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ORIGINAL ARTICLE

The influence of individual and contextual psychosocial work factors on the perception of the indoor environment at work: a multilevel analysis

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Abstract
Purpose The aims of this study was to investigate the role of the psychosocial work environment—at the individual level as well as the workplace level—in explaining the variability in the employees' perception of the indoor environment.
Methods The perception of the indoor environment was surveyed by questionnaires among 3,281 employees in 39 randomly selected workplaces. Multilevel logistic regression analyses included individual-level and workplace-level covariates to examine the effect of context. Associations between psychosocial risk factors at the workplace level and the employees' perception of the indoor environment was calculated as the interval odds ratios while between-workplace variations were quantified by intraclass correlations and median odds ratios.
Results We found moderate differences between the workplaces in the perception of the indoor environment, but large differences between individuals in the same building indicating that some occupants of a building do perceive problems in the indoor environment even in the absence of a general indoor air problem in the workplace. The type of organisation accounted for some of the variation in perceived indoor environment. Psychosocial work environment factors at the individual level, but not at the workplace-level, were associated with the individual perception of the indoor environment. In addition, an increased tendency to report symptoms was strongly associated with complaints about the indoor environment suggesting bias due to a tendency to "over-report".
Conclusion In studies investigating "sick buildings" contextual factors may be important. Multilevel analyses should be used in future research within workplaces where clustering could be expected.

Keywords Sick building · Indoor environment · Perception · Job satisfaction · Multilevel analysis

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Introduction

Complaints about poor indoor environment quality may comprise stuffy air, odours, noise, static electricity, and temperature discomfort. Such complaints often lead to worry about adverse health effects resulting in extensive and expensive technical or microbiological investigations in the buildings. In addition, dissatisfaction with the indoor environment may increase sick leave and decrease performance or productivity (Mendell and Heath 2005; Milton et al. 2000; Wargocki et al. 2002). Hence the occupants' perception of the indoor environment in a building may have substantial economic consequences.

Considerable variations have been found between the reported prevalence of different indoor environment complaints between buildings as well as within buildings (Bluyssen et al. 1996; Nelson et al. 1995; Nordstrom et al. 1999; Zweers et al. 1992). Furthermore, indoor environment complaints are common not only in "sick buildings", but also in "healthy buildings" with no obvious indoor environment problem (Bakke et al. 2007; Bluyssen et al. 1996; Nordstrom et al. 1999; Reijula and Sundman-Digert 2004; Skov and Valbjorn 1987; Smedje et al. 1997;

Stenberg et al. 1993; Zweers et al. 1992), suggesting that other factors than the physical, chemical or microbiological environment in the building contribute to a person's perception of the indoor environment. However, studies examining the relationship between the psychosocial work environment and the perception of the indoor environment quality are few (Brauer et al. 2006b; Mendelson et al. 2000; Norback 1995; Smedje et al. 1997).

Individual factors such as gender, allergic diseases, dissatisfaction with the psychosocial work climate, and a general tendency to complain seem to affect a person's perception of the indoor environment (Bakke et al. 2007; Brauer et al. 2006b; Lahtinen et al. 2004b; Lundin 1999; Norback 1995; Smedje et al. 1997). Rumours among employees about indoor environment problems may also generate even more complaints about the indoor environment (Lahtinen et al. 2002). The impact of communication and organisational workplace factors when solving indoor air problems has also been debated (Lahtinen et al. 2002, 2004a; Reynolds et al. 1996; Thorn 2000). Thus psychosocial factors at individual level as well as at workplace level seem to contribute to indoor air problems.

In sociology and public health research it has been suggested for several years that a person's health and behaviour is affected both by individual characteristics and by characteristics of the social group to which they belong (Diez-Roux 2000; Merlo et al. 2001; Pickett and Pearl 2001; Robert and Reither 2004). Hence, persons within the same neighbourhood may be more alike than persons from different neighbourhoods indicating clustering. It has been suggested to use multilevel analysis in research where contextual factors may be important (Larsen and Merlo 2005; Merlo 2003; Snijders and Bosker 1999). Multilevel analysis allows the simultaneous examination of the effect of individual-level variables and group-level variables on individual-level outcomes while accounting for clustering by allowing for residual correlation. In research on indoor environment at work it is very likely that employees in the same workplace are influenced not only by individual factors but also by similar exposures in the indoor environment or by their social context. Hence clustering within workplaces could be expected and consequently it may be relevant to apply multilevel analysis in this research. However, to our knowledge only two previous studies on the indoor work environment have used multilevel analysis (Marmot et al. 2006; Mendell et al. 1996).

This study aims to investigate the role of the psychosocial work environment—at the individual level as well as at the workplace level—in explaining the variability in the employees' perception of the indoor environment using multilevel analysis. The study was restricted to buildings without known problems in the indoor environment.

Methods

The study was a cross-sectional questionnaire study of employees in 39 workplaces located throughout Denmark. The workplaces were recruited from The Central Business Register among workplaces with at least 40 employees. Only non-industrial workplaces were eligible for inclusion. A total of 79 workplaces were invited by mail to participate in "a study about the indoor environment and well-being at work". Of these, 20 workplaces declined to participate because they recently had conducted a survey of the working environment and additionally 13 workplaces declined because they were too busy or lacked resources. Four of the workplaces were excluded because of prolonged indoor environment problems and further three because the workplace consisted of several small local branches at different addresses. Hence 39 workplaces participated in the study. The study took place from November 2001 to April 2002. After the workplaces had accepted to participate, the research team visited the workplaces to get further information about the building from the manager and safety representative and to ensure that none of the workplaces had obvious indoor environment problems. We obtained information about building characteristics such as heating and ventilation system, roof construction, flooring and ceiling materials, smoking policy, water damage, and renovations in the workplace.

At each workplace the human resources departments made a list of all staff members and on the basis of this list an employee representative distributed and collected the questionnaires. The participants were allowed to fill in the questionnaire at work. They returned the questionnaires in sealed envelopes to the employee representative who sent the unopened envelopes to us. Full anonymity was guaranteed to all participants.

In all 4,139 employees received a questionnaire. There were 3,342 respondents yielding a response rate of 81% (range 52–100% for the separate workplaces). Subsequently 61 employees who were students or substitutes were excluded from the analyses, because they generally worked only few hours a week. The analyses are based on the remaining responses from 3,281 employees in 39 workplaces.

The study was carried out in accordance with the requirements of the national and regional ethics committees in Denmark.

Perceived indoor environment

The outcome measure was the individual perception of the indoor environment at work. It was assessed with the question: "Have you been exposed to any of the following factors in your work environment during the past four

weeks?" A checklist with 17 items about the indoor environment followed this question (draught, draught along the floor, too low temperature, too high temperature, temperature variations, stuffy air, unpleasant odour, dry air, static electricity, noise in the room, noise from other rooms, noise from outside, illumination problems, reflective surfaces, cramped for space, poor cleaning, and environmental tobacco smoke). The response options to each of the 17 items were: "no", "yes, sometimes", "yes, several times a week", and "yes, daily" and were scored (0,0,1,1). The questionnaire is a Danish standard questionnaire on indoor climate that has been used in previous studies (Brauer et al. 2006a; Ebbehoj et al. 2005; Meyer et al. 2004) and has been validated by interviews and test–retest (Brauer et al. 2000). It has shown good to excellent test–retest reliability with kappa coefficients ranging between 0.42 and 0.90 (average 0.72) (Brauer et al. 2000; Cohen 1960).

The responses to the individual items were summed to generate an Indoor Environment Quality score (IEQ score), ranging for 0–17. Where a participant completed only 16 items ($n = 181$), the missing item was assigned a score on the basis of the average of the items they responded to. Participants who completed 15 items or fewer were excluded from the analyses ($n = 98$). The IEQ score was dichotomised at the upper quartile corresponding to a cut-off score $\geq$4.25.

Psychosocial work-environment risk factors

Individual-level variables

Psychosocial work characteristics were measured with ten global questions addressing job demands ("How demanding do you feel your work is, all in all?", 1 = hardly demanding at all, 6 = extremely demanding), job decision authority ("How much influence do you normally have on the organisation and execution of your work?", 1 = a lot, 6 = very little), job support ("If you have problems with your work, can you obtain the necessary help and support from your colleagues or management?", 1 = always, 5 = never, 6 = I have no colleagues or supervisors), effort-reward imbalance ("Do you feel your work efforts are sufficiently appreciated?", 1 = to a very great extent, 6 = hardly at all), workloads ("Do you have sufficient time and resources to perform your tasks satisfactorily?", 1 = to a very great extent, 6 = hardly at all), social climate at work ("What is the atmosphere and psychological working climate like at your workplace?", 1 = very good, 6 = very bad), motivation ("How much do you normally feel like going to work?", 1 = very much, 6 = extremely reluctant), stressful work ("Is your normal daily work stressful in an unpleasant way", 1 = rarely/never, 6 = always), stimulating work ("Do you find your work stimulating, educational and involving?", 1 = to a very great extent, 6 = hardly at all), and overall satisfaction with the work ("How satisfied are you with your work, all in all?", 1 = very satisfied, 6 = very dissatisfied). In the analyses the responses were dichotomised. Decisions on where to dichotomise the responses were made a priori on the basis of the wordings of the response options to indicate a high risk. These questions were developed as part of a short form questionnaire of psychosocial exposures used as an addendum to the Danish standard questionnaire on indoor climate. They have shown good to excellent test–retest reliability with kappa coefficients ranging between 0.47 and 1.00 (average 0.65).

Workplace-level variables

For each of the 39 workplaces we calculated the mean of the ten above-mentioned psychosocial work characteristics. We used these means to make a dichotomous workplace–level variable classifying the workplaces into high level and low level workplaces as regards the respective psychosocial risk factor by splitting at the the median of these means.

Potential confounders

Individual-level variables

The individual variables age, sex, hypersensitivity, smoking, and a general tendency to report symptoms were used as potential confounders in the analyses. 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). Smoking status was categorised as non-smoker or current smoker. A general tendency to report symptoms was assessed with a symptom checklist of 15 symptoms that are not usually connected with indoor environment problems (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 strong tendency to report symptoms as having at least four symptoms among the 15 symptoms (symptoms present very often or often vs. sometimes, rarely or never) (Brauer et al. 2006a).

Workplace-level variables

The type of organisation was used as a potential workplace confounder. The 39 workplaces were classified into seven

groups according to the type of organisation: offices within the private sector (information technology and consulting), offices within the public sector (town halls or other administrative offices), hotel or retail trade (a conference centre, a supermarket, and a mail-order company), hospitals, primary and lower secondary school, upper secondary education, and college or vocational education.

Statistical analysis

The 3,281 participants were clustered in 39 workplaces allowing us to study effects at the individual level and at the workplace level. A multilevel logistic regression model was used to study the associations between the psychosocial work-environment risk factors and the individual perception of the indoor environment at work. The outcome measure was the individual IEQ score dichotomised at the upper quartile. In all analyses a random workplace effect was included in the model to take the cluster structure of the data into account.

Analyses were done stepwise. Firstly, we analysed an "empty" model which did not include any explanatory variables, but only the random workplace effect, examining how the individual IEQ scores differed between the workplaces (Merlo et al. 2005). Hence in the empty model the probability of complaining about the indoor environment was a function only of the participant's workplace. Secondly, we considered each of the psychosocial work environment risk factors at the individual level one at a time adjusting for the potential confounders (sex, age, hypersensitivity, smoking, a general tendency to report symptoms) and the random workplace effect (model A). Thirdly, a two-level model was analysed where we additionally controlled each of the individual-level risk factor for the corresponding workplace-level risk factor (model B). Thus in model B the probability of complaining about the indoor environment was a function of, for example, the individual variable of job demands, the workplace-level variable of job demands, the potential confounders, and the random workplace effect. Finally, the type of organisation was also included in the model (model C).

All analyses were done with SAS® System version 9.1 using the GLIMMIX procedure (Littell et al. 2006). The results concerning measures of association between the individual-level risk factor and the outcome are presented as odds ratios (OR) with 95% confidence interval. The association between the workplace-level risk factors and the outcome is presented as the interval odds ratio (IOR-80) (Larsen and Merlo 2005; Merlo et al. 2006). The IOR-80 is not a confidence interval. It is an interval of odds ratios between two persons with similar individual covariates but different workplace-level risk factors covering the middle 80% of the odds ratios. It means, for example, that when comparing all possible pairs of persons with similar individual covariates, in which the one person is from a workplace with a high level of job demands and the other person is from a workplace with a low level of job demands, the odds ratio for complaining about the indoor environment will lie within this interval in 80% of the cases. The interval is narrow if the variation between workplaces is small and wide if the variation is large. If the interval contains the value one, it indicates that the workplace-level risk factor cannot explain the variation between workplaces. The intraclass correlation coefficient (ICC), the residual intraclass correlation coefficient and the median odds ratio (MOR) are used as measures of the variance between workplaces or clustering (Larsen and Merlo 2005; Merlo et al. 2006). If the MOR is equal to one, there is no difference between the workplaces in the probability of complaining about the indoor environment. The MOR is directly comparable with the ORs of individual and workplace variables. See the "Appendix" for more details about the IOR-80, ICC and MOR.

Results

Of the 3,281 participants, 67% were women, 91% were non-manual workers, 29% were smokers, and 38% had hypersensitivity (Table 1). In the psychosocial work environment the participants most frequently complained about high job demands, low job support and heavy workloads. The median of the individual IEQ scores was 2 and the 75th percentile was 4.25.

Figure 1 shows the distribution of the IEQ score in the 39 workplaces ranked according to the workplace mean of the IEQ score. It shows that the individual variation in score was wide in all workplaces ranging between 0 and 17 in some workplaces. The workplace mean of the IEQ score varied between 1.3 and 5.1. The questionnaires were generally completed thoroughly, but 98 participants had to be excluded from the multilevel analyses because of more than one missing item in the outcome (the IEQ score), leaving 3,183 participants in the analyses.

Table 2 shows the characteristics of the 39 workplaces. The workplaces were built between 1864 and 1999 with 15% of the workplaces built before 1900, 46% built from 1900 to 1969, and 38% built in 1970 or later. In average, there were 84 participants in each workplace (range 33–225). Approximately 40% of the workplaces were office buildings and 43% were educational establishments. The majority of the workplaces were located in a town or suburb. Most of the buildings had some kind of central heating system and mechanical ventilation. About one-third of the buildings had carpets on the floors, the rest had

Table 1 Characteristics of the 3,281 participants in 39 workplaces in Denmark

	Participants *N* (%)
Women	2,186 (67.1)
Married or cohabitating	2,445 (83.5)
Age (years)	
18–29	281 (8.6)
30–39	786 (24.0)
40–49	971 (29.7)
50–59	1,072 (32.7)
60+	165 (5.0)
Hypersensitivity[a]	1,242 (38.0)
Smokers, every day	941 (28.8)
Employment	
Self-employed	3 (0.1)
Non-manual workers, public sector	2,407 (74.5)
Non-manual workers, private sector	539 (16.7)
Skilled manual workers	128 (4.0)
Unskilled manual workers	152 (4.7)
Perceived indoor environment (IEQ score[b])	
Missing values, more than 1 missing[c]	98 (3.0)
0–1	1,405 (42.8)
2–3	749 (22.8)
≥4	1,029 (31.4)
Psychosocial work characteristics	
High job demands	1,303 (39.9)
Low decision authority	372 (11.4)
Poor support, co-workers and supervisors	978 (30.2)
High effort-reward imbalance	502 (15.4)
Heavy workloads	900 (27.5)
Bad social climate	448 (13.7)
Low motivation	222 (6.8)
Stressful work	537 (16.5)
Non-stimulating work	747 (22.9)
Overall dissatisfaction	396 (12.2)

[a] Defined as allergy to pollen, furry animals or house dust mite or a history of asthma, hay fever or childhood eczema

[b] IEQ score, range 0–17. For further information see text

[c] Participants with more than 1 missing value in the IEQ score were excluded from the multilevel analyses

bare floors. Smoking was permitted in the whole building in 28% of the workplaces and restricted to separate rooms in 69% of the workplaces. Water damage had occurred previously in 67% of the buildings, but most of the water damage was in small areas and of short duration. None of the building characteristics were significantly associated with the participants' perception of the indoor environment (data not shown).

Figure 2 shows the frequencies of complaints about the indoor environment in the seven types of organisation. Differences were found between the seven types of organisation for all the 17 indoor environment factors except for "draught along the floor" (Chi square test, $p < 0.001$). Employees at offices complained the least about the indoor environment, the prevalence of complaints being below 20% for most of the 17 indoor environment factors. In the group of hotels and retail trade the complaints were mostly about dry air and noise in the room while the employees at hospitals complained about draught and dry air. The patterns for the primary and lower secondary schools and for the upper secondary school were much alike with complaints primarily about noise, poor cleaning and too little space. At colleges or trade schools with vocational education the complaints were about noise in the room and environmental tobacco smoke.

Table 3 shows the measures of variation or clustering in the different models as well as the effects of the potential confounders on the perception of the indoor environment demonstrated with the model including job demands. In the empty model the ICC was equal to 0.07 meaning that 7% of the total individual differences in the IEQ score were at the workplace level suggesting some degree of clustering. All the potential confounders had an independent effect on the participants' perception of the indoor environment. Women, younger persons, smokers, and persons with hypersensitivity were more likely to complain about the indoor environment. A tendency to report symptoms was strongly associated with complaining about the indoor environment. Employees working in primary or lower secondary schools were also more likely to complain about the indoor environment. The odds ratios for the potential confounders were of the same magnitude regardless of the psychosocial risk factor in the model (data not shown).

Table 4 shows the measures of clustering and the effects of both the individual-level and the workplace-level risk factors on the individual perception of the indoor environment. The results from model A and model B were almost similar and hence the results from model A are not shown. In model B the individual-level risk factor is adjusted for the corresponding workplace-level risk factor, sex, age, hypersensitivity, smoking, a general tendency to report symptoms, and the random workplace effect. The measures of clustering indicated that the individual tendency to complain about the indoor environment varied somewhat between workplaces with the residual ICC about 8% and the MOR of 1.6 or 1.7. All the individual-level psychosocial risk factors were significantly associated with the individual perception of the indoor environment with odds ratios between 1.3 and 2.8 (model B). The MOR was of the same size as most of the individual-level OR suggesting that the unexplained variation between the workplaces was as relevant as the person's level of the risk factor for understanding variations in the odds of

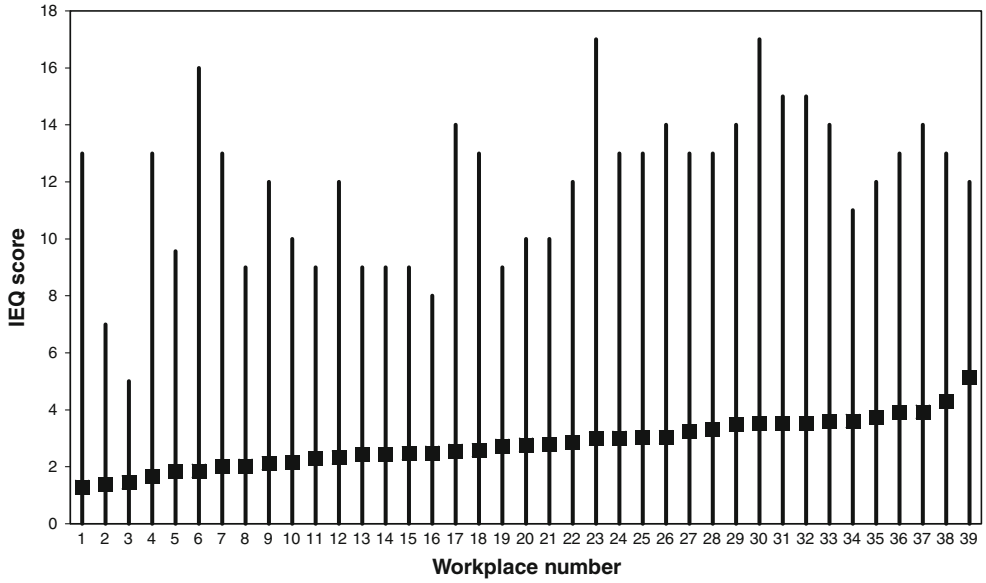

Fig. 1 The distribution of the IEQ score in the 39 workplaces. Individual minimum and maximum values of the IEQ score and the workplace mean of IEQ score. Ranked according to the workplace mean of the IEQ score (*filled square* = workplace mean)

complaining about the indoor environment. However, the workplace-level psychosocial risk factors could not explain the heterogeneity as all the IOR-80 contained the value one. In addition, the IOR-80 intervals were fairly wide reflecting an unexplained variation between workplaces in the tendency to complain about the indoor environment.

When the type of organisation was introduced into the model (Table 4, model C) the residual ICC decreased to about 3.5% and the MOR to 1.4, indicating that the type of organisation explained some of the differences between the workplaces. Adjusting for the type of organisation had no effect on the estimates of the individual-level risk factors. Their odds ratios did not change and all remained statistically significant. The IOR-80 all included the value 1, again indicating no effect of the workplace-level variables. However, the IOR-80 intervals became narrower reflecting less variation.

Results were the same for men and women (data not shown) and if the cut-off point of the IEQ score was set at the median instead of the upper quartile. If allowing for 2 missing values instead of 1 in the IEQ score, the results were similar.

Discussion

In this study we found a moderate variation between the workplaces in the perception of the indoor environment. None of the building characteristics were associated with complaints about the indoor environment. Nevertheless, it seems that some occupants of a building do perceive problems in the indoor environment even in the absence of a general indoor air problem in the workplace. Psychosocial work environment factors at the individual level were associated with the individual perception of the indoor environment. However, at the workplace-level, the psychosocial work environment surprisingly had no effect. We had expected a stronger effect of the workplace level variables based on experience from "sick buildings" where organisational workplace factors such as poor patterns of communication may lead to persisting complaints (Thorn 2000). An explanation for no effect in the present study could be that the workplaces were not "sick". The type of organisation accounted for some of the variation in perceived indoor environment between the workplaces, but the individual psychosocial risk factors had a considerable independent effect on the person's perception of the indoor environment even after adjustment for the type of organisation. In addition, persons with an increased tendency to report symptoms were more likely to complain about the indoor environment.

The differences between the workplaces in the perception of the indoor environment may be due to a different composition of the workplaces in terms of individual characteristics that we have not measured rather than a true contextual effect. In addition, the different types of organisations showed different patterns of indoor environment complaints suggesting that some of the differences between the workplaces could be explained by different indoor environment conditions, for example, noise in

Table 2 Characteristics of the 39 workplaces in Denmark, in average 84 participants per workplace, $N = 3,281$ participants

	Workplaces *N* (%)	Participants *N* (%)
Type of organisation		
Office, private sector	3 (7.7)	271 (8.3)
Office, public sector	13 (33.3)	1,019 (31.1)
Hotel or retail trade	3 (7.7)	270 (8.2)
Hospital	3 (7.7)	558 (17.0)
Primary and lower secondary school	9 (23.1)	626 (19.1)
Upper secondary education	2 (5.1)	129 (3.9)
College or vocational education	6 (15.4)	408 (12.4)
Location		
Town centre	20 (51.3)	1,546 (47.1)
Suburb	11 (28.2)	981 (29.9)
Industrial area	5 (12.8)	472 (14.4)
Country side	3 (7.7)	282 (8.6)
Renovations made in the building		
No (or only minor renovations)	7 (18.0)	479 (14.6)
Yes	25 (64.1)	2,126 (64.8)
Partly	7 (18.0)	676 (20.6)
Roof construction		
Flat	9 (23.1)	733 (22.3)
Sloping	17 (43.6)	1,446 (44.1)
Flat and sloping (on different buildings)	13 (33.3)	1,102 (33.6)
Heating system[a]		
Central heating (water or air)	36 (92.3)	2,909 (88.7)
Electric heaters and central heating	3 (7.7)	372 (11.3)
Ventilation		
Natural ventilation	4 (10.3)	408 (12.4)
Natural and mechanical	27 (69.2)	2,383 (72.6)
Mechanical ventilation	8 (20.5)	490 (14.9)
Flooring		
Bare floor	26 (66.7)	2,321 (70.7)
Carpets	12 (30.8)	880 (26.8)
Information missing	1 (2.6)	80 (2.4)
Smoking policy		
Permitted in the whole building	11 (28.2)	967 (29.5)
Restricted to separate rooms	27 (69.2)	2,168 (66.1)
Information missing	1 (2.6)	146 (4.4)
Water damage previously		
No	13 (33.3)	1,092 (33.3)
Yes, only small areas and for a short time	23 (59.0)	1,944 (59.3)
Yes, larger areas but now repaired	3 (7.7)	245 (7.5)

[a] More than one type of heating was possible

schools. Another explanation of the differences between the workplaces could be a general worry about the indoor environment (Lahtinen et al. 2002; Marmot et al. 2006; Nelson et al. 1995; Skov et al. 1989; Smedje et al. 1997). However, we included only non-problem buildings, because reports among participants in buildings with widespread concerns about the indoor environment may be biased (Brauer and Mikkelsen 2003). In the present study it seems more likely that the complaints about the indoor environment are biased by a general tendency to over-report among some persons, because the individual level and not the workplace level variables concerning dissatisfaction with the psychosocial work environment were associated with the reports. Furthermore, complaints about the indoor environment were also much more prevalent among individuals complaining about different bodily symptoms that not readily can be associated with indoor environment factors. When we used this symptom check list in the study, it was meant as a proxy for a personality trait describing a behavioural habit to complain. We are aware, that a high number of symptoms may mean that the respondent actually suffers from these symptoms, so that the scores reflect disease. However, the strong correlation between these symptoms and the complaints about the indoor environment suggests a general tendency to "over-report".

Most epidemiological studies on the indoor environment focus on symptoms among the occupants of the buildings and do not try to explain the perception of the indoor environment. A few studies have compared measured exposures and the subjective perception of the indoor environment and the associations were generally weak or inconsistent (Norback 1995; Smedje et al. 1997; Zweers et al. 1992). These studies also examined associations between the psychosocial work environment and the perception of the indoor air quality and in accordance with our findings they found that the indoor environment was perceived as worse by those who were dissatisfied with the psychosocial work climate. In our study women, younger persons, smokers, and persons with hypersensitivity were more likely to complain about the indoor environment. Similar observations have been made in other studies (Andersson 1998; Reijula and Sundman-Digert 2004; Zweers et al. 1992).

The study has some limitations. The study is not longitudinal and therefore unsuitable for causal conclusions. We only have self-reports on the psychosocial work environment and we have no measurements of indoor environment parameters. Hence we cannot rule out that some of the workplaces actually have general problems with the psychosocial work environment or the indoor environment. Nevertheless, the effect of the psychosocial risk factors was found only at the individual level and not at the workplace level. We included only non-industrial workplaces and the study population was predominantly female, so the sample is not representative for the entire workforce and generalisation should be made with caution. However, it is not

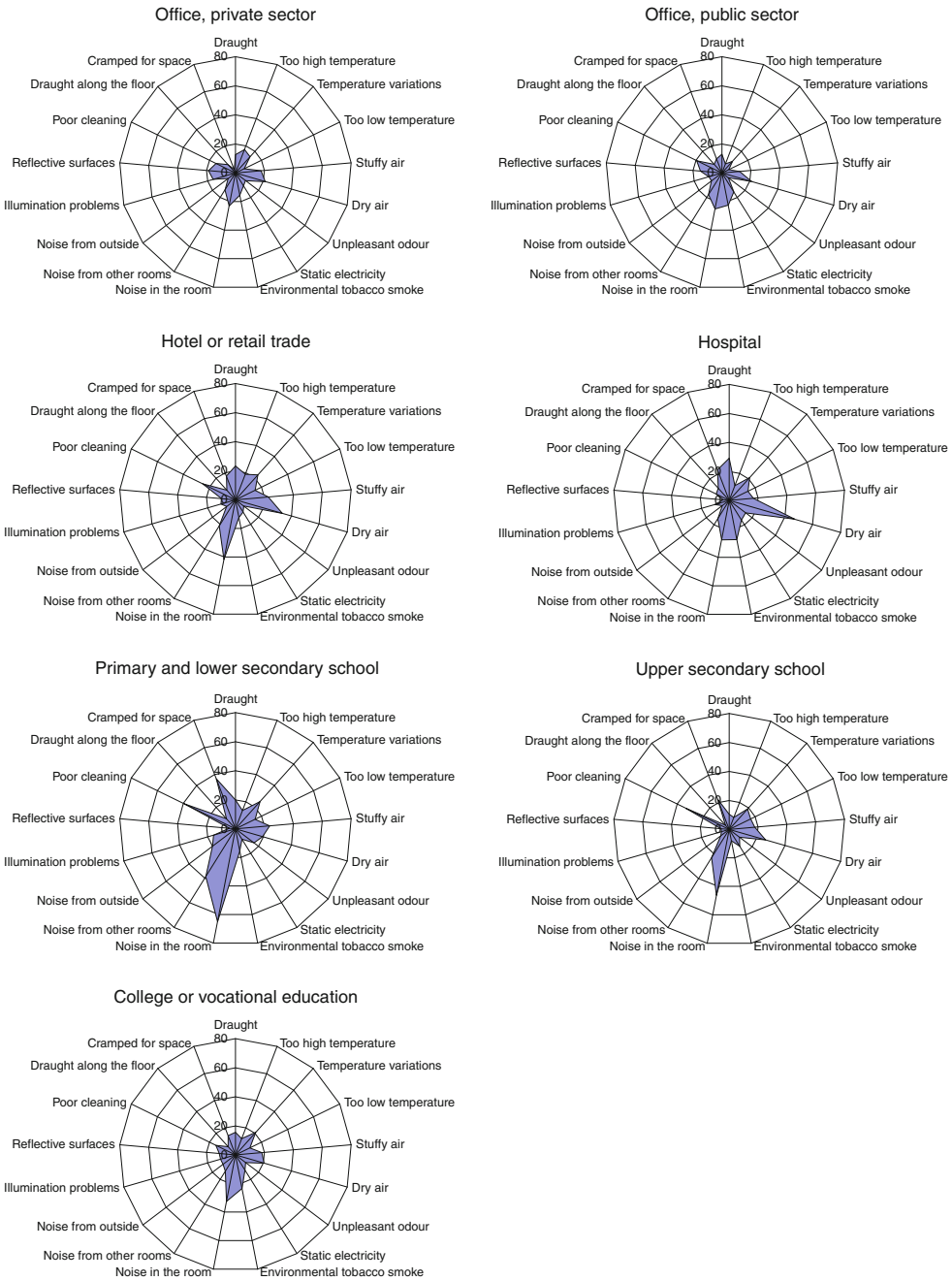

Fig. 2 The patterns of indoor environment complaints in the seven different types of organisation. Frequencies in percent

obvious that these limitations should have affected our results notably. The possibility of selection bias must be considered as about 40% of the invited workplaces declined to participate. Conversely, we selected workplaces from all over Denmark, we included all employees at the workplaces instead of focusing on specific groups of employees and the participation rate was very high for the participating workplaces. This means that the workplaces are heterogeneous in terms of geographical region, occupation and working conditions and hence could be regarded as representative for Danish non-industrial workplaces. An important strength of our study was the random selection of workplaces, which was possible because a database exists covering all workplaces in Denmark. Accordingly participants and workplaces were not selected on the basis of explicit concerns about indoor environment quality and health. Another strength was that all data were collected in the heating season. Season may affect the indoor environment, so by collecting data during the same winter period bias was reduced.

Table 3 Effect of the potential confounders on the perception of the indoor environment at work here shown with the model including job demands as an example, 39 workplaces, $N = 3,183$

Risk factor	Empty model	Model A	Model B	Model C
Measures of association				
Individual level variables, OR (95% CI)				
Job demands, high versus low	–[a]	1.6 (1.4–2.0)	1.6 (1.4–1.9)	1.6 (1.4–1.9)
Female (vs. male)	–	2.3 (1.9–2.8)	2.3 (1.9–2.8)	2.3 (1.9–2.9)
Age (years)	–			
60+		1.0	1.0	1.0
50–59		1.8 (1.0–3.0)	1.8 (1.0–3.0)	1.7 (1.0–3.0)
40–49		1.9 (1.1–3.2)	1.9 (1.1–3.2)	1.8 (1.1–3.1)
30–39		2.8 (1.7–4.8)	2.8 (1.7–4.8)	2.8 (1.7–4.8)
<30		3.0 (1.7–5.3)	3.0 (1.7–5.3)	2.9 (1.6–5.2)
Hypersensitivity (yes vs. no)	–	1.3 (1.1–1.6)	1.3 (1.1–1.6)	1.3 (1.1–1.6)
Smoking (yes vs. no)	–	1.7 (1.4–2.0)	1.7 (1.4–2.0)	1.6 (1.4–2.0)
High (vs. low) tendency to report symptoms	–	3.4 (2.5–4.7)	3.4 (2.5–4.7)	3.5 (2.6–4.9)
Workplace level variables				
Job demands, high versus low, IOR-80	–	–	0.44–2.97	0.41–1.46
Type of organisation, OR (95% CI)	–	–	–	
Office, private sector				1.0
Office, public sector				0.7 (0.4–1.3)
Hotel or retail trade				1.1 (0.5–2.4)
Hospital				1.2 (0.6–2.6)
Primary and lower secondary school				2.4 (1.2–5.0)
Upper secondary education				1.2 (0.5–3.0)
College or vocational education				1.1 (0.6–2.3)
Measures of variation or clustering				
Workplace level variance (SE)	0.26 (0.08)	0.27 (0.09)	0.28 (0.09)	0.12 (0.06)
ICC, %	7.3	7.7[b]	7.8[b]	3.5[b]
MOR	1.6	1.6	1.7	1.4

3,281 questionnaire responders excluding 98 responders with more than one missing value in IEQ score (see text)

[a] Not included

[b] residual ICC

Empty model, adjusted only for a random workplace effect

Model A, adjusted for individual levels of sex, age, hypersensitivity, smoking, a general tendency to report symptoms, and a random workplace effect

Model B, is further adjusted for the corresponding workplace risk factor (in this example: job demands)

Model C, is further adjusted for type of organisation

Our study showed that even in non-problem buildings rather different patterns of indoor environment complaints can be found suggesting that different reference values must be used depending on which type of organisation is being studied. The "sick building syndrome" is often linked to office buildings (Bluyssen et al. 1996; Burge et al. 1987; Mendell et al. 2008; Skov and Valbjorn 1987). In our study, however, the participants in office buildings were the ones who complained the least about the indoor environment, whereas employees at schools complained the most. At the schools the complaints were primarily about noise, poor cleaning and too little space, which is hardly surprising, but is easy to discover without conducting expensive investigations. The low level of complaints among participating office workers could be because of an unusual high quality of the participating office buildings. This is less likely, however, as the participating offices was a random sample of buildings consisting of both public and private offices. Our study suggests that the indoor environment at offices is perceived as satisfactory by most of the occupants and that sick office buildings is not a widespread problem anymore, at least in Denmark. However,

Table 4 Individual and workplace risk factors

Risk factor	Model B					Model C				
	Measures of clustering			Measures of association		Measures of clustering			Measures of association	
	Workplace-level variance (SE)	Residual ICC %	MOR	Individual-level variables OR (95% CI)	Workplace-level variables IOR-80	Workplace-level variance (SE)	Residual ICC %	MOR	Individual-level variables OR (95% CI)	Workplace-level variables IOR-80
Job demands, high versus low	0.28 (0.09)	7.8	1.7	1.6 (1.4–1.9)	0.44–2.97	0.12 (0.06)	3.5	1.4	1.6 (1.4–1.9)	0.41–1.46
Decision authority, low versus high	0.29 (0.09)	8.0	1.7	1.5 (1.2–1.9)	0.33–2.32	0.11 (0.06)	3.3	1.4	1.5 (1.2–2.0)	0.65–2.16
Job support, low versus high	0.32 (0.10)	8.8	1.7	1.8 (1.5–2.2)	0.33–2.51	0.11 (0.06)	3.3	1.4	1.8 (1.5–2.2)	0.70–2.37
Effort-reward imbalance, high versus low	0.30 (0.10)	8.4	1.7	2.3 (1.8–2.9)	0.31–2.27	0.12 (0.06)	3.6	1.4	2.3 (1.8–2.9)	0.57–2.02
Workloads, high versus low	0.30 (0.10)	8.4	1.7	2.0 (1.7–2.5)	0.26–1.93	0.13 (0.06)	3.8	1.4	2.0 (1.7–2.5)	0.47–1.76
Social climate, bad versus good	0.29 (0.09)	8.0	1.7	2.8 (2.2–3.6)	0.27–1.86	0.12 (0.06)	3.6	1.4	2.8 (2.2–3.6)	0.43–1.53
Motivation, low versus high	0.26 (0.09)	7.4	1.6	1.8 (1.3–2.5)	0.28–1.79	0.11 (0.06)	3.2	1.4	1.9 (1.4–2.6)	0.44–1.45
Stressful work, high versus low	0.27 (0.09)	7.7	1.6	2.1 (1.7–2.6)	0.32–2.15	0.12 (0.06)	3.5	1.4	2.1 (1.7–2.6)	0.48–1.66
Stimulating work, low versus high	0.29 (0.09)	8.0	1.7	1.3 (1.1–1.6)	0.39–2.69	0.12 (0.06)	3.5	1.4	1.3 (1.1–1.6)	0.48–1.66
Dissatisfaction with job versus satisfaction with job	0.29 (0.09)	8.0	1.7	1.8 (1.4–2.4)	0.35–2.39	0.12 (0.06)	3.5	1.4	1.8 (1.4–2.3)	0.52–1.82

Effect of each psychosocial work-environment risk factor on the perception of the indoor environment at work, 39 workplaces, $N = 3{,}183$

3,281 questionnaire responders excluding 98 responders with more than one missing value in IEQ score (see text)

Model B, separate analyses with each individual psychosocial risk factor and the corresponding workplace risk factor, adjusted for individual levels of sex, age, hypersensitivity, smoking, a general tendency to report symptoms, and a random workplace effect

Model C, is further adjusted for type of organisation

our study also showed that some persons perceive problems in the indoor environment even if there is no general problem at the workplace.

Only two previous studies on the indoor environment have used multilevel analysis to allow for the possible non-independence of participants within the same building (Marmot et al. 2006; Mendell et al. 1996). These studies did not report the degree of variation in the perception of the indoor environment between the workplaces and did not include workplace-level measures of the psychosocial factors and thus they cannot be compared with our study. In these studies all but one building were non-problem buildings, so multilevel analysis has not been used in studies investigating "sick buildings" in which contextual factors may be even more important. The multilevel technique should be used in future research on indoor environment or other common problems within workplaces where clustering could be expected.

Conflict of interest statement The authors declare that they have no conflict of interest.

Appendix

The interval odds ratio (IOR-80)

The IOR-80 describes the effect of the workplace-level risk factor. Consider all possible pairs of persons with similar individual covariates, in which one person works in a workplace with a low value of the aggregate workplace risk factor and the other in a workplace with a high value of the same aggregate workplace risk factor. For all possible pairs the OR is computed and we obtain a distribution of the OR. The IOR-80 is defined as the interval centred on the median of the distribution that comprises 80% of the values of the OR. If the interval contains the value 1, it indicates that the workplace risk factor does not account for a substantial amount of the variation between the workplaces.

The lower and the upper bounds of the IOR were computed with the following formula (Larsen and Merlo 2005; Merlo et al. 2006):

$$\mathrm{IOR}_{\mathrm{lower}} = \exp\left[\beta + \sqrt{(2 \times \mathrm{V_A})} \times (-1.2816)\right]$$

$$\mathrm{IOR}_{\mathrm{upper}} = \exp\left[\beta + \sqrt{(2 \times \mathrm{V_A})} \times 1.2816\right]$$

where β is the regression coefficient for the workplace-level variable, $\mathrm{V_A}$ is the workplace-level variance, and the values -1.2816 and $+1.2816$ are the 10th and 90th percentiles of the normal distribution with mean 0 and variance 1.

The intraclass correlation coefficient (ICC)

The ICC is a measure of clustering often used in multilevel linear regression which gives information about the proportion of total variance in the outcome that is attributable to the area level as for instance a workplace level (Merlo et al. 2005). A high ICC indicates clustering and suggests that the workplaces are very important in understanding individual differences in outcome. Conversely, an ICC of 0 suggests that the workplace context is irrelevant in understanding individual differences in outcome. It is computed as $\mathrm{ICC} = \mathrm{V_A}/(\mathrm{V_A} + \mathrm{V_I})$ where $\mathrm{V_A}$ is the area-level variance and $\mathrm{V_I}$ is the individual level variance (Merlo et al. 2005, 2006). In multilevel linear regression both the area-level variance and the individual level variance are expressed on the same scale, but in multilevel logistic regression these variances are not directly comparable as the area-level variance is on the logistic scale and the individual level variance is on the probability scale. Snijders and Bosker have described a method to compute the ICC in the case of logistic regression (Snijders and Bosker 1999). This method converts the individual level variance from the probability scale to the logistic scale before computing the ICC which then can be calculated with the following formula that was used in the present study:

$$\mathrm{ICC} = \mathrm{V_A}/\left(\mathrm{V_A} + \pi^2/3\right)$$

where $\mathrm{V_A}$ is the workplace-level variance.

In the text the intraclass correlation coefficient refers to the variances in the empty model while residual intraclass correlation coefficient refers to the variances in the models which control for the effect of explanatory variables (Snijders and Bosker 1999).

The median odds ratio (MOR)

The MOR is also a measure of clustering (Larsen and Merlo 2005; Merlo et al. 2006). Considering all possible pairs of persons with similar individual covariates but working in different workplaces, the OR of all these pairs can be computed yielding a distribution of the OR. The MOR is defined as the median value of this distribution. It corresponds to the increased risk that (in median) a person would have, if moving to another workplace with a higher risk. If MOR is equal to 1, there is no workplace variance.

The MOR was computed in the following way:

$$\mathrm{MOR} = \exp\left[\sqrt{(2 \times \mathrm{V_A})} \times 0.6745\right]$$

where $\mathrm{V_A}$ is the workplace-level variance, and 0.6745 is the 75th percentile of the cumulative distribution function of the normal distribution with mean 0 and variance 1.

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