ENVIRONMENTAL EXPOSURE

Prevalence and incidence of respiratory symptoms in relation to indoor dampness: the RHINE study

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Background: An association between indoor dampness and respiratory symptoms has been reported, but dampness as a risk factor for the onset or remission of respiratory symptoms and asthma is not well documented.
Method: This follow up study included 16 190 subjects from Iceland, Norway, Sweden, Denmark, and Estonia who had participated in the European Community Respiratory Health Survey (ECRHS I). Eight years later the same subjects answered a postal questionnaire that included questions on respiratory symptoms and indicators of indoor dampness.
Results: Subjects living in damp housing (18%) had a significantly ($p<0.001$) higher prevalence of wheeze (19.1% *v* 26.0%), nocturnal breathlessness (4.4% *v* 8.4%), nocturnal cough (27.2% *v* 36.5%), productive cough (16.6% *v* 22.3%) and asthma (6.0% *v* 7.7%). These associations remained significant after adjusting for possible confounders. Indoor dampness was a risk factor for onset of respiratory symptoms but not for asthma onset in the longitudinal analysis (OR 1.13, 95% CI 0.92 to 1.40). Remission of nocturnal symptoms was less common in damp homes (OR 0.84, 95% CI 0.73 to 0.97).
Conclusions: Subjects living in damp housing had a higher prevalence of respiratory symptoms and asthma. Onset of respiratory symptoms was more common and remission of nocturnal respiratory symptoms was less common in subjects living in damp housing.

Indoor dampness in the home is a very common phenomenon. An estimated 17–24% of homes in the Nordic countries, 25% in the Netherlands, and 37% in Canada and New Zealand exhibit signs of indoor dampness such as water leakage or visible moulds on walls, floor or ceilings.[1–6] It has been noted that disabilities due to respiratory symptoms such as cough, wheeze and asthma have generally increased, as have the costs for treatment.[7]

Exposure to dampness at home or at work is related to respiratory symptoms such as cough, wheeze and, in some studies, asthma.[4 8–10] Most studies are, however, cross sectional and the available evidence on indoor dampness as a cause for asthma is insufficient. There are no existing longitudinal studies on whether respiratory symptoms are alleviated in a dry home environment.

It is important to investigate whether indoor dampness is a cause of respiratory disease in order to limit such exposure via public information and regulation. The aims of this study were to analyse the association between indoor dampness and respiratory symptoms in a cross sectional study, followed by a longitudinal analysis of indoor dampness as a risk factor for onset and remission of respiratory symptoms and asthma.

METHODS

Study design and target population

The Respiratory Health in Northern Europe (RHINE) study (www.rhine.nu) is a follow up study of subjects who participated in the European Respiratory Health Survey (ECRHS) stage I in 1990–4.[11] In stage I, men and women aged 20–44 years were randomly selected from the population register in each participating centre. A postal questionnaire was sent to 3000–4000 subjects at each centre.[12]

The target population for the RHINE study were all subjects from Reykjavik in Iceland, Bergen (Norway), Umeå, Uppsala and Göteborg (Sweden), Aarhus (Denmark), and Tartu (Estonia) who had responded in stage I of the ECRHS ($n = 21\,802$, response rate 84%). Eligible subjects from ECRHS stage I still alive in 1999–2001 received a postal questionnaire. Subjects not responding to the first mailing received two reminders. The local ethic committees at each centre approved the study protocols.

Signs of building dampness

Exposure to indoor dampness was considered if any of the following three damage types had been observed within the housing during the last 12 months: (1) water leakage or water damage indoors on walls, floor or ceilings; (2) bubbles or yellow discoloration on plastic floor covering or black discoloration of parquet floor; or (3) visible mould growth indoors on walls, floor or ceilings. Subjects reporting one or more signs of dampness are referred to as reporting any sign of indoor dampness in the last 12 months.

For the longitudinal analysis, signs of indoor dampness were based on a separate question where subjects were asked if they had had any water damage, leakage or mould growth in the home between the surveys. Based on the answer to this question, the homes were classified as being damp or dry.

Questions on participant housing specifications such as year of building and housing type (apartment, semi-detached, detached) were also included.

Respiratory symptoms

Respiratory symptoms were defined as a positive reply to any of the following four signs during the past 12 months: (1) wheezing or whistling in the chest; (2) being woken by an attack of shortness of breath; (3) being woken by an attack of coughing; or (4) usually bring up phlegm or have any

problem in bringing up phlegm. Subjects reporting any of these were considered to have respiratory symptoms.

Onset of respiratory symptoms was defined as reporting no symptoms in the first survey but reporting symptoms in the follow up survey. A converse response was subsequently defined as a remission of respiratory symptoms.

Asthma was defined as reporting an attack of asthma and/or the use of asthma medication in the last 12 months. Onset of asthma was defined as a negative answer to both of these questions in the first survey but responding positively to either question in the follow up.

Socioeconomic index

A socioeconomic index was created using information on current occupation. On the basis of this, the subjects were divided into the following five categories: (I) Managers and professionals; non-manual (legislators, senior officials, managers and professional); (II) Other non-manual (technicians and associate professionals, clerks, service workers and market sales workers); (III) Skilled manual (skilled agricultural and fishery workers and craft and related trades workers); (IV) Semi-skilled or unskilled manual (plant and machine operators and assemblers and elementary occupations); and (V) Unclassifiable or unknown (housewife, student, not classifiable job, unemployed, not working because of poor health and retired).

Other variables

Body mass index (BMI) was calculated as weight (kg)/height (m^2). Based on questions on smoking habits in the follow up study, subjects were classified as smokers, ex-smokers or current smokers. The definition ''having rhinitis'' was based on a positive answer to the question: ''Do you have any nasal allergies including hay fever?''

Statistical analysis

Statistical analysis was performed using Stat View 5.0 (SAS Institute Inc, Cary, NC, USA) and Stata 8.0 (Stata Corporation, College Station, Texas, USA). The χ^2 test and unadjusted logistic regression were used when comparing subjects living in dry versus damp homes. Multiple logistic regression analysis was performed on aggregate data from all centres in order to analyse the influence of different risk factors, and the results are presented as adjusted odds ratios (OR) with 95% confidence interval (CI). Indicators of indoor dampness were entered one at a time in the analysis. To detect any significant heterogeneity between centres in the relationship between indoor dampness and respiratory symptoms, the adjusted OR was calculated for each centre. A mean effect estimate was derived and potential heterogeneity between centres was examined using standard methods for random effects meta-analysis.[13] A p value of <0.05 was regarded as statistically significant.

RESULTS

A total of 16 190 subjects responded to the questionnaire (response rate 74.2%). The mean (SD) age of the subjects was 40 (7) years and 8587 (53%) were women. The mean follow up time was 7.9 (1) years. A total of 15 995 subjects responded to one or more questions on building dampness.

Non-responders to the follow up survey were somewhat younger than responders (30.8 *v* 31.9 years, $p<0.0001$) with a larger proportion of men (53.4% *v* 46.6%, $p = 0.001$). Non-responders reported more wheeze (24.1% *v* 21.5%, $p<0.0001$) and more nocturnal symptoms in 1990–4 than responders (16.1% *v* 13.9%, $p = 0.001$). No significant difference was found between responders and non-responders with regard to the prevalence of asthma in 1990–4 (4.3% *v* 4.7%, $p = 0.20$).

In the second survey 18% of the subjects reported exposure to indoor dampness during the previous 12 months. Water damage was reported by 13.4%, dampness in floor material by 3.8%, and visible moulds by 6.7%. Indoor dampness was observed by 27% of the subjects since the previous survey (table 1). Reports of respiratory symptoms in the second survey show that 20.6% of the subjects reported wheeze, 5.3% reported nocturnal breathlessness, 29% reported nocturnal cough, 18% productive cough, and 6.7% of the subjects reported asthma.

The characteristics of the study population based on reported indoor dampness are presented in table 2. Subjects living in damp homes were younger and a larger proportion of them were women. Significant differences were also found when looking at building type and age, with indoor dampness being more common in older apartments.

All four respiratory symptoms and asthma were significantly more prevalent in subjects exposed to indoor dampness (table 2). These associations remained significant after adjustment for possible confounders such as age, study centre, sex, body mass index, rhinitis, smoking status, type of housing, age of the building, and socioeconomic status. All three indicators of indoor dampness (water damage, dampness in the floor material, and visible mould) were significant risk factors for every respiratory symptom, but water damage was not found to be a significant risk factor for asthma (table 3). The strongest associations were found between dampness in floor material and all respiratory symptoms and asthma.

In the longitudinal analysis, data from the ECRHS I is used together with RHINE data to identify 1488 subjects with onset of wheeze, 551 with onset of nocturnal breathlessness, 551 with onset of nocturnal cough, and 596 subjects with onset of asthma. Onset of respiratory symptoms was more common in subjects living in damp homes. The prevalence for onset of respiratory symptom in dry versus damp homes was 11.1% *v* 13.7%, for wheeze ($p = 0.0001$), 3.2% *v* 4.4% for nocturnal breathlessness ($p = 0.0006$), 18.7% *v* 22.4% for nocturnal cough ($p<0.0001$), and 3.8% *v* 4.1% for asthma

Table 1 Prevalence of indoor dampness (%)

	Water damage	Wet floors	Visible moulds	Any dampness	Dampness between surveys
Reykjavík	20.1	6.4	6.6	22.9	33.6
Aarhus	14.4	2.1	10.1	18.9	21.8
Bergen	13.4	2.2	4.5	16.4	29.8
Göteborg	7.7	4.5	4.5	12.1	21.3
Uppsala	9.1	4.1	6.2	14.6	26.4
Umeå	9.8	5.4	3.5	13.9	23.6
Tartu	23.4	2.6	13.6	31.6	34.5
Total	13.4	3.8	6.7	18.0	26.7

Table 2 Characteristics of the study population and prevalence of respiratory symptoms and asthma in dry versus damp homes

	Any dampness		
	No (n = 13122)	Yes (n = 2873)	p value
Mean (SD) age (years)	40.1 (7.3)	38.5 (7.2)	<0.0001
Women	52.1	57.0	<0.0001
Smoking history			0.0008
Never smokers	46.2	42.9	
Ex-smokers	25.1	25.2	
Current smokers	28.6	31.9	
Type of housing			<0.0001
Apartment	40.2	50.4	
Semi-detached	15.5	14.3	
Detached	44.2	35.2	
Age of housing (years)			<0.0001
0–10	10.7	5.9	
11–20	19.6	16.4	
21–40	34.1	36.0	
>40	35.7	41.7	
Respiratory symptoms			
Wheeze	19.1	26.0	<0.0001
Nocturnal breathlessness	4.4	8.4	<0.0001
Nocturnal cough	27.2	36.5	<0.0001
Productive cough	16.6	22.3	<0.0001
Asthma	6.0	7.7	0.0009

Values are percentages unless otherwise stated.

onset (p = 0.30). Remission from nocturnal respiratory symptoms between the two surveys was less likely in subjects living in damp homes (p = 0.002).

After adjusting for possible confounders (age, study centre, sex, body mass index, rhinitis, smoking status, type of housing, age of building, and socioeconomic status), indoor dampness was found to be an independent risk factor for onset of respiratory symptoms but not for asthma onset. Indoor dampness was also found to be an independent risk factor for persistent nocturnal symptoms such as breathlessness and cough (table 4).

The association between indoor dampness and respiratory symptoms was assessed by meta-analysis in order to detect heterogeneity between the centres (fig 1). Meta-analyses were also performed for the association of the incidence and remission of symptoms and asthma in relation to building dampness. In all analyses the estimates were almost identical to those derived when analysing the pooled data and no significant centre heterogeneity was detected (p>0.10).

DISCUSSION

The main findings in this study are that subjects living in damp homes have a higher prevalence of respiratory symptoms and asthma. The onset of respiratory symptoms in the period between the two surveys was more common in subjects living in damp homes, and the remission of nocturnal respiratory symptoms was less common in those in damp homes. These findings remained significant after adjusting for possible confounders.

To the best of our knowledge, this is the largest study to have addressed the effects of dampness in the home on respiratory symptoms in adults. It is also the first study to address the long term effect of dampness on the onset and remission of respiratory symptoms and asthma in adults. The adverse effect of dampness on respiratory health has been suspected for many years. Many large cross sectional prevalence studies on both adults and children have confirmed this.[4 8 14 15] A meta-analysis performed by Peat *et al* adds further support to these findings, and in a recent review on the subject the authors concluded that ''dampness in buildings appears to increase the risk for health effects in the airway such as cough, wheeze and asthma'' with the relative risk in the range of odds ratios 1.4–2.2.[9 10] The results of our current study concur with the findings of these previous studies.

Signs of indoor dampness during the previous 12 months were reported by 18% of the present population and by 27% of the subjects in the longitudinal analysis. Other Scandinavian studies have reported the prevalence of indoor dampness as 17–24%,[1–3] and our findings are thus in accordance with earlier findings in the region.

Indoor dampness was identified as an independent risk factor for the onset of respiratory symptoms in the longitudinal analysis. It is recognised that dampness facilitates the growth of microorganisms such as bacteria and moulds.[16 17] It is also acknowledged that dampness can trigger processes within building materials, and can result in the release of airway irritating fumes into the indoor environment.[1 2 18] Higher levels of house dust mite allergens

Table 3 Adjusted* odds ratio (OR) with 95% confidence intervals (CI) for respiratory symptoms and asthma in relationship to indoor dampness

	Water damage	Wet floors	Visible moulds	Any dampness
Wheeze	1.32 (1.17 to 1.49)	1.54 (1.25 to 1.90)	1.54 (1.31 to 1.80)	1.38 (1.24 to 1.53)
Nocturnal breathlessness	1.81 (1.50 to 2.19)	2.58 (1.93 to 3.45)	1.72 (1.35 to 2.20)	1.80 (1.51 to 2.15)
Nocturnal cough	1.34 (1.21 to 1.49)	1.66 (1.38 to 2.00)	1.41 (1.22 to 1.63)	1.40 (1.28 to 1.54)
Productive cough	1.34 (1.18 to 1.51)	1.52 (1.23 to 1.87)	1.36 (1.15 to 1.61)	1.34 (1.20 to 1.50)
Asthma	1.18 (0.95 to 1.44)	1.67 (1.22 to 2.27)	1.53 (1.18 to 1.98)	1.27 (1.06 to 1.52)

*All values are adjusted for age, study centre, sex, body mass index, rhinitis, smoking status, type of housing, age of the building, and socioeconomic status. Each variable for indoor dampness was entered one at a time.

Table 4 Adjusted* odds ratios for onset and remission of respiratory symptoms and asthma in relationship to reported indoor dampness between surveys

	Onset in damp homes	Remission in damp homes
Wheeze	1.28 (1.12 to 1.46)	0.88 (0.74 to 1.03)
Nocturnal breathlessness	1.33 (1.09 to 1.63)	0.68 (0.48 to 0.96)
Nocturnal cough	1.26 (1.13 to 1.41)	0.84 (0.73 to 0.97)
Asthma	1.13 (0.92 to 1.40)	0.65 (0.36 to 1.17)

*All values are adjusted for age, study centre, sex, body mass index, rhinitis, smoking status, type of housing, age of building, and socioeconomic status.
Subjects reporting onset of respiratory symptoms were compared with those with no symptoms or asthma in both surveys. Subjects reporting remission of respiratory symptoms were compared with those with persistent symptoms or asthma.

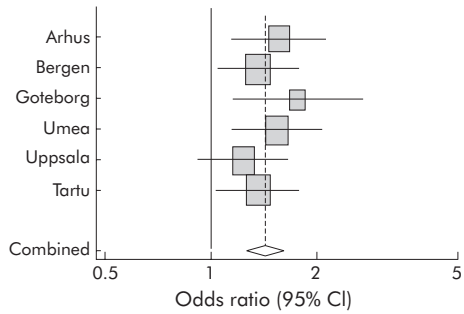

Figure 1 Adjusted odds ratios and 95% confidence intervals of wheeze in subjects living in homes with reported dampness compared with those living in homes without dampness (adjusted within centre for age, sex, smoking history, type of housing and age of home, rhinitis, body mass index, and socioeconomic status) with a combined odds ratio (diamond indicates 95% confidence interval) from the model with centre as the random effect. The size of each square is proportional to the sample size.

have also been noted in damp homes.[17] Nicolai *et al*[19] reported that dampness at home during childhood was a significant risk factor for the persistence of bronchial hyperresponsiveness and respiratory symptoms, but that this risk could only partially be explained by exposure to house dust mite antigen. Sears *et al*[20] recently reported that sensitisation to house dust mite, bronchial hyperresponsiveness, female sex, smoking, and early onset of asthma were all risk factors for relapsing or persistent wheeze in adulthood.

Indoor dampness was not found to be an independent risk factor for asthma onset in the longitudinal analysis. Very few studies have looked prospectively at indoor dampness as a risk factor for the onset of asthma in adults. In a 3 year prevalent case-control study, visible moulds and/or mould odour in the work place were found to be risk factors for onset of asthma in adults.[21] Another study has reported that working in buildings affected by dampness and mould resulted in a fourfold risk of asthma.[22] A positive relationship has been reported between allergic sensitisation to moulds and the severity of asthma.[23] A Swedish case-control study found that sensitisation to moulds was more common in damp housing and related to current asthma in adults.[24] In a publication issued by the European Community Respiratory Health Survey (ECRHS), mould exposure was associated with asthma symptoms and bronchial responsiveness. In centres with a higher prevalence of indoor mould exposure, the prevalence of asthma was also found to be high.[25]

The lack of a positive association between onset of asthma and indoor dampness in this study is probably not explained by a lack of power as it included 596 new asthma cases. A possible explanation is that floor dampness was the indicator with the strongest relationship to asthma in the cross sectional analysis. Dampness in the floor material is a sign of dampness in the building construction, and this does not necessarily correlate to high indoor air humidity. On the other hand, visible mould is a sign of high indoor humidity, water leakage, and/or poor ventilation. The longitudinal analysis was only based on a single question with no differentiation between different types of building dampness.

Our data support the view that living in a dry home facilitates remission of nocturnal respiratory symptoms since remission was less likely in damp homes. This is a new finding. Most studies have looked at risk factors for the onset of diseases or symptoms and not for factors that increase the chance of remission. One factor known to increase the chance of remission in childhood asthma and to reduce the risk of asthma onset is early contact with older children. Such contact is a marker of prolonged intermittent exposure to infectious agents.[26]

Several methodological issues in this study need to be addressed. The study is exclusively based on self-reported data with no objective measurement and the information on building dampness in the longitudinal analyses was collected retrospectively. Good reproducibility of self-administered questions on building humidity, visible moulds, and flooding has been reported.[1 27] The questions used in the RHINE study have been validated with regard to the relationship between observed and self-reported dampness. The sensitivity and specificity for the presence of at least one sign of building dampness were 74% and 71%, respectively.[1]

Recall bias can be a potential problem, as is the possibility that the subjects overestimated or underestimated their personal symptoms and/or signs of indoor dampness. On the other hand, two studies have established that there was no difference in the reporting rate of indoor dampness between symptomatic and non-symptomatic subjects,[28] and that both groups tended to underestimate the signs of indoor dampness.[29] Selective avoidance of damp housing by symptomatic subjects is also a possible source of bias.

This survey is a cross sectional analysis of a follow up study. Therefore, even if the response rate in both stages was reasonably high, only 60% of the original population responded to both questionnaires. Analysis of non-responders to the second survey showed that younger male smokers were less likely to respond and that non-responders reported more respiratory symptoms in the previous survey than responders. This is a possible source of bias, but it is difficult to predict how this might influence our results. Younger people in general report fewer respiratory symptoms than responders in the older age group, but smokers in general report more respiratory symptoms than non-smokers. It is also possible that an unmeasured variable may have confounded the results. It was nevertheless possible to control for the most important covariants such as age, sex, BMI, smoking, rhinitis, type of housing, age of building, socioeconomic status, and different centres.

The strength of this study lies in the large sample size which provides sufficient power to control for many potential confounders simultaneously. The study is population based, which suggests that findings can be applied to other similar populations. It is, however, important to keep in mind possible bias in the data (such as selection bias) when discussing the results and applying them to the general population. The validity of our results is to some extent strengthened by the fact that there were no significant differences in the factors associated with asthma or

respiratory symptoms when the results from each study centre were compared.

The relationship between building dampness and respiratory symptoms is once again confirmed by this study, and further cross sectional studies are probably not going to add much to what is currently known. Interventional studies are now required to determine whether or not this is a causal relationship. As indoor dampness is common and can have an adverse effect on respiratory health, preventive work is important. The aim should be avoidance of dampness during building construction, improving indoor ventilation, and effective repairs of water leaks.

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