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BRIEF REPORT

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Adult onset asthma in non-allergic women working in dampness damaged buildings: A retrospective cohort study

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Background: There is still no consensus about the association between working in dampness-damaged buildings and new onset of asthma among adults. The purpose of this study was to assess asthma in the staff of two psychiatric clinics where some premises were suffering from dampness.
Methods: A 20-year retrospective cohort study was performed using questionnaires.
Results: Incidence rate ratios (IRR) for asthma were non-significantly elevated (IRR = 2.3) among exposed individuals. The risk was greater among females (IRR = 3.5, 95% CI 1.0-16). IRR for non-atopic women was 8.8 (95% CI 1.4-196). Adjusting for smoking habits weakened the risks marginally (IRR = 7.3, 95% CI 1.1-167). The number of male participants was too low to draw conclusion regarding the risk for men.
Conclusion: The results suggest that working in dampness-damaged buildings might be a possible health hazard. This finding is most pronounced in non-atopic females.

KEYWORDS
asthma, dampness damaged buildings, retrospective cohort study, susceptible groups

1 | INTRODUCTION

Many studies have reported an association between dampness damaged buildings and an increased risk of respiratory symptoms and disorders. A Nordic Interdisciplinary review concluded that dampness in buildings appears to increase the risk of coughs, wheezing and asthma; the relative risks for these disorders are in the range 1.4-2.2.[1] The review also noted elevated rates of other symptoms among the inhabitants of dampness damaged buildings; these include tiredness, headaches and airway infections.

Torén et al reviewed the international literature on dampness damaged buildings and the possible risk of asthma in adults (ie, individuals over 18 years old).[2] Twenty-eight relevant articles published between 1980 and 2009 were identified and found to be of satisfactory quality. Unlike Bornehag et al, Torén et al concluded that there is no evidence to support the existence of an excess risk of new asthma-onset in adults due to living in dampness damaged buildings.[1,2] The discrepancy between these two conclusions may be due to the fact that most of the articles reviewed by Bornehag et al focused on children, while Torén et al focused on adults. Another review by Mendell et al presents three meta-analyses of the effects on respiratory organs of living in dampness damaged buildings.[3] These analyses suggest that the odds ratio for asthma among individuals (adults and children combined) living in dampness damaged buildings is around 1.3.

In a review and meta-analysis on the risk of developing asthma based on 14 studies on children and two on adults the authors find an elevated risk for incident asthma in one of the study on adults, as well as in most of the studies on children.[4] WHO (2009) in their guidelines for indoor air quality concludes that that there is sufficient evidence of an association between indoor dampness related factors and asthma development.[5] The WHO guidelines did not perform a formal meta-analysis. Instead, the WHO guideline refers to meta-analyses by Fisk et al.[6] Their key results includes odds ratio of 1.34 for asthma development (not statistically significant based) on four studies on adults.

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The literature on the health effects of living in dampness damaged buildings is extensive and features contradictory conclusions. We have had the opportunity to study the health effects of long-term exposure in a well-defined occupational group and compare these with a similar but unexposed category of employed individuals. We decided to take advantage of the opportunity in order to address the lack of clarity in this area.

The aim of this study was to evaluate the risk of new-onset adult asthma resulting from working in buildings that are known to be suffering from dampness.

2 | MATERIALS AND METHODS

In 2009, all staff working at two psychiatric clinics in the same health care region were invited to complete a questionnaire containing 15 questions. In total 673 members (clinic A; $n = 243$, clinic B; $n = 430$) were invited to participate in the study. Three postal reminders were issued. We received responses from 74 % in clinic A ($n = 180$) and 48 % in clinic B ($n = 206$), in total 386 individuals (57%). In total 220 individuals (157 in clinic A and 63 in clinic B) was exposed to dampness at their workplace for a shorter or longer time during the study period. There were 29 were asthmatics whose year of diagnosis predated the start of this study period (1990). Four individuals could not give information about the year of start of exposure despite repeated questions from our group. Thus, 353 subjects were included in the study.

A six-page questionnaire was distributed to staff at two psychiatric clinics in 2009.

The questionnaire was designed by our group to give information about exposure to dampness damaged locations at the two hospitals. The questionnaire included questions about respondents' length of employment at their current workplace, the positions they had held between 1990 and 2008/09 and which clinic, department and rooms they had worked in. This information was combined with an assessment carried out by external building consultants in order to classify each individual as exposed or unexposed.

The questions about health concerned self-reported allergies and which agents respondents were allergic to (pollen, animal or other); symptoms upon contact with the allergen(s); and any allergy tests they had taken. To be classified as asthmatic, respondents had to respond positively to the question about physician-diagnosed asthma and year of diagnosis. For respondents to be classified as atopic, they had to confirm that they had had a diagnosis of allergy before the age of 16.

Respondents were also asked to say whether they had ever been prescribed any medicines for more than three months or whether they had ever suffered a long-term illness (over 6 months). Smoking habits were categorized from the answers to questions about when respondents started and stopped smoking and number of cigarettes per day.

If respondents failed to answer a question, our staff contacted them to ask for the missing information.

The project was approved by the Regional Ethical Research Committee of Linköping, no. M 121–08.

Both clinics had suffered from dampness over a period of several years,

Information about the buildings' history and occurrence of dampness were obtained from the property managers. At both clinics, the property managers had used external consultants to assess the extent of the dampness, both old and new damage. The external consultants carried out several inspections of the buildings, in the course of which they noted the smell and visual evidence of dampness in parts of the buildings. Increased levels of VOC found in air samples were thought to originate from the breakdown of flooring adhesive. No elevated levels of microbiological particles were detected in the air, although several material samples contained mould spores.

Psychiatric clinic (A) had extensive dampness resulting from both the nature of its construction and internal leakage from pipes. The older parts of this six-story building date back to the 1970s. It was constructed with a flat roof whose drains are integrated into the building. After approximately 15 years the roof started to leak and water damage was detected in several locations within the building. The damage was repaired but leaks continued to occur until finally part of the building was demolished after this study was performed. The windows in this building had also been poorly sealed, allowing water to penetrate the building via the windows. There were also several internal water leaks due to pipes bursting and inadequate water sealing in the showers. The older parts of the building were brick with a concrete plaster finish on the outside. A newer part of the building dating from the 1980s was a concrete construction. Water leaks had been detected in both the old and the new parts. Inspections revealed the smell of mould, damage to the flooring, and visible patches of dampness on the ceilings and walls on several floors.

Psychiatric clinic (B) was also a brick building with a concrete plaster finish and dated back to the 1970s. However, it did not exhibit any general leakage problems; only smaller localized instances of water damage were reported.

Respondents were classified as exposed or unexposed on the basis of their answers to questions about which hospital, department and rooms they had worked in. These locations were classified as suffering from dampness or not according to the external consultants' reports. Some participants worked elsewhere for part of the study period. Data for those participants for the years in question were excluded from the analysis.

The two psychiatric clinics were similar with regard to other factors such as work task organization and working conditions.

This is a retrospective cohort study.

Incident rate ratios (IRR) for asthma were calculated on the basis of person years from 1990 to the year of asthma diagnosis or to 2009 for non-diagnosed individuals. IRRs were then calculated separately for subgroups based on gender, childhood allergies, smoking habits, and exposure to dampness damaged buildings. Individuals who had been diagnosed with asthma before the start of exposure during the study period 1990-2009 were excluded. Incident rate ratios for the different subgroups were calculated and complemented with a Cox regression

analysis. Unadjusted Kaplan-Meier plots were used to illustrate the cumulative yearly probability of suffering from asthma.

All statistical analyses were performed with Stata v14.0 (StataCorp LP, College Station, TX).

3 | RESULTS

In total, 353 subjects (53% of the invited subjects) fulfilled our inclusion criteria, giving a dataset spanning 4741 person years. Of these person years, 2560 were for individuals not exposed to dampness damaged workplace and 2181 were for individuals who had been exposed to a dampness damaged workplace. Ten respondents declined to provide information about their gender. Overall, 74% of the respondents were female and 26% were male. The respondents' mean age was 48 and their mean length of employment was 13.3 years (Table 1).

Of 2181 person years of exposure to dampness damaged workplaces, ten respondents were diagnosed with asthma. Of 2560 person years without exposure, there were five diagnoses of asthma, yielding an IRR of 2.3 (95% CI 0.8-7.4; see Table 2). A Cox regression HR adjusted for gender and age yielded a similar value; HR = 2.2, 95 % CI 0.7-6.4 (not shown in table).

Stratifying the population by gender revealed an increased risk of asthma in females (IRR = 3.5, 95% CI 1.0-16) but not males (Table 2). Among unexposed women, three incident cases per 1733 person years were found, corresponding to 1.7 cases per 1000 person years. The incident rate in exposed women was 6.1 per 1000 person years. Dividing females and males into subgroups based on allergy in childhood strengthened the risk associated with working in dampness damaged buildings relative to that for women without childhood allergies (IRR = 8.8, 95% CI 1.4-196; see Table 3). Similarly, an age-adjusted Cox regression analysis of females without allergies in childhood yielded a HR of 8.2 (95% CI 1.0-66) for exposure to dampness damaged buildings (data not shown in table). Stratifying the female population by smoking habits marginally affected the risk of asthma: the IRR for non-smoking, non-allergic females was 7.3 (95% CI 1.1-167; not shown in table). A Kaplan-Meier plot was constructed to illustrate the probability of asthma by years of exposure in women (Figure 1). Cumulative incidence rate ratio for asthma in exposed females increased continuously during the study period 1990-2009.

4 | DISCUSSION

Asthma onset was higher among people who worked in buildings which suffered from dampness. This risk primarily affected women, especially those without childhood allergies.

The incidence of asthma among the exposed females in this study was 6.1 per 1000 person-years. The incidence for unexposed females was 1.7 per 1000 (calculations from Table 2). This incidence among the

TABLE 1 Description of the study populations: unexposed vs exposed individuals

	Unexposed		Exposed		Total		
	n	%	*n*	%	*n*	%	*P*-value *
All	131**		222		353		
Females	85	67.5	168	77.4	253	73.8	
Males	41	32.5	49	22.6	90	26.2	
Mean age in 2009	48.25		48.6				0.97
Mean years of employment in 2009	14.4		12.6		13.3		<0.001
Allergy in childhood	19	14.7	48	21.6	67	19	0.12
Incidence of asthma during study period	5	0.04	10	0.05	15	0.04	0.10
Current smoker	29	22.1	39	17.5	68	19.3	0.53
Ex-smoker	46	35.1	83	39.6	129	36.5	0.53
Never smoked	50	38.1	93	41.9	143	40.5	0.53
Pollen allergy	18	14	41	19	59	17	0.30
Allergy to animals	17	13	34	15	51	14	0.64
Allergy to other agents	31	24	59	27	90	26	0.61
Done allergy RAST-testing	14	11	38	17	52	15	0.09
Done allergy skin prick testing	19	15	41	18	60	17	0.46
Provocation allergy testing	1	1	6	3	7	2	0.25
Drug intake for more than 3 months	42	32	70	32	112	32	0.91
Diagnosis or symptoms for more than 6 months	34	26	51	23	85	24	0.52

Ten individuals did not state their gender.

*P-value for x^2 test 2-sided comparing the two groups

**As ten participants did not state their gender the total value are higher than the combined values for men and women.

TABLE 2 Incidence rate ratios for asthma among participants exposed to dampness damaged buildings, calculated as incidences per person-year

Subjects unexposed			Subjects exposed		
	Cases	Person years	Cases	Person years	IRR 95/CI
Females					
Asthma	3	1733	10	1631	3.5 (1.0-16)
Males					
Asthma	2	718	0	505	n.c
All					
Asthma	5	2560[a]	10	2181[a]	(0.8-6.8)

[a]As ten participants did not state their gender the total value are higher than the combined values for men and women.

unexposed is in line with the incidence rate among Swedish adults in a sample of the general population, which is reportedly 1.8/1000 person years for women.[7] The number of men with asthma in our dataset (two) was too low to justify computing an incidence per thousand person years. Because there were so few men in the study, the results obtained by gender segregating the respondents should only be seen as indicative.

Our findings are supported by the literature. A study of office workers in a water-damaged 20-story building in the United States found that the incidence of asthma rose from 1.9/1000 person years before exposure to 14.5/1000 person-years after exposure, giving an incidence rate ratio of 7.5.[8] Women accounted for 73% of the studied population. In a Finnish cohort, the incidence of asthma among the general population was observed to be 1.85 per 1000 person years, whereas that for a study population exposed to indoor dampness at work was 26.7 per 1000 person years.[9] A Swedish case-referent study of asthma in adults reported an odds ratio of 4.6 (95% CI 2.0-10.5) for subjects living in homes with dampness in the floors resulting from construction errors.[10] An earlier population-based case-referent study conducted by our clinic into the incidence of adult asthma found an odds ratio of 4.7 (95% CI 1.5-14.3) among individuals who self-reported dampness at their place of work.[11] A fifth study of adult onset asthma reported significant odds ratios of around two for subjects exposed to visible mold in their homes.[7] Taken together, these results provide reasonably strong indications that dampness damaged buildings have an asthmatogenic effect.

Our study suggests that females are more susceptible than males to adult-onset asthma caused by dampness damaged buildings. We were not able to calculate a meaningful IRR for men since relatively few men worked at the psychiatric clinics in our study. A female-gender susceptibility effect was observed in a Finnish study of adult-onset asthma and indoor dampness,[12] indicating that exposed females were subject to a significant risk of asthma (OR 1.67) but males were not. In a Swedish case-referent study of adult-onset asthma, self-reported visible dampness and mold could be associated with a significantly increased odds ratio (1.8) for females but not for males.[13] Females living with dampness at home are subject to an additional decline in Forced Expiratory Volume according to a longitudinal study with an average follow up time of 8.9 years in eight European countries.[14] The decline was only significant in women. Thus, there seems to be a gender susceptibility in females to dwelling in dampness damaged buildings, that we do not have any profound explanation to. It should

TABLE 3 Incidence rate ratios for asthma in individuals working in dampness damaged buildings, stratified by gender and childhood allergies

Unexposed				Exposed		
		Cases	Person year	Cases	Person year	IRR 95/CI
Females						
Allergy in childhood	+	2	314	2	328	1.0 (0.1-9.2)
	–	1	1401	8	1274	8.8 (1.4-196)
Males						
Allergy in childhood	+	0	64	0	121	nc
	–	2	614	0	364	nc
All						
Allergy in childhood	+	2	378	2	451[a]	0.8 (0.1-8.1)
	–	3	2124[a]	8	1681[a]	3.3 (0.9-16)

nc, not calculable.

[a]As ten participants did not state their gender the total value are higher than the combined values for men and women.

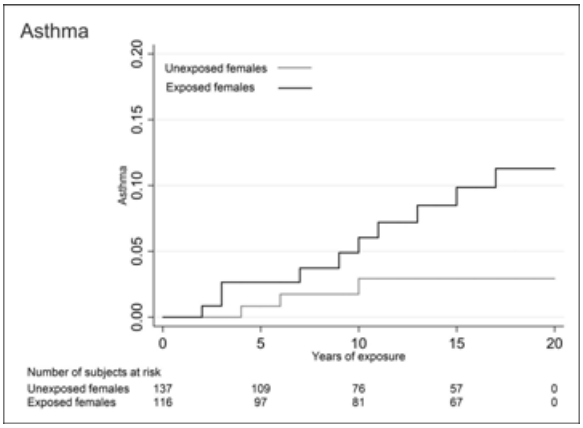

FIGURE 1 Unadjusted Kaplan-Meyer plots of the cumulative probability of asthma for females working in dampness damaged buildings (exposed females) and females not working in dampness damaged buildings (unexposed females)

be noted that female gender per se is a risk factor for adult asthma (see eg, Torén et al[7]). This is described by Koper et al as an oestrogenic effect.[15] Testosterone, on the other hand, has immune-suppressive effects and is suggested to be protective against the immune-inflammatory processes that trigger asthma.[15]

In the present study we obtained information about study participants' self-reported allergic history by using a questionnaire in which we asked about childhood allergies (ie, allergies between birth and age 16) including atopic dermatitis, persistent coughs, hay fever, and red or irritated eyes. We found that not having had a childhood allergy was associated with an increased risk of adult-onset asthma (in females) if they were exposed to dampness at work (see Table 3). Analogously, Cox-Ganser et al found the percentage of atopy in post-occupancy asthmatics was lower than in pre-occupancy asthmatics.[8] On the other hand Karvala et al and Norbäck et al observed no differences in incidence rates of adult-onset asthma between atopic and non-atopic subjects working in damp indoor environments (OR = 5.0).[9,16,17]

As such, the evidence for the importance of atopy for adult-onset asthma among occupants of dampness damaged buildings is somewhat contradictory. To broaden the perspective, a recent study of irritation-induced asthma among women using bleach/chlorine for home cleaning[18] found that non-allergic women, unlike allergic women, had an excess risk of adult-onset asthma. Non-eosinophilic asthma is common; a review concluded that only 50% of asthma cases are attributable to eosinophilic airway inflammation.[19] However, atopy per se is a known risk factor for asthma.[20,21]

To the best of our knowledge, no previous study on asthma incidence in relation to dampness damaged buildings has analyzed populations by stratifying participants according to both gender and atopy.

Many patients and staff at psychiatric clinics smoke, however, stratifying the material on smoking habits only marginally affected the effect from dampness damaged building on asthma incidence.

Our finding that there is an increased incidence of asthma among women who work in dampness damaged buildings may be explained by prolonged irritation of the mucous membranes of the airways. Irritation-induced asthma has been identified as a potential reason for the increased incidence of asthma in populations exposed to various kinds of air pollution. These include people living near traffic-polluted areas, miners, construction workers, welders, plumbers, wood-processing workers, asphalt roofing workers, and industrial cleaners.[22]

The subjects in our study were exposed to both molds and chemical emissions from decomposed building materials such as two ethyl hexanol from PVC flooring. It is possible that different emissions will cause different harmful reactions among the exposed. To be able to make more precise exposure-effect observations we would need to find a population with a more homogenous exposure.

Strengths of this study: The respondents' long mean exposure time (14.4 years for the unexposed and 12.6 for the exposed) provided a good opportunity to study the effects of prolonged exposure to dampness damaged buildings. Information about the duration of exposure is fundamental in epidemiological studies, but is very often omitted in papers about sick-building syndrome.

We also had the opportunity to analyze the combined effect of gender and atopy in relation to working in dampness damaged buildings where no other known sources of air pollution that could confound the results. However, due to small numbers of cases the results should only be considered as indicative.

Information about exposure was obtained from inspection documents written by professional building consultants, and not by self-report from the study participants or by a brief walk-through inspection. In addition, we were able to carefully classify the buildings, departments and rooms occupied by individual respondents in order to classify their exposure.

Weaknesses of the study: Our pool of respondents is rather small. Only two males were diagnosed with adult-onset asthma during the study period, which made it impossible to draw any firm conclusions about risk and gender. Additionally, only 46% of the staff at clinic B completed the questionnaire even after receiving three reminders. It is likely that employees who had not experienced respiratory symptoms or disorders would be less likely to complete the questionnaire than those who had complaints about the buildings or their health. If this were the case, there would be a lower proportion of responses from unexposed staff, which would cause the risk of illness to be underestimated. At clinic A, 74% of the staff completed the questionnaire. Ten individuals did not state their gender, however they are included in the total number of participants. Including or excluding those ten individuals in the analyses with gender pooled, yielded similar results of association between exposure and asthma incidence (data not shown).

The asthma diagnosis, is based on questionnaire responses rather than clinical examinations or interviews conducted by physicians.

However, the respondents all worked in psychiatric hospitals and were thus familiar with general medical concepts such as allergies and asthma. Moreover, the professional activities and exposure to other agents (eg, administered drugs) of respondents in both buildings would have been similar.

In conclusion, the results presented here suggest that working in dampness damaged buildings increases the incidence of asthma, most pronounced in non-atopic females. The incidence continues to increase during exposure for at least one decade.

We propose that further studies on asthma incidence that examine subjects exposed to dampness damaged buildings should consider stratifying subjects on gender, allergy or other features of susceptibility. The various results in existing studies on the associations between dwelling in dampness damaged buildings and incident asthma may be due to differences in the proportions of sensitive individuals in various populations studied.

AUTHORS' CONTRIBUTIONS

PG and UF designed the study and conducted the data collecting. MF and ILB has done the statistical analysis. All authors participated in the writing of the manuscript.

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ETHICS APPROVAL AND INFORMED CONSENT

The project was approved by the Regional Ethical Research Committee of Linköping in 2008, no. M 121-08.

DISCLOSURE (AUTHORS)

The authors report no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

DISCLAIMER

None.

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