilator use, and home dampness indicators in the whole population.

2 Analyses of log-transformed individual PSD values for cough, phlegm, lower respiratory symptoms, upper respiratory symptoms and bronchodilator use for the group of children who actually reported symptoms or bronchodilator use during the period of observation, by linear regression models. These analyses describe the association between home dampness and the occurrence of symptoms or bronchodilator use in that part of the population that reported these symptoms during the study period. The resulting regression coefficients can be interpreted as the difference in symptom or bronchodilator use frequency between the exposed and the unexposed children. In our presentation of the results, we have calculated the ratios of the period prevalences

found in the exposed children over the period prevalence found in the unexposed children (PPR for period prevalence ratio).

Children in the study came from different regions of Europe. The association between home dampness and the health outcome variables could be influenced by regional differences in climate or housing factors (effect modification). An analysis was made to investigate the differences between three European regions. These regions were defined as:

North-West Europe: Amsterdam, Kuopio, Oslo, Berlin, Umeå and Malmö;

Eastern Europe: Cracow, Katowice, Prague, Teplice and Budapest;

Southern Europe: Pisa and Athens.

Berlin was incorporated in the region NW-Europe because the study population of Berlin lived in former West Berlin.

Results

The age of the children varied from 5 to 13 years. There were 896 boys and 718 girls in the study. Because the study centres were spread over an area with big differences in climate, economic development and historical and cultural background, the variation in housing factors between the study centres was large. The reported rates for moisture stains varied from 2.9% for Oslo (Norway) to 38.8% for Cracow (Poland). The lowest and highest rates for reported moulds were found in Oslo 2.9% and Pisa (Italy) 36.0% (Table 1). There was no correlation between home dampness and the average air pollution levels which were generally low in Scandinavia, higher in Western and Central Europe, and highest in Eastern and Southern Europe.

Table 2 shows data on housing factors and education of parents for all study centres. The data show that there was a wide range across centres in almost all variables listed in the table. Central heating was the main source of heating except for Oslo and Umeå where electrical heating was most frequently used. In the Scandinavian study centres less than 3% of the homes were equipped with a gas range or gas oven for cooking, while in Amsterdam, Pisa, Cracow, Budapest and Katowice 70% or more of the families used gas for cooking. Regularly smoking in the living quarters occurred most frequently in Athens (71.3%) and Katowice (64.7%) and most infrequently in Kuopio (4.0%) and Umeå (8.8%). Amsterdam had the most cats (31.8%), Prague the most dogs and rodents (29.1 and 22.2%) and Athens the most birds (18.7%).

Table 3 shows that for all variables tested the variability of PEF increased when moisture stains or moulds were reported. Also the Percentage of Symptom Days (PSD) of respiratory symptoms increased as moisture stains or

Table 1. Description of population and exposure variables

Study centre	<i>n</i>	Boys (%)	Moisture stains (%)	Moulds (%)
Amsterdam				
(The Netherlands)	86	51.2	38.4	25.6
Kuopio (Finland)	150	56.0	15.3	8.0
Oslo (Norway)	104	52.9	2.9	2.9
Berlin (Germany)	104	48.1	22.1	13.5
Pisa (Italy)	114	60.5	38.6	36.0
Athens (Greece)	150	55.3	22.0	13.3
Cracow (Poland)	129	59.7	38.8	14.0
Prague (Czech Republic)	117	59.0	27.4	12.0
Budapest (Hungary)	106	54.7	28.3	22.6
Umeå (Sweden)	137	59.9	27.0	15.3
Malmö (Sweden)	137	55.5	16.1	11.7
Teplice (Czech Republic)	144	49.3	25.0	20.1
Katowice (Poland)	136	56.6	18.4	12.5
Total population	1614	55.5	24.2	15.6

Table 2. Study centres values and means of housing factors and education of parents

Factors	KUO ¹	OSL	UME	MAL	AMS	BER	CRA	KAT	PRA	TEP	BUD	PIS	ATH	Mean
Heating														
Combustion (%)	0	18	2	4	21	4	10	14	11	4	17	20	10	9.7
Electrical (%)	14	63	66	44	0	2	5	2	5	0	1	1	6	16.7
Central (%)	86	19	32	52	79	94	85	84	85	96	82	79	84	73.6
Use of														
Gas range or gas oven for cooking (%)	1	1	0	2	90	29	73	88	48	61	70	99	9	42.4
Unvented gas fired water heater (%)	0	0	0	0	10	0	1	6	1	1	4	1	0	1.6
Unvented heaters (%)	1	1	9	0	9	1	5	7	2	2	4	3	13	2.0
Smoking in the living quarters (%)	4	33	9	23	36	46	56	65	27	37	39	53	71	38.7
Pets														
Cat (%)	7	12	13	20	31	15	14	9	15	11	7	14	7	12.6
Dog (%)	14	12	7	16	26	9	25	18	29	24	12	10	14	15.4
Bird (%)	1	10	6	11	14	15	14	14	11	13	13	5	19	11.3
Rodent (%)	7	10	10	10	13	15	19	18	22	20	8	1	1	11.3
Other (%)	0	1	2	1	0	3	9	0	6	5	8	3	4	3.2
Own bedroom (%)	59	73	83	78	87	62	19	38	32	41	35	43	21	50.0
Crowding (persons per room)	1.0	0.8	0.9	0.9	0.9	0.9	2.0	1.3	1.1	1.0	1.7	0.9	1.4	1.14
Age of the residence (years)	16	34	26	31	34	35	32	20	23	24	22	25	18	26.2
Full time education of														
Father (years)	13	14	13	11	13	15	12	12	14	13	13	12	12	12.1
Mother (years)	14	14	14	12	13	15	13	12	14	12	13	12	11	13.0

¹ KUO, Kuopio (Finland); OSL, Oslo (Norway); UME, Umeå (Sweden); MAL, Malmö (Sweden); AMS, Amsterdam (the Netherlands); BER, Berlin (Germany); CRA, Cracow (Poland); KAT, Katowice (Poland); PRA, Prague (Czech Republic); TEP, Teplice (Czech Republic); BUD, Budapest (Hungary); PIS, Pisa (Italy); ATH, Athens (Greece).

Table 3. Geometric mean of PEF variability indices, and percentage of children that reported symptoms on 1 or more days of the study period, in relation to reporting of moisture stains and mould in the home

PEF variability index	Geometric mean			
	Moisture stains		Moulds	
	No	Yes	No	Yes
PEF variation within days (%)	5.57	5.80	5.52	6.23
CV morning PEF (%)	7.23	7.54	7.23	7.75
CV evening PEF (%)	6.73	7.15	6.76	7.19
Minimal morning PEF variation ¹ (%)	66.6	65.2	66.6	64.4
Respiratory symptoms	Children that reported symptoms (%)			
Cough	86.5	88.5	86.9	87.6
Phlegm	57.4	59.1	57.5	59.4
Lower respiratory symptoms	47.0	52.2	47.6	51.8
Upper respiratory symptoms	91.9	94.1	92.5	92.0
Bronchodilator use	23.3	24.0	23.0	26.3

¹ Lower minimal morning PEF variation corresponds to a higher variability in lung function.

moulds were reported except for upper respiratory symptoms in relation to reported moulds.

Table 4 gives the crude and adjusted associations between the home dampness indicators and health outcomes. For reported moisture stains no significant effects on PEF variability was present. For moulds, there was an effect on the PEF variability in the crude analysis but in the adjusted analysis the effect was not significant anymore.

Table 4 also shows that the prevalence of respiratory symptoms was higher when either moisture stains or mould were reported. However, significance was not reached. Also the prevalence of bronchodilator use was not significantly related to either moisture stains or mould. In the group of children with symptoms during the observation period, all period prevalence ratios (PRRs) were above unity, several of them reaching statistical significance levels of less than 0.05. In this group, bronchodilator use was also related with moisture stains and mould.

The use of bronchodilators might be an intermediate variable because it may lead to increased PEF and amelioration of respiratory symptoms. Therefore analyses were done leaving out the group of children that used bronchodilators. The differences in the results (not shown) compared with the former analyses were small, however.

Stratified analyses were carried out using the variables of bronchodilator use, use of unvented gas-fired water heaters,

unvented heaters, gas for cooking, crowding and age of the residence for stratification. For reported moisture stains as well as moulds the variability ratios for PEF, and the PRRs for respiratory symptoms were in almost all analyses higher in homes where unvented heaters were used compared to the absence of such heaters. No other differences were found.

The results of the analyses of regional differences in Europe are shown in Table 5. For PEF, the variability ratios for reported moisture stains in South Europe were lower than unity. In the case of reported moulds the variability ratios in East Europe were also lower than unity. In the children who reported symptoms during the study period, the PRRs for cough, phlegm and lower respiratory symptoms were highest in houses with moisture stains in East Europe.

Table 6 gives the results of an analysis with atopy as the stratification variable. The children with a positive reaction to one or more of the six tested allergens were classified as atopic ($n = 716$). No differences were found in PEF variability in atopic or non-atopic children in relation to reported moisture stains. With moulds the PEF variability ratios for atopic children were higher than for non-atopic children. In the group of children who reported symptoms during the study period, the PRRs for moulds as well as moisture stains in relation to cough, phlegm, and bronchodilator use were higher in the atopic children.

Table 4. Crude and adjusted associations between moisture stains and moulds and respiratory morbidity indices

Lung function	Variability ratios					
	Moisture			Moulds		
	Crude	Adjusted ¹		Crude	Adjusted ¹	
		95% CI			95% CI	
PEF variation within days	0.99	0.98	0.92–1.03	1.06†	1.05	0.98–1.12
CV morning PEF	0.99	0.98	0.92–1.04	1.03	1.04	0.97–1.11
CV evening PEF	1.01	1.01	0.95–1.07	1.03	1.04	0.97–1.11
Min. morning PEF variation	1.00	0.99	0.97–1.02	1.01	1.00	0.97–1.03
Prevalance of respiratory symptoms in whole group	Prevalence rate ratio					
Cough	1.02	1.01	0.89–1.16	1.01	1.01	0.87–1.18
Phlegm	1.03	1.05	0.89–1.23	1.03	1.06	0.88–1.27
Lower respiratory symptoms	1.11	1.04	0.88–1.24	1.09	1.03	0.84–1.26
Upper respiratory symptoms	1.02	1.03	0.91–1.17	1.00	1.00	0.86–1.16
Bronchodilator use	1.03	1.00	0.78–1.29	1.15	1.09	0.82–1.45
PSD ² of respiratory symptoms in group with symptoms	Period prevalence ratio					
Cough	1.11	1.11	0.97–1.28	1.19‡	1.17‡	1.00–1.37
Phlegm	1.19‡	1.16	0.98–1.38	1.19	1.19	0.97–1.46
Lower respiratory symptoms	1.17	1.09	0.90–1.33	1.17	1.09	0.86–1.38
Upper respiratory symptoms	1.15‡	1.11	0.99–1.26	1.34*	1.32*	1.15–1.52
Bronchodilator use	1.34‡	1.31	0.98–1.74	1.49‡	1.39	1.00–1.95

‡ $P < 0.05$; * $P < 0.005$. ¹ Adjusted for study centre, smoking in the living quarters, heating, own bedroom, pets, education of parents, age of residence. ² PSD = Percentage of Symptom Days.

Because home dampness is possibly associated with house dust mite allergen exposure, a second analysis on atopy was done using only a positive skin-prick test on *Dermatophagoides pteronyssinus* as indication for atopy ($n = 257$). The results of this analysis were not different from the analysis of all atopic children, however, (data not shown). Analysing the data after restriction of children with a positive SPT for moulds ($n = 67$) showed that mould allergic children living in houses with moulds had a variability ratio for PEF of about 1.7. The results of the analysis of respiratory symptoms were unstable because of the small number of children with a positive SPT for moulds.

Discussion

In this study, PEF variability in atopic children was found to

be associated with reported moulds in the home. In non-atopic children, there was no relationship between home dampness and PEF variability. In children who reported respiratory symptoms or medication use during the period of observation, the period prevalence of several respiratory symptoms and bronchodilator use was also associated with moulds, as well as with moisture stains in the home. These associations were generally stronger in atopic children.

Several indices of PEF variability were evaluated. The strongest associations with home dampness were generally found for PEF variability within days. An explanation might be that daily PEF variability is a better indicator of changes in respiratory health than other indicators of PEF variability [26].

To what extent could these results have been influenced by bias? It has been suggested that awareness of a possible

Table 5. Regional differences within Europe for the association between moisture stains and moulds and respiratory morbidity indices. Associations adjusted for study centre, smoking in the living quarters, heating, own bedroom, pets, education of parents, age of residence

	Variability ratios for moisture stains						Variability ratios for moulds					
	North-West Europe		Eastern Europe		Southern Europe		North-West Europe		Eastern Europe		Southern Europe	
	95% CI		95% CI		95% CI		95% CI		95% CI		95% CI	
PEF variability index												
PEF variation within days	0.97	0.88–1.06	1.00	0.92–1.10	0.92	0.79–1.08	1.07	0.96–1.19	1.00	0.90–1.11	1.11	0.93–1.31
CV morning PEF	1.01	0.92–1.11	0.99	0.91–1.09	0.90	0.77–1.04	1.07	0.95–1.19	0.92	0.83–1.03	1.05	0.89–1.25
CV evening PEF	1.02	0.93–1.13	1.03	0.94–1.14	0.90	0.78–1.05	1.08	0.97–1.21	0.92	0.82–1.03	1.03	0.87–1.22
Minimal morning PEF variation	1.00	0.96–1.03	1.01	0.96–1.05	0.95	0.89–1.02	1.04	0.99–1.08	0.97	0.92–1.01	1.01	0.93–1.08
	PSD ¹ ratios for moisture stains, of respiratory symptoms in group with symptoms						PSD ¹ ratios for mould, of respiratory symptoms in group with symptoms					
PSD of respiratory symptoms in group with symptoms												
Cough	1.04	0.83–1.32	1.26‡	1.01–1.52	1.02	0.74–1.40	1.27	0.97–1.66	1.09	0.86–1.38	1.21	0.84–1.73
Phlegm	1.01	0.75–1.36	1.35‡	1.03–1.79	1.13	0.76–1.68	1.19	0.84–1.67	1.28	0.92–1.78	1.13	0.74–1.73
Lower respiratory symptoms	1.03	0.74–1.43	1.27	0.94–1.73	0.99	0.62–1.60	1.14	0.76–1.70	1.07	0.74–1.45	1.14	0.68–1.91
Upper respiratory symptoms	1.15	0.94–1.41	1.09	0.91–1.30	1.09	0.82–1.46	1.43‡	1.11–1.83	1.28‡	1.04–1.58	1.25	0.90–1.73
Bronchodilator use	1.46	0.89–2.39	1.22	0.72–2.06	1.30	0.76–2.22	1.56	0.89–2.75	1.50	0.80–2.81	0.99	0.56–1.77

‡ $P < 0.05$; * $P < 0.005$. ¹ PSD = Percentage of Symptom Days.

relationship between living in a damp home and respiratory morbidity may lead to over-reporting of symptoms by inhabitants of damp homes, or over-reporting of home dampness by subjects with respiratory symptoms, or both [10]. Our study is vulnerable to these biases to some extent, as we did not collect objective information about home dampness and respiratory symptoms. However, our assessment of PEF variability was based on objective measurements, and we consider it unlikely that children living in damp homes would know how to bias the results of the PEF measurements in a manner that would lead to a biased relationship between home dampness and PEF variability. Also, we collected objective information on atopy by performing skin-prick tests. The tests were performed and read without knowledge of the questionnaire information, and we consider the difference between atopics and non-atopics in their respective associations between home dampness and respiratory morbidity as arguing against reporting bias as well. Acute respiratory infections are well known to affect PEF variability and respiratory symptoms, which in turn may lead to increased use of bronchodilators. No objective data was collected on respiratory infections, although in all panels, the daily prevalence of 'fever' was noted in the diaries. However, 'fever' was rarely reported in the diaries, and was unrelated to reporting of home dampness.

The stronger associations we found in the atopic children

are intriguing. In a case control study we conducted in The Netherlands, we found that associations between home dampness and respiratory morbidity seemed to be largely mediated by house dust mite allergy [14]. In a study on Dutch schoolchildren with asthmatic symptoms Zock *et al.* [15] found a positive relation between daily PEF variability and exposure to house dust mite allergen measured in floor dust from carpeted bedroom floors. In another study on Dutch asthmatic children, Voûte *et al.* [16] found that daily PEF variability in children sensitized to dust mites was associated with the house dust mite allergen contents of their mattress dust. Other studies [14,17,18] have documented associations between mite allergen exposure in the home and medication requirements as well as peak flow variability in asthma patients. If moulds are an 'indicator' of the presence of elevated dust mite concentrations in house dust, our results are compatible with the effects of dust mite allergen exposure documented in the literature. However, restriction of our analyses to subjects with a positive SPT to house dust mite did not make the associations stronger, which argues against a specific role for house dust mite allergy in the present study. Restriction to subjects with a positive SPT for moulds did result in a stronger association with PEF variability, which suggests that mould allergy may be important in the European populations we studied in the framework of the PEACE study.

Table 6. Associations between reported moisture stains and moulds, and respiratory morbidity indices stratified for atopy, adjusted for study centre, smoking in the living quarters, heating, own bedroom, pets, education of parents, age of residence

PEF variability index	Variability ratios for moisture stains				Variability ratios for mould			
	Non-atopic		Atopic		Non-atopic		Atopic	
	95% CI		95% CI		95% CI		95% CI	
PEF variation within days	0.99	0.92–1.07	0.99	0.90–1.08	1.05	0.96–1.15	1.15‡	1.03–1.28
CV morning PEF	1.00	0.92–1.09	1.02	0.93–1.11	1.05	0.95–1.16	1.11	0.99–1.24
CV evening PEF	1.01	0.93–1.10	1.04	0.95–1.14	1.05	0.95–1.16	1.10	0.98–1.22
Min. morning PEF variation	1.00	0.97–1.03	0.99	0.95–1.03	1.00	0.96–1.04	1.02	0.97–1.06
PSD ¹ ratios for moisture stains of respiratory symptoms in group with symptoms					PSD ¹ ratios for mould, of respiratory symptoms in group with symptoms			
PSD of respiratory symptoms in group with symptoms								
Cough	1.03	0.85–1.25	1.18	0.96–1.45	1.05	0.84–1.31	1.30‡	1.02–1.65
Phlegm	1.08	0.83–1.41	1.29	0.99–1.69	1.05	0.77–1.42	1.45‡	1.07–1.97
Lower respiratory symptoms	1.13	0.84–1.52	0.97	0.73–1.29	1.08	0.77–1.50	1.03	0.73–1.47
Upper respiratory symptoms	1.24‡	1.05–1.48	1.05	0.87–1.26	1.41*	1.15–1.72	1.23	0.98–1.54
Bronchodilator use	0.90	0.55–1.46	1.49	1.00–2.24	1.01	0.59–1.71	1.69‡	1.05–2.71

‡ $P < 0.05$; * $P < 0.005$. ¹ PSD = Percentage of Symptom Days.

Stratification for European regions show that for reported moisture stains the associations with PEF variability and respiratory symptoms were somewhat stronger in Eastern Europe than in North-West or Southern Europe. For reported moulds, the associations were somewhat stronger in North-West Europe. The greatest difference between European regions was found in the use of bronchodilators in relation to moulds: the period prevalence ratio (PRR) in Eastern Europe was 1.6 times higher than in Southern Europe. The 95% confidence interval was large, however. In view of this, we hesitate to put too much weight on the differences that were found. An explanation for differences between the regions might be different reporting habits for the respiratory symptoms caused by linguistic or cultural differences. However, such factors can not explain the differences between the regions for PEF variability, as this is derived from objective measurements.

Stratification for atopy showed that for atopic children living in houses with moulds, PEF variability was greater than in non-atopic children. In children living in houses with moisture stains, no differences were found between atopic and non-atopic children with respect to variation in PEF. The presence of moisture stains does not necessarily lead to the presence of allergens and therefore, mould reports are more strongly associated with allergy-mediated effects on

PEF. In the analyses of symptoms and bronchodilator use, associations in the atopic children were stronger for moulds than for moisture stains, which points in the same direction. In studies on the relationship between chronic respiratory symptoms and home dampness, associations between mould and respiratory morbidity have tended to be stronger than associations between moisture stains and respiratory morbidity as well [4,5,8,9].

The difference, on a group level, of PEF variability between exposed and unexposed children was not large, with the exception of the mould allergic children in whom the PEF variability was 1.7 times larger when exposed to mould than when unexposed. The mean PEF variabilities of generally less than 10% would not be of clinical concern, but we need to realize that these means are the results of averaging over a large number of days within individuals, and then averaging over a large number of individuals within exposure categories. It is well known that small shifts in the population distribution of variables such as PEF variability or lung function level may significantly increase the proportion of subjects with clinically important increases of PEF variability, or lung function reductions [27,28]. Relatively small shifts in the means of such population distributions therefore need to be viewed with some concern.

In conclusion, PEF variability in atopic children was associated with reported moulds in the home. In children who reported respiratory symptoms or medication use during the period of observation, the period prevalence of several respiratory symptoms and bronchodilator use was also associated with moulds, as well as with moisture stains in the home. These associations were generally stronger in atopic children, and stronger for mould than for moisture stains in the home.

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