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ORIGINAL ARTICLE

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No consistent risk factor pattern for symptoms related to the sick building syndrome: a prospective population based study

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Abstract *Objectives*: To examine associations between perceived indoor environment at work and the non-specific symptoms that are often referred to as the sick building syndrome (SBS), using cross-sectional and prospective analyses for a large cohort from the general population. *Methods*: The sample comprised 2,164 adults in employment, who completed a postal questionnaire in April 2001. Of these 1,402, who were still working and living in the same place, completed a second questionnaire a year later. The outcome measures were the prevalence of mucous membrane symptoms and general symptoms at baseline and the incidence and persistence of these symptoms at follow-up. Self-reports of the indoor environment from the baseline questionnaire were used as predictors in the analyses. *Results*: Inconsistent results were found between the cross-sectional and the longitudinal analyses for the associations between perceived indoor environment factors at work and symptoms. Whereas mucous membrane symptoms in the cross-sectional analysis were significantly associated with self-reported high temperature and dry air, the prospective analyses showed that onset of mucous membrane symptoms was associated with the sensation of draught, dry air, and noise. Persistent mucous membrane symptoms were associated only with stuffy air. General symptoms were associated with self-reported stuffy air and dry air in the cross-sectional analysis, while draught was the only predictor of onset of general symptoms. We found no predictors in the indoor environment for the persistence of general symptoms. *Conclusions*: The symptoms that are often connected with SBS are very common symptoms in the general population among manual workers as well as non-manual workers. Our study gives only limited support to the hypothesis of causal relationships between the indoor environment and these symptoms. We found no evidence of persistent mucous membrane symptoms and general symptoms related to specific factors in the indoor environment.

Keywords Sick building syndrome · Epidemiological study · Cohort study · Risk factors · Indoor air quality

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Introduction

During the last two decades environmental illnesses including the sick building syndrome (SBS) has been a health issue that has attracted much research effort and considerable attention in the media. The SBS has been defined empirically on the basis of case reports in which the occupants of a specific building described similar symptoms that they attributed to indoor climate problems (World Health Organization 1983). The symptoms related to the SBS are non-specific and are seldom accompanied by pathological abnormalities. The symptom pattern has been described in all kinds of non-industrial environments such as offices, schools, day care centres, and hospitals as well as in dwellings and the general population (Bjornsson et al. 1998; Engvall et al. 2001; Franck et al. 1993; Li et al. 1997; McDonald et al. 1993; Norback et al. 1990b; Nordstrom et al. 1995; Sundell et al. 1994). Several investigations have been performed in so-called ‘problem buildings’ in which a high proportion of workers have experienced symptoms

(Bachmann and Myers 1995; Engelhart et al. 1999; Hodgson et al. 1998; McDonald et al. 1993; Norback et al. 1990a). However, often a hazardous exposure has not been identified. A high prevalence of symptoms has also been found in non-problem buildings (Finnegan et al. 1984; Muzi et al. 1998; Nelson et al. 1995; Ooi et al. 1998; Skov and Valbjorn 1987). Despite extensive research only few objectively measured factors in the indoor environment have been associated with symptoms, but these factors cannot explain the large variations in symptoms and discomfort between buildings. Hence the aetiology of SBS is still unknown.

Although the SBS symptoms are considered reversible, patients often worry about possible long-term health effects due to different factors in the indoor environment. However, earlier studies on the SBS symptoms are predominantly cross-sectional and hence have been unable to study the temporal relationship between exposure and symptoms as well as the course of the SBS symptoms. Except for a few intervention studies, we are aware of only one epidemiological study evaluating longitudinal relationships between the indoor environment and non-specific building-related symptoms (Chao et al. 2003). The number of participants in that study, however, was relatively small ($N=98$) and the authors recommended large-scale longitudinal studies to further investigate the health effects of environmental exposures.

We used a prospective design to study perceived risk factors in the indoor environment at work for the incidence and persistence of the group of symptoms included in the SBS in a cohort of approximately 1,400 adults.

Methods

The study is a 1-year prospective study based on questionnaires from a random sample of adults from the Danish population.

Study population

Four thousand persons aged 18–59 years were selected randomly from the Danish Civil Registration System with the same number of women and men and an equal number in each year group. The participants were invited by mail to take part in 'a study about indoor environment, stress and health'. Data collection was made by postal questionnaires in April 2001 and April 2002. The time lag of 1 year was chosen to control for seasonal changes. Non-respondents were reminded once. The questionnaire included items concerning symptoms related to the SBS, indoor environment factors at work, psychosocial work characteristics, and personal characteristics. At follow-up, identical questions on symptoms and potential risk factors were used.

In Denmark, projects based on questionnaires do not have to be notified to the ethics committee system, but the study was carried out in accordance with the requirements of the national and regional ethics committees in Denmark.

Outcome measures

Symptoms that are traditionally connected with the SBS were measured with a questionnaire that has been validated in other studies (Brauer et al. 2000; Brauer 2005). The participants answered whether they during the past 4 weeks had been bothered by the following eight symptoms: eye irritation, nose irritation, nasal congestion, throat irritation, hoarseness, fatigue, headache, and concentration difficulty. Each question had four response options: 'No', 'yes, sometimes', 'yes, several times a week', and 'yes, daily'. Data were dichotomised so that a symptom occurring several times a week or daily was a positive answer. The dichotomised symptoms were grouped in two symptom indices: a mucous membrane symptom index consisting of five items: eye irritation, nose irritation, nasal congestion, throat irritation, and hoarseness (range 0–5); and a general symptom index consisting of three items: fatigue, headache, and concentration difficulty (range 0–3).

At baseline the prevalence of mucous membrane symptoms and general symptoms was assessed as a score > 0 on the symptom index. At follow-up, the outcomes of interest were the incidence and the persistence of mucous membrane symptoms and general symptoms. Incidence of symptoms was defined as a score > 0 on the symptom index at follow-up among participants with a score $= 0$ on the respective score index at baseline. Persistence of symptoms was defined as having a score > 0 at follow-up as well as at baseline.

Indoor environment factors

Perceived exposures in the indoor environment (17 items) were assessed with the following question: 'Have you been exposed to any of the following factors in your work environment during the past 4 weeks?' with the same four response options as for the questions on symptoms. Exposures were regarded as relevant if they were present several times a week or daily. In addition, a question was asked whether there were patches of damp or mildew in the workplace using the response options: 'No', 'yes', and 'I don't know'. Only the answer 'yes' was regarded a positive answer. The questions were grouped into nine groups: a draught index (draught, too low temperature, and draught along the floor, range 0–3), a temperature index (too high temperature and temperature variations, range 0–2), a stuffy air index (stuffy air and unpleasant odour, range 0–2), a dry air index (dry air and static electricity, range 0–2), a noise index (noise in the room, noise from other rooms, and noise from outside, range 0–3), a light index (illumination problems and reflective surfaces, range 0–2), a space/dust index (cramped for space and poor cleaning, range 0–2), environmental tobacco smoke (0–1), and patches of damp or mildew (0–1). This grouping was tested for unidimensionality, and each index was accepted with the Martin-Löf test, which is suitable for dichotomous items in contrast to factor analysis (Gustafsson 1980; Streiner 1994). We used the free software DIGRAM for the Martin-Löf test (http://www.biostat.ku.dk/~skm/skm/index.html).

Other risk factors

Information about age, sex, and municipality of living was obtained from the Danish Civil Register; all other covariates were self-reported. Hypersensitivity was defined as reporting either allergy to pollen, furry animals or house dust mite or a history of asthma, hay fever or childhood eczema (Johansson et al. 2001). A person who reported smoking tobacco daily was regarded a current smoker.

A general tendency to report symptoms was measured with a symptom checklist, which we slightly modified so it only contained symptoms that are usually not included in the SBS (stomach ache, chest pain, heart palpitations, shortness of breath, vertigo, muscle tension, sweating, powerlessness, depression, restlessness, nervousness, sleeping problems, tendency to cry, unable to relax, and difficulty in making decisions) (Setterlind and Larsson 1995). We defined a high level of symptom reporting as at least four symptoms among the 15 symptoms. General health was assessed by the Short Form 12 Health Survey (SF-12) and was scored according to the manual resulting in a physical and a mental summary score (Gandek et al. 1998).

Psychosocial work characteristics were measured with four global questions designed for the present study addressing job demands, job decision latitude, support from colleagues or supervisors, and effort-reward imbalance (Karasek and Theorell 1990; Siegrist 1996). The personality traits 'negative affectivity' and 'type A behaviour' were determined by two questions used in a previous study (Andersen et al. 2003). Questions on 'self-efficacy', social support from family and friends, and a tendency to worry about health were designed for the study. The responses were reported on a seven-point ordinal scale ranging from not at all to very much. Decisions on where to dichotomise the responses were made a priori on the basis of the wordings in the response options to indicate a high degree of the characteristic.

Statistical analysis

Logistic regression was used to examine the association between perceived indoor environment at work and mucous membrane symptoms and general symptoms. In analyses of follow-up data, we used information from the baseline questionnaire on the indoor environment and other risk factors as predictors of developing new symptoms or having persistent symptoms after 1 year. In order to keep the indoor environment as constant as possible, analyses at follow-up were restricted to the 1,402 participants who were still employed in the same company and who still lived in the same dwelling as they did at baseline.

The analyses of the cross-sectional data as well as follow-up data were done in a three-stage process. Initially, we adjusted each of the indoor environment indices for sex, age, hypersensitivity, and a general tendency to report symptoms. These four potential confounders were considered essential and hence included in all the following models irrespective of level of significance. The measure of 'a tendency to report symptoms' was included to adjust for reporting bias. In the next step, we in addition adjusted for other personal factors and factors in the psychosocial work environment (model 1). Potential personal or psychosocial confounders comprised marital status, smoking, negative affectivity, type A behaviour, a tendency to worry about health, self-efficacy, support from family and friends, job demands, job control, work support, and effort–reward imbalance. An interaction term between high job demands and low decision latitude (job strain) was also included in accordance with the original job strain model (Karasek and Theorell 1990). We used backward elimination to choose which of these covariates to keep in the model and chose 0.10 as the significance level of the Wald chi-square for keeping a variable in the model, because a low level of significance may fail to identify variables of importance. Finally, we additionally adjusted each indoor environment index for the other indoor environment indices, testing whether the effect for individual environment factors could be explained by the other indoor environment factors (model 2). Again we used backward elimination at a 0.10 significance level to decide which of the indoor environment indices to keep in the final model together with the potential confounders chosen at stage two. The variables that were kept in the models were chosen independently for baseline data and follow-up data as well as for mucous membrane symptoms and general symptoms and thus could differ from model to model. The variables in the different models are specified in the footnotes at the bottom of Tables 3, 4, and 5. To examine a dose–response effect we additionally used a test for trend analysing the models with the indoor environment indices as continuous variables in the models.

Results are presented as odds ratios (OR) with their 95% confidence intervals (CI) and *P*-values of a maximum likelihood test for trend. An association was regarded as significant if the top level of the index had a 95% CI not including 1.0 or if the *P*-value was below 0.05 in the linear tests for trend. There were no remarkable differences in the estimates between the first two steps of the analyses, and therefore only the results for models 1 and 2 are shown.

Finally, we checked for an effect of interactions between the indoor environment indices and the four essential confounders (sex, age, hypersensitivity, and symptom reporting tendency) and for interactions between the indoor environment indices in model 2. Two-way interaction terms were added to the model one at a time, and their significance were assessed using likelihood ratio test with $P=0.05$ as the significance level. We checked the variables in the final models for collinearity by computing the tolerance (Allison 1999). A tolerance below 0.40 was regarded as problematic. The logistic regression models were tested for goodness of fit with the Hosmer and Lemeshow method (Hosmer and Lemeshow 2000). Logistic regression analyses were done with SAS System version 8.2.

Results

At baseline 2,710 participants (68%) completed the questionnaire. However, the participants had to be in employment, so 546 participants were not eligible for inclusion because of being unemployed or receiving education. Thus at baseline the study group comprised 2,164 participants. At follow-up 1,740 participants (80%) completed the questionnaire, of whom 1,402 were eligible for participation because they were still working and living in the same place as at baseline.

The 2,164 persons in the baseline population were comprised of 1,114 women (52%), the mean age was 41 years (range 18–59), 38% had hypersensitivity, 32% were current smokers, and 9% had a general tendency to report symptoms. The general mental and physical health of the participants was like the average general population (measured with the SF-12). The majority of the participants were non-manual workers (64%), 28% were manual workers, and 8% were self-employed. The non-respondents at baseline were more likely to be men, but did not differ from the respondents with respect to age or geographical region. Among the non-respondents at follow-up there was an overrepresentation of young persons (< 30 years), unmarried persons,

Table 1 Mucous membrane symptoms and general symptoms by sex, age, and occupation

	Baseline, $N=2{,}164$[a]				Follow-up, $N=1{,}402$[a]							
	Prevalence				Incidence				Persistence			
	N	Symptoms at baseline	%	*P*-value	No symptoms at baseline	Symptoms at follow-up *n*	%	*P*-value	Symptoms at baseline	Symptoms at follow-up *n*	%	*P*-value
Mucous membrane symptom index[b]												
Overall	2,164	607	28.1		1,039	152	14.6		360	183	50.8	
Sex												
Men	1,050	242	23.1	< 0.0001	544	68	12.5	0.04	145	69	47.6	0.31
Women	1,114	365	32.8		495	84	17.0		215	114	53.0	
Age group												
18–29 years	397	141	35.5	0.002	116	28	24.1	0.001	63	34	54.0	0.16
30–39 years	597	159	26.6		289	50	17.3		94	40	42.6	
40–49 years	613	172	28.1		319	43	13.5		113	56	49.6	
50–59 years	557	135	24.3		315	31	9.8		90	53	58.9	
Occupation[c]												
Manual workers	581	171	29.4	0.95	248	37	14.9	0.84	86	42	48.8	0.60
Non-manual workers	1,339	396	29.6		673	104	15.5		257	134	52.1	
General symptom index[d]												
Overall	2,164	500	23.1		1,109	103	9.3		288	146	50.7	
Sex												
Men	1,050	174	16.6	< 0.0001	589	50	8.5	0.33	98	49	50.0	0.87
Women	1,114	326	29.3		520	53	10.2		190	97	51.1	
Age group												
18–29 years	397	111	28.0	< 0.0001	129	16	12.4	0.34	49	21	42.9	0.42
30–39 years	597	141	23.6		306	32	10.5		77	36	46.8	
40–49 years	613	160	26.1		328	29	8.8		104	57	54.8	
50–59 years	557	88	15.9		346	26	7.5		58	32	55.2	
Occupation[c]												
Manual workers	581	120	20.7	0.05	270	23	8.5	0.50	64	37	57.8	0.29
Non-manual workers	1,339	332	24.8		725	72	9.9		203	102	50.3	

Prevalence at baseline, incidence, and persistence at 1-year follow-up in numbers and percentage. *P*-values from chi-square test

[a]Because of missing values for the outcome or explanatory variables a few numbers and percentages differ from what can be calculated from the Table

[b]One or more mucous membrane symptoms (eye irritation, nose irritation, nasal congestion, throat irritation, hoarseness)

[c]Self-employed excluded from this analysis

[d]One or more general symptoms (fatigue, headache, concentration difficulty)

smokers, self-employed persons, and unskilled manual workers, but there was no notable difference in baseline characteristics on perceived indoor environment, mucous membrane symptom index or general symptom index.

Table 1 shows the prevalence of mucous membrane and general symptoms at baseline and the incidence and persistence of the symptoms at 1-year follow-up. At baseline the prevalence of mucous membrane symptoms and general symptoms were 28 and 23%, respectively. The most common symptoms were nasal congestion (16%) followed by fatigue (15%), headache (12%), nose irritation (11%), and eye irritation (10%). At follow-up the incidence of mucous membrane symptoms and general symptoms was 15 and 9%, respectively. About half of the participants who had symptoms at baseline also had symptoms at follow-up.

In the indoor environment at baseline the most common complaint was noise, where 46% had a score > 0 on the noise index. The space/dust index and dry air index were also prevalent with a score > 0 among 38 and 30%, respectively. A total of 583 persons (28%) did not complain about any of the nine indoor environment indices; the median was two positive indices, and 5% complained about seven to nine of the indoor environment indices. Table 2 shows the correlation coefficients between the nine indoor environment indices. Most correlation coefficients were between 0.15 and 0.35. The majority of participants remained at the same level of indoor environment complaints (63–94%), and only few changed more than one score on an index (1–7%).

Risk factors at baseline

All indoor environment factors except patches of damp or mildew at work were associated with mucous membrane symptoms, after taking account of sex, age, hypersensitivity, a tendency to report other symptoms than SBS symptoms, other personal factors and psychosocial work characteristics (Table 3, mucous membrane symptoms, model 1). In model 2 we additionally adjusted for those of the other indoor environment factors that were associated with mucous membrane symptoms with *P*-values < 0.10 in the backward selection analysis. After this adjustment, temperature index and dry air index were the only factors that remained significant (Table 3, mucous membrane symptoms, model 2). A dose–response pattern was seen for both factors.

The prevalence of general symptoms was associated with all the self-reported indoor environment factors except patches of damp or mildew, after adjustment for sex, age, hypersensitivity, a tendency to report other symptoms, other personal factors and psychosocial work characteristics (Table 3, general symptoms, model 1). After adjusting for other indoor environment factors, stuffy air index and dry air index were the only factors that remained significant risk factors for general symptoms with a dose–response pattern (Table 3, general symptoms, model 2). The light index was of borderline significance. The Hosmer–Lemeshow goodness-of-fit test in model 2 for mucous membrane symptoms and general symptoms yielded *P*-values ranging from 0.10 to 0.93 suggesting that the models were acceptable.

Risk factors at follow-up

Incidence

The incidence of mucous membrane symptoms was associated with all of the indoor environment factors except environmental tobacco smoke when controlling for sex, age, hypersensitivity, symptom reporting, other personal factors and psychosocial work factors (Table 4, mucous membrane symptoms, model 1). Adjusting for other indoor environment factors, the draught index, dry air index and noise index were the only factors that showed a dose–response pattern and were significantly associated with onset of mucous membrane symptoms (Table 4, mucous membrane symptoms, model 2).

The incidence of general symptoms was associated with all indoor environment factors except environmental tobacco smoke and noise index, after adjustment for sex, age, hypersensitivity, symptom reporting, other

Table 2 Spearman correlation coefficients between perceived indoor environment at baseline

	Indoor environment factor								
	1	2	3	4	5	6	7	8	9
1. Draught index	1								
2. Temperature index	0.53	1							
3. Stuffy air index	0.33	0.39	1						
4. Environmental tobacco smoke	0.19	0.19	0.26	1					
5. Dry air index	0.25	0.31	0.42	0.18	1				
6. Noise index	0.34	0.30	0.30	0.26	0.24	1			
7. Light index	0.32	0.23	0.28	0.15	0.25	0.27	1		
8. Space/dust index	0.40	0.35	0.36	0.20	0.28	0.43	0.35	1	
9. Patches of dampness	0.16	0.12	0.14	0.10	0.06	0.11	0.12	0.17	1

N = 2,027 (persons with missing values are excluded)

Table 3 The associations of perceived indoor environment with the prevalence of mucous membrane symptoms and general symptoms at baseline

Risk factor	Values	Mucous membrane symptoms ($n=607$)								General symptoms ($n=500$)							
		Prevalence[a]		Model 1		Test for trend	Model 2		Test for trend	Prevalence[a]		Model 1		Test for trend	Model 2		Test for trend
		Number	%	OR[b]	95% CI	*P*-value	OR[c]	95% CI	*P*-value	Number	%	OR[d]	95% CI	*P*-value	OR[e]	95% CI	*P*-value
Draught index	0	350	23.1	**1**			1			297	19.6	**1**			1		
	1	129	44.2	**2.2**	**1.7–3.0**		1.7	1.2–2.2		88	30.1	**1.3**	**0.9–1.8**		1.1	0.7–1.5	
	2	62	38.3	**1.8**	**1.2–2.5**		1.2	0.8–1.8		51	31.5	**1.5**	**1.0–2.2**		1.1	0.7–1.7	
	3	49	41.9	**1.9**	**1.3–2.9**	**< 0.001**	1.1	0.7–1.8	0.178	47	40.2	**1.8**	**1.1–2.8**	**0.002**	1.2	0.8–2.0	0.339
Temperature index	0	351	23.3	**1**			**1**			302	20.1	**1**			1		
	1	148	37.8	**1.8**	**1.4–2.4**		**1.3**	**1.0–1.8**		116	29.6	**1.4**	**1.1–1.9**		1.1	0.8–1.5	
	2	88	48.1	**2.8**	**2.0–3.9**	**< 0.001**	**1.7**	**1.1–2.5**	**0.002**	63	34.4	**1.7**	**1.1–2.4**	**0.001**	1.1	0.7–1.6	0.513
Stuffy air index	0	373	23.3	**1**			1			291	18.2	**1**			**1**		
	1	131	42.3	**2.1**	**1.6–2.8**		1.3	0.9–1.7		109	35.2	**2.1**	**1.5–2.8**		**1.9**	**1.4–2.6**	
	2	83	49.1	**2.5**	**1.8–3.6**	**< 0.001**	1.3	0.9–1.9	0.115	80	47.3	**2.9**	**2.0–4.2**	**< 0.001**	**2.8**	**1.9–4.1**	**< 0.001**
Environmental	0	401	26.1	**1**			1			322	21.0	**1**			1		
tobacco smoke	1	185	34.7	**1.4**	**1.1–1.7**	**0.004**	1.1	0.8–1.3	0.608	157	29.4	**1.4**	**1.1–1.8**	**0.009**	1.1	0.8–1.4	0.429
Dry air index	0	296	20.4	**1**			**1**			265	18.3	**1**			**1**		
	1	190	42.3	**2.6**	**2.0–3.3**		**2.2**	**1.7–2.8**		146	32.5	**1.5**	**1.2–2.0**		**1.2**	**0.9–1.6**	
	2	102	56.0	**4.4**	**3.1–6.2**	**< 0.001**	**3.6**	**2.5–5.1**	**< 0.001**	72	39.6	**2.2**	**1.5–3.2**	**< 0.001**	**1.4**	**0.9–2.1**	**0.040**
Noise index	0	250	22.1	**1**			1			200	17.7	**1**			1		
	1	168	35.2	**1.7**	**1.3–2.2**		1.4	1.0–1.8		126	26.4	**1.4**	**1.1–1.9**		1.3	0.9–1.7	
	2	112	36.8	**1.7**	**1.3–2.3**		1.2	0.9–1.7		107	35.2	**2.0**	**1.5–2.8**		1.7	1.2–2.3	
	3	58	34.2	**1.5**	**1.0–2.1**	**< 0.001**	1.0	0.7–1.5	0.412	49	29.0	**1.2**	**0.8–1.8**	**0.002**	0.9	0.6–1.4	0.148
Light index	0	444	25.6	**1**			1			356	20.5	**1**			1		
	1	95	38.6	**1.6**	**1.2–2.1**		1.1	0.8–1.6		82	33.3	**1.5**	**1.1–2.1**		1.2	0.9–1.7	
	2	49	48.5	**2.1**	**1.3–3.2**	**< 0.001**	1.2	0.8–1.9	0.275	44	43.6	**2.0**	**1.2–3.2**	**< 0.001**	1.5	0.9–2.5	0.075
Space/dust index	0	288	22.4	**1**			1			250	19.5	**1**			1		
	1	210	35.8	**1.7**	**1.4–2.1**		1.2	0.9–1.5		163	27.8	**1.2**	**0.9–1.6**		0.9	0.7–1.2	
	2	89	42.4	**2.2**	**1.6–3.0**	**< 0.001**	1.3	0.9–1.8	0.061	69	32.9	**1.5**	**1.0–2.1**	**0.021**	0.9	0.6–1.4	0.536
Patches of damp/mildew	0	534	27.9	1			1			426	22.2	1			1		
	1	47	35.3	1.1	0.7–1.6	0.636	0.9	0.6–1.4	0.795	48	35.8	1.3	0.8–2.0	0.258	1.1	0.7–1.7	0.814

Bold is used to highlight a significant effect

Results from logistic regression analyses and test for trend, $N=2{,}164$

[a]Because of a few missing values for the outcome and explanatory variables numbers do not exactly sum to totals

[b]Model 1, mucous membrane symptoms: adjusted for sex, age, hypersensitivity, a tendency to report symptoms, job demands, job decision latitude, job strain, support at work, negative affectivity and type A behaviour

[c]Model 2, mucous membrane symptoms: in addition adjusted for draught index, temperature index, and dry air index

[d]Model 1, general symptoms: adjusted for sex, age, hypersensitivity, a tendency to report symptoms, job demands, job decision latitude, job strain, support at work, effort-reward imbalance, negative affectivity, and support from family/friends

[e]Model 2, general symptoms: in addition adjusted for stuffy air index and noise index

Table 4 The associations of perceived indoor environment with the incidence of mucous membrane symptoms and general symptoms at 1-year follow-up among participants with no symptoms at baseline

Risk factor	Values	Mucous membrane symptoms ($n=152$)								General symptoms ($n=103$)							
		Incidence[a]		Model 1		Test for trend	Model 2		Test for trend	Incidence[a]		Model 1		Test for trend	Model 2		Test for trend
		Number	%	OR[b]	95% CI	*P*-value	OR[c]	95% CI	*P*-value	Number	%	OR[d]	95% CI	*P*-value	OR[e]	95% CI	*P*-value
Draught index	0	97	12.4	**1**			**1**			59	7.1	**1**			**1**		
	1	20	18.4	**1.4**	**0.8–2.3**		**1.0**	**0.6–1.8**		19	14.5	**2.1**	**1.1–3.6**		**1.5**	**0.8–2.8**	
	2	14	20.6	**1.4**	**0.7–2.7**		**1.1**	**0.5–2.2**		11	16.4	**2.2**	**1.0–4.5**		**1.6**	**0.7–3.7**	
	3	19	38.8	**4.1**	**2.1–7.8**	**<0.001**	**2.5**	**1.2–5.1**	**0.029**	12	24.5	**3.5**	**1.6–7.1**	**<0.001**	**2.4**	**1.0–5.7**	**0.021**
Temperature index	0	100	12.9	**1**			1			58	7.1	**1**			1		
	1	35	21.0	**1.5**	**1.0–2.4**		1.2	0.7–1.9		31	16.9	**2.2**	**1.3–3.6**		1.5	0.8–2.7	
	2	14	21.2	**1.7**	**0.8–3.2**	**0.031**	1.0	0.5–2.0	0.742	12	15.0	**1.9**	**0.9–3.8**	**0.003**	1.2	0.5–2.7	0.419
Stuffy air index	0	106	12.9	**1**			1			71	8.0	**1**			1		
	1	26	21.1	**1.6**	**1.0–2.7**		1.2	0.7–2.0		22	16.2	**2.1**	**1.2–3.5**		1.5	0.8–2.8	
	2	18	31.6	**2.9**	**1.5–5.4**	**<0.001**	1.8	0.9–3.7	0.110	8	14.8	**1.6**	**0.7–3.5**	**0.024**	1.1	0.4–2.7	0.514
Environmental	0	103	13.5	1			1			77	9.5	1			1		
tobacco smoke	1	46	19.6	1.4	0.9–2.1	0.108	1.0	0.7–1.6	0.918	24	9.2	0.9	0.5–1.4	0.533	0.7	0.4–1.1	0.095
Dry air index	0	99	12.7	**1**			**1**			62	7.9	**1**			1		
	1	36	20.8	**1.6**	**1.0–2.5**		**1.4**	**0.9–2.3**		25	11.5	**1.3**	**0.8–2.2**		1.1	0.6–1.9	
	2	15	25.9	**2.4**	**1.2–4.5**	**0.002**	**1.9**	**0.9–3.6**	**0.041**	14	19.2	**2.4**	**1.2–4.6**	**0.015**	1.7	0.8–3.6	0.225
Noise index	0	65	10.8	**1**			**1**			55	8.5	1			1		
	1	36	18.0	**1.7**	**1.1–2.7**		**1.5**	**0.9–2.4**		20	8.9	1.0	0.5–1.6		0.7	0.4–1.2	
	2	27	21.4	**1.9**	**1.1–3.1**		**1.6**	**0.9–2.7**		15	12.2	1.5	0.8–2.7		1.0	0.5–1.9	
	3	22	28.2	**2.9**	**1.6–5.2**	**<0.001**	**2.4**	**1.2–4.4**	**0.004**	11	13.4	1.3	0.6–2.6	0.255	0.7	0.3–1.7	0.513
Light index	0	112	13.0	**1**			1			76	8.3	**1**			1		
	1	31	28.2	**2.3**	**1.4–3.6**		1.8	1.0–2.9		19	15.8	**1.9**	**1.0–3.2**		1.3	0.7–2.4	
	2	7	18.9	**1.7**	**0.6–3.8**	**0.004**	1.0	0.3–2.3	0.228	6	15.8	**1.8**	**0.6–4.3**	**0.031**	1.3	0.4–3.4	0.578
Space/dust index	0	78	11.7	**1**			1			46	6.5	**1**			1		
	1	52	20.5	**1.6**	**1.1–2.4**		1.2	0.8–1.9		42	15.0	**2.2**	**1.4–3.5**		1.8	1.1–3.0	
	2	20	22.7	**2.2**	**1.2–3.9**	**0.001**	1.3	0.6–2.5	0.269	13	13.4	**2.1**	**1.0–3.9**	**0.002**	1.5	0.7–3.2	0.056
Patches of damp/mildew	0	130	13.9	**1**			1			90	9.0	**1**			1		
	1	16	28.1	**2.1**	**1.1–4.0**	**0.023**	1.7	0.8–3.3	0.078	10	17.5	**2.2**	**1.0–4.4**	**0.039**	1.5	0.6–3.1	0.308

Bold is used to highlight a significant effect

Results from logistic regression analyses and test for trend, $N=1{,}402$

[a] Because of a few missing values for the outcome and explanatory variables numbers do not exactly sum to totals

[b] Model 1, mucous membrane symptoms: adjusted for sex, age, hypersensitivity, a tendency to report symptoms, job decision latitude, and support from family/friends

[c] Model 2, mucous membrane symptoms: in addition adjusted for dry air index, noise and light index

[d] Model 1, general symptoms: adjusted for sex, age, hypersensitivity, a tendency to report symptoms, effort-reward imbalance, self-efficacy, and support from family/friends

[e] Model 2, general symptoms: in addition adjusted for draught index, temperature index, environmental tobacco smoke, and space/dust index

Table 5 The associations of perceived indoor environment with the persistence of mucous membrane symptoms and general symptoms at 1-year follow-up among participants having symptoms at baseline

Risk factor	Values	Mucous membrane symptoms ($n = 183$)								General symptoms ($n = 146$)							
		Persistence[a]		Model 1		Test for trend	Model 2		Test for trend	Persistence[a]		Model 1		Test for trend	Model 2		Test for trend
		Number	%	OR[b]	95% CI	P-value	OR[c]	95% CI	P-value	Number	%	OR[d]	95% CI	P-value	OR[e]	95% CI	P-value
Draught index	0	103	47.0	1			1			83	49.7	1			1		
	1	39	52.7	1.1	0.6–1.9		0.9	0.5–1.6		26	50.0	0.9	0.5–1.8		0.9	0.4–1.8	
	2	24	64.9	2.0	0.9–4.2		1.7	0.8–3.7		22	57.9	1.3	0.6–2.8		1.1	0.5–2.4	
	3	16	59.3	1.5	0.6–3.5	0.114	1.1	0.5–2.8	0.338	15	55.6	1.2	0.5–2.8	0.529	0.8	0.3–2.1	0.809
Temperature index	0	101	47.6	1			1			82	48.2	1			1		
	1	47	52.2	1.3	0.8–2.3		1.2	0.7–2.0		38	52.1	1.1	0.6–1.9		0.8	0.5–1.5	
	2	33	61.1	1.5	0.8–2.9	0.153	1.2	0.6–2.3	0.544	25	62.5	1.8	0.9–3.8	0.168	1.3	0.6–3.0	0.704
Stuffy air index	0	103	44.4	**1**			**1**			76	45.2	1			1		
	1	50	61.7	**2.0**	**1.2–3.4**		**2.0**	**1.2–3.4**		41	60.3	1.8	1.0–3.3		1.7	0.9–3.2	
	2	28	65.1	**2.0**	**1.0–4.2**	**0.008**	**2.0**	**1.0–4.2**	**0.008**	28	60.9	1.6	0.8–3.1	0.079	1.5	0.7–3.1	0.150
Environmental	0	121	48.6	1			1			108	54.0	1			1		
tobacco smoke	1	59	55.7	1.3	0.8–2.2	0.216	1.2	0.7–1.9	0.538	37	45.1	0.8	0.5–1.4	0.392	0.8	0.4–1.4	0.413
Dry air index	0	79	45.9	1			1			79	49.7	1			1		
	1	69	54.8	1.4	0.8–2.2		1.2	0.7–1.9		45	54.9	1.2	0.7–2.1		1.2	0.7–2.1	
	2	33	56.9	1.5	0.8–2.8	0.150	1.2	0.6–2.3	0.530	22	51.2	1.0	0.5–2.1	0.710	1.0	0.5–2.1	0.817
Noise index	0	82	50.0	1			1			60	51.3	1			1		
	1	49	51.0	1.0	0.6–1.6		0.9	0.5–1.5		38	52.8	1.1	0.6–2.0		1.0	0.5–1.9	
	2	30	46.9	0.8	0.4–1.4		0.7	0.3–1.2		32	47.8	0.9	0.5–1.6		0.6	0.3–1.1	
	3	20	62.5	1.7	0.8–3.9	0.626	1.4	0.6–3.2	0.818	16	57.1	1.3	0.5–3.0	0.913	1.3	0.5–3.2	0.563
Light index	0	134	49.8	1			1			107	51.4	1			1		
	1	31	53.4	1.0	0.6–1.9		1.0	0.5–1.8		28	58.3	1.2	0.6–2.4		1.2	0.6–2.3	
	2	16	55.2	1.0	0.5–2.3	0.903	0.9	0.4–2.0	0.742	11	39.3	0.5	0.2–1.1	0.271	0.5	0.2–1.1	0.225
Space/dust index	0	80	44.7	**1**			1			74	52.5	1			1		
	1	66	53.7	**1.3**	**0.8–2.1**		1.1	0.7–1.9		50	51.0	0.9	0.5–1.6		0.8	0.5–1.5	
	2	35	64.8	**2.2**	**1.2–4.3**	**0.018**	1.7	0.9–3.5	0.165	22	48.9	0.8	0.4–1.6	0.490	0.7	0.3–1.4	0.292
Patches of damp/mildew	0	164	50.0	1			1			131	51.6	1			1		
	1	17	68.0	1.6	0.7–4.2	0.279	1.5	0.6–3.9	0.439	13	50.0	0.8	0.3–1.9	0.635	0.7	0.3–1.9	0.510

Bold is used to highlight a significant effect

Results from logistic regression analyses and test for trend, $N = 1{,}402$

[a]Because of a few missing values for the outcome and explanatory variables numbers do not exactly sum to totals

[b]Model 1, mucous membrane symptoms: adjusted for sex, age, hypersensitivity, and a tendency to report symptoms

[c]Model 2, mucous membrane symptoms: in addition adjusted for stuffy air index

[d]Model 1, general symptoms: adjusted for sex, age, hypersensitivity, and a tendency to report symptoms

[e]Model 2, general symptoms: in addition adjusted for job demands, support at work, effort-reward imbalance and negative affectivity

personal factors and psychosocial work factors (Table 4, general symptoms, model 1). After adjustment for other indoor environment factors, draught index was the only factor that remained significant and showed a dose–response pattern, although space/dust index was of borderline significance (Table 4, general symptoms, model 2).

The Hosmer–Lemeshow goodness-of-fit test yielded *P*-values ranging from 0.06 to 0.95.

Persistence

The persistence of mucous membrane symptoms was associated with the stuffy air and space/dust indices, after controlling for sex, age, hypersensitivity, and symptom reporting. No other personal factors or psychosocial work characteristics met the criterion of a *P*-value below 0.10 to be included in model 1. In model 2 the stuffy air index was retained in the model, and the effect of space/dust disappeared, thus leaving stuffy air index the only significant association (Table 5, mucous membrane symptoms, models 1 and 2).

The persistence of general symptoms was not associated with any of the indoor environment factors in any of the models, the OR was close to 1 and no dose–response relationships were found (Table 5, general symptoms, models 1 and 2). The range of the CI was of the same magnitude as in the analyses of the incidence of symptoms suggesting satisfactory statistical power.

The Hosmer–Lemeshow goodness-of-fit test yielded *P*-values ranging from 0.06 to 0.94.

Other results

In Table 6 the relative contributions of the psychosocial work characteristics and the personal factors that were kept in model 2 for the prevalence, incidence and persistence of the symptoms. Women were more likely to report mucous membrane symptoms and general symptoms in the cross-sectional analysis, but not in the longitudinal. Young persons had an elevated risk of having general symptoms at baseline as well as developing new mucous membrane symptoms at follow-up. Hypersensitivity was associated with mucous membrane symptoms in both the cross-sectional and the longitudinal analysis with OR ranging between 1.4 and 1.9, but was not associated with general symptoms. A general tendency to report symptoms was a predictor of having mucous membrane symptoms at baseline, of developing new mucous membrane symptoms at follow-up and of having persistent mucous membrane symptoms at follow-up (OR between 2.3 and 2.5). General symptoms were also strongly associated with a tendency to report symptoms at baseline (OR 7.2), but a tendency to report symptoms were only of borderline significance at follow-up. Only few associations were found as regard the psychosocial work characteristics and personality traits, negative affectivity being the most important factor.

In order to test whether we made over-adjustments when controlling for a tendency to report other symptoms than SBS symptoms, the analyses were repeated without 'symptom reporting' in the model. The estimates of the effects of the indoor environment factors changed only slightly, however, and we chose to keep the

Table 6 The associations of other risk factors with mucous membrane symptoms and general symptoms at baseline and 1-year follow-up

Risk factor	Mucous membrane symptoms			General symptoms		
	Baseline, $N = 2,164$	Follow-up, $N = 1,402$		Baseline, $N = 2,164$	Follow-up, $N = 1,402$	
	Prevalence	Incidence	Persistence	Prevalence	Incidence	Persistence
Women	**1.3 (1.0–1.6)**	1.3 (0.9–1.9)	1.0 (0.6–1.6)	**1.8 (1.4–2.3)**	1.3 (0.8–2.0)	0.9 (0.5–1.6)
Age[a]	0.9 (0.8–1.0)	**0.7 (0.6–0.8)**	1.1 (0.9–1.4)	**0.8 (0.7–0.9)**	0.8 (0.7–1.0)	1.2 (0.9–1.6)
Hypersensitivity	**1.7 (1.3–2.0)**	1.4 (1.0–2.1)	**1.9 (1.2–2.9)**	1.2 (0.9–1.5)	1.1 (0.7–1.7)	0.6 (0.3–1.0)
A tendency to report symptoms[b]	**2.3 (1.6–3.3)**	**2.5 (1.3–4.8)**	**2.3 (1.2–4.5)**	**7.2 (5.0–10.6)**	2.2 (0.9–5.2)	1.7 (0.9–3.2)
High job demands						1.7 (1.0–2.8)
Low decision latitude		1.4 (0.8–2.4)				
Job strain[c]	1.5 (0.8–2.5)			1.6 (0.6–4.0)		
Poor support at work				**1.5 (1.1–1.9)**		0.6 (0.3–1.0)
Effort-reward imbalance				**1.5 (1.1–2.0)**	1.3 (0.8–2.3)	**3.1 (1.7–6.0)**
Negative affectivity	1.4 (1.0–1.9)			**1.6 (1.1–2.3)**		**2.4 (1.2–5.0)**
Type A behaviour	**1.5 (1.1–1.9)**					
Worry about health						
Low self-efficacy					1.9 (1.0–3.4)	
Poor support from family/friends		**1.8 (1.2–2.8)**		1.4 (1.0–1.9)	1.6 (0.9–2.6)	

Bold is used to highlight a significant effect

Results from logistic regression analyses. Figures are presented for the variables that were kept in model 2 for the prevalence, incidence, and persistence of the symptoms

[a]Continuous variable; data show effect of 10-year increments

[b]At least four symptoms among 15 symptoms

[c]The interaction term between high job demands and low decision latitude. When the interaction term was in the model, the main effects were also retained in the model

variable 'symptom reporting' in the models, as it was our a priori hypothesis that this factor was important.

We found only few sporadic interaction terms with a *P*-value below 0.05. The interactions, however, were difficult to interpret and did not exceed what could be expected by chance. No tolerance were below 0.58, hence we found no sign of problematic collinearity.

Discussion

The present study showed inconsistent results between the cross-sectional and the longitudinal analyses for the associations between perceived indoor environment factors and symptoms. Whereas mucous membrane symptoms in the cross-sectional analysis were significantly associated with self-reported high temperature and dry air, the prospective analyses showed that onset of mucous membrane symptoms was associated with the sensation of draught, dry air, and noise. General symptoms were associated with self-reported stuffy air and dry air in the cross-sectional analysis, while draught was the only predictor of onset of general symptoms. Persistent mucous membrane symptoms were associated only with stuffy air, and persistent general symptoms were not associated with any of the predictors in the indoor environment, suggesting that persistent symptoms were independent of problems in the indoor environment.

We found that mucous membrane symptoms and general symptoms are very common symptoms, as approximately 25% of the population reported to have these symptoms regularly. In our study 10–15% of the participants developed new symptoms and 50% recovered from symptoms during the 1-year follow-up period. The SBS symptoms are usually connected with persons working in non-industrial environments such as offices, schools, day-care centres, and hospitals. However, our study showed no difference between manual and non-manual workers in prevalence or 1-year incidence of mucous membrane symptoms or general symptoms. In addition, we have checked for interactions between occupation and the indoor environment factors and found no remarkable interactions (data not shown). Thus our study indicates that mucous membrane symptoms and general symptoms are equally common symptoms among manual and non-manual workers in a normal population sample.

In our analyses we adjusted not only for personal and psychosocial factors, but also for the other indoor factors, and as a result most associations disappeared. This may reflect confounding, but could also be due to over-adjustment because of an overlap or a correlation between the indoor factors. However, the indices have been tested for unidimensionality, so we believe that the different indices express different factors. Two of the indices were moderately correlated, but the rest showed low correlation coefficients which could not explain the findings. We also checked for collinearity and found no indications of that. Consequently, our interpretation is that the indoor factors function as confounders and thus should be adjusted for.

Cross-sectional studies examining the SBS symptoms have found different associations between reported symptoms and self-reported exposures in the indoor environment. Mucous membrane symptoms have been associated with perception of dry air, too little air movement, noise, static electricity, dust, and dampness (Engvall et al. 2001; Koskinen et al. 1999; Nelson et al. 1995; Norback and Edling 1991; Nordstrom et al. 1995; Wan and Li 1999). General symptoms have been related to reported odours, humidity, temperature, too little air movement, static electricity, dampness, and noise (Bachmann and Myers 1995; Engvall et al. 2001; Koskinen et al. 1999; Nelson et al. 1995; Nordstrom et al. 1995; Wan and Li 1999). Large-scale cross-sectional studies with objective environmental measurements have found only few associations between indoor environment variables and symptoms (Harrison et al. 1992; Nelson et al. 1995; Skov et al. 1990; Zweers et al. 1992). In addition the associations were weak, and the findings were inconsistent or contradictory. The only longitudinal epidemiological study of which we are aware also found only few significant associations among an extensive panel of variables (Chao et al. 2003). Thus the only findings from previous studies that could be reproduced in our longitudinal study were that mucous membrane symptoms were associated with dry air and noise and that general symptoms were associated with stuffy air. A possible explanation for only reproducing few earlier findings may be reporting bias, as many previous studies are cross-sectional where the exposure and outcome are self-reported and measured simultaneously. Because of the inconsistency between risk factors identified in the cross-sectional and the prospective analyses, the nature of the relationship between these risk factors and symptoms is not very clear. Specifically, a causal relation seems questionable. Moreover, some of the findings are not biologically plausible. We find it hard, for example, to see the biological pathway between noise and mucous membrane symptoms.

A limitation in our study is that we have only self-reports on the exposure, which may be biased towards more significant positive associations. Some researchers have compared self-reports with measurements of indoor environment and found a good correlation between perceived and measured indoor temperature, light, noise, and draught (Broder et al. 1990; Robertson et al. 1989; Tang 1997; Toftum 2004; U.S. Environmental Protection Agency 1991). There are divergent findings on perceived dry air and measured relative humidity (Nordstrom et al. 1994; Reinikainen and Jaakkola 2001; U.S. Environmental Protection Agency 1991). Thus self-reports seem to reflect measurable factors in the indoor environment to some degree. A risk of reporting bias still exists, but in our analyses of follow-up data the exposure and outcome is measured on different points in time. This will reduce but not completely eliminate reporting bias. To take further account of reporting bias, we have controlled for symptom reporting as a measure of a tendency to aggravate. A symptom reporting tendency was associated with SBS symptoms, but the estimates of the effect of the indoor environment factors changed only slightly when symptom reporting was included in the models, suggesting that symptom reporting is not a true confounder.

The possibility of selection bias and bias due to loss to follow-up must be considered. At baseline, women were more likely to respond, but it was only a small overrepresentation, and we found no differences in age or geographical region between responders and non-responders. Hence a major selection bias is unlikely. The participants who were lost to follow-up did not differ from the cohort in baseline characteristics on perceived indoor environment and symptoms; thus we consider the drop out to be less important.

Implicit in the SBS definition is a temporal relationship between symptoms and staying in a building, and some questionnaires do try to assess whether symptoms get better away from work. In our study the participants also had to specify, if the particular symptom was more pronounced on working days, but we have earlier shown that such information most probably is seriously biased (Brauer and Mikkelsen 2003). Accordingly we chose not to use the information about work-relatedness and consequently we regarded any symptoms, work-related or not, as the outcome. This choice, however, might lead to underestimation of possible effects.

The strengths of the present study are the prospective design, the large population, the random selection of participants, and the response rate. A response rate of 68% at baseline and 80% at follow-up can be considered satisfactory for a population study, if there is no selection bias. The prospective design made it possible to evaluate a temporal relation measuring the exposure before the outcome, on the assumption that the exposure was relatively stable during the 1-year follow-up period. We have no information about redecorations at home, different work place situations, or other changes in the indoor environment during this year, but we excluded participants who had changed job in order to keep exposure conditions as constant as possible. In addition, we did the surveys with a time lag of 1 year to account for seasonal variations and, in fact, the majority of participants remained at the same level of complaints regarding the indoor environment factors. As the cohort is a random sample of adults who presumably work in about 1,400 different workplaces, it is also unlikely that the indoor climate would have changed considerably in many of these buildings.

In conclusion, this is the first large-scale prospective epidemiological study examining associations between the indoor environment at work and the non-specific symptoms that are often referred to as SBS. We found that mucous membrane symptoms and general symptoms are very common in the general population, among manual workers as well as non-manual workers. As only one relationship showed consistency in both the cross-sectional and the longitudinal analyses, our study gives only limited support to the hypothesis of a causal relationship between the perceived indoor environment and these symptoms. We found no evidence of persistent mucous membrane symptoms and general symptoms related to specific factors in the indoor environment.

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