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Possible factors influencing perceived symptoms in the indoor environment of office buildings

Version 2

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Abstract

Introduction: Vague subjective symptoms assigned to indoor environment is often difficult to investigate. Technical measurements are expensive and often hard to interpret. In Örebro, the Department of Occupational and Environmental Medicine has developed a standardized model to investigate adverse health effects from the indoor environment. One part of the investigation involves a questionnaire, were the dwellers in the building investigated answer questions about perceived indoor environment, perceived symptoms and other factors. The data received from the questionnaires may be used to explore the inference between symptoms and indoor environment.

Objective: To investigate which possible factors that can explain the existence of different symptoms in office buildings. Identifying the relevant factors could aid in the prevention of symptoms and in a longer perspective reduce the sick leave. The study could also be used as a starting point for improving the Örebro-questionnaire.

Method: A large database with answers from the Örebro-questionnaire (MM 040 NA kontor) was analyzed. Factors from the questionnaire were selected, processed and then analyzed statistically with multiple logistic regression analysis. Selected factors were tested versus three outcome groups: "General symptoms", "Mucous symptoms" and "Skin symptoms".

Results: More factors were significant when tested versus "General symptoms" than when tested versus "Mucous symptoms" and "Skin symptoms". The factors "Dry air" "Unpleasant odor", "Static electricity, often causing shocks", "Dust and dirt", "Work interesting and stimulating", "Age", "Gender", "Easy irritated in eyes or respiratory airways", "Frequent colds or other infections" and "Atopy" were significant in all the runs. "Eye lenses" was not tested significant in any of the runs.

Conclusion: Almost all of the variables were significant when tested versus "General symptoms". This may imply that the group "General symptoms" is of a more multifactorial origin than the two other symptom groups. All the symptom groups appeared to be affected by factors describing air quality, "Gender" and sensitivity factors.

Keywords: SBS, multiple logistic regression analysis, indoor environment.

Abbreviations

CI – Confidence interval

DA – Discriminant analysis

OLS – Ordinary least squares

SBS – Sick building syndrome

VIF – Variance inflation factor

Contents

1. Introduction

In the 1970's, symptoms that were assigned to the indoor environment of newly built or renovated domestic buildings and workplaces started to be reported more frequently in the Western world [1]. It is thought that the symptoms of adverse health effects were related, at least partly, to new building techniques trying to minimize the energy expenditure following the oil crisis. Other explanations include the use of new synthetic materials in the construction and more people working in offices [2].

1.1 The sick building syndrome

The symptoms had in common that they were vague, subjective and rather common in the whole population. They included general symptoms such as headache and nausea, mucosal symptoms e.g. coughing and skin problems like dry skin and itching. Soon these vague symptoms related to indoor environment were collected under the concept sick-building syndrome (SBS) [3]. The use of the term SBS has later been criticized due to the vagueness of the term and the difficulties of exploring it scientifically [4, 5].

1.2 The Örebro model

There are strong indications suggesting that poor indoor environment might cause illness [6]. For instance, difference in ventilation has been connected to infectious diseases in the respiratory tract and SBS symptoms [7]. However, the technical measurements of such environmental factors are often hard to interpret when performed in a building with possible environmental problems. The exposure levels are often too small to give any conclusive evidence of adverse effects. Technical measurements are also expensive and might lead to more confusion if not performed in a standardized manner [8]. The difficulty to correlate the symptoms with technical measurements in the buildings prompted the use of additional methods [9]. In the 80's the Department of Occupational and Environmental Medicine in Örebro developed a standardized model for investigating the indoor environment in buildings where complaints are being addressed. The first step is to visit the building and look for obvious causes to the complaints. Secondly, a questionnaire is sent to the dwellers with questions about perceived indoor environment and symptoms. The answers point out possible causes to the environmental problems and the symptoms. If it is deemed necessary further technical measurements may follow. Finally, the investigation culminates in

recommendations of measures that need to be taken in order to improve the indoor environment of the building [8, 10].

The answers from the questionnaire contain information about perceived indoor environment and experienced symptoms, but also data on e g smoking habits, atopy and levels of stress. The questionnaire has been validated and tested for many years [8] and has been used in several countries [11, 12].

1.3 Objective

One way to explore the inference between the reported indoor environment in a questionnaire and perceived symptoms is to use logistic regression analysis. This approach is suitable when the response variable is binary (effect = 1 or no effect = 0). This study used multiple logistic regression analysis to test to what extent the different reported variables in the Örebro-questionnaire (MM 040 NA kontor) could explain the perceived symptoms in office buildings in the Örebro area, using a large database containing more than 18000 answers from the Örebro-questionnaire.

2. Material and methods

2.1 Database characteristics

The database consisted of answers to the office version of the Örebro-questionnaire (MM 040 NA kontor), (see appendix 1), collected during the period 2003 to 2013 in the Örebro area. The number of office buildings was 263 and in all 18293 individuals answered the questionnaire. Of the respondents 66% were females, the mean age was 46 years and 9.4% were smokers. All of the buildings in the database had been in contact with the Department of Environmental Medicine at Örebro University Hospital to investigate possible indoor climate problems. It is therefore probable that the perceived indoor environment and symptoms were worse than in a general population. The number of individuals in the buildings not answering the questionnaire was not known exactly for all the objects, but in general the response rate was 65-70 % [13].

2.2 Database processing

Some of the answers in the questionnaire were selected as variables in the following statistical analysis. The variables were chosen if they were deemed relevant for the study. A number of variables were not included in the analysis because they were too similar to the ones included, as this would increase the risk of multicollinearity and complicate the interpretation.

One group of questions concerned background factors. The variables included in the analysis were e g "Gender", "Eye lenses", "Education" etc. The possible answers to "Education" were: "Nine-year school", "Upper secondary school", "University/college" or "Other". In variables like this the entry "Other" has been recoded to a missing value, because it could not be considered an ordinal category. "Work with computer/day" was the other ordinal factor included in the analysis. Strictly speaking ordinal variables like this do not fit in a logistic regression. Despite this, they are often used as if they were continuous variables in regression analyses [14]. Compared to ordinal variables, logistic regression is not that sensitive to continuous factors [14]. "Age" was the only continuous variable included in the final analysis.

The main group of questions had to do with the perceived indoor environment. The participants were asked in the manner: "Have you been bothered during the last three months by any of the following factors at your work place?". The possible answers were: "Yes, often (every week)", "Yes, sometimes" or "No, never". The variables were dichotomized to a "Yes" group, including the answer "Yes, often (every week)" and a "No" group, including the answers "Yes, sometimes" and "No, never". This was done to exclude uncertainty, given that "Yes, often (every week)" could be regarded as a more definitive answer and factual description of poor indoor environment. The questions on psychosocial environment were also dichotomized in order to better fit into the analysis. The possible answers to the questions concerning psychosocial environment were: "Yes, often", "Yes, sometimes", "No, seldom" and "No, never". The answers were dichotomized to a "Yes" group containing the answers "Yes, often" and "Yes, sometimes" and a "No" group containing the answers "No, seldom" and "No, never".

2.3 Symptom groups as outcome

The answers to the questions on symptoms in the database were assigned group membership in a previous study using factor analysis [13]. These generalized group structures have been

adopted in the present study. The group "General symptoms" contained at least one symptom from the questions "Fatigue", "Feeling heavy-headed", "Headache", "Nausea/dizziness" or "Difficulties concentrating". At least one symptom from the questions "Itching, burning or irritation of the eyes", "Irritated, stuffy or runny nose" "Nose-bleeding", "Hoarse or dry throat" or "Cough" constituted the group "Mucous symptoms". The group "Skin symptoms" contained at least one symptom from the questions "Dry or flushed facial skin", "Scaling/itching scalp or ears" or "Hand dry, itching, red skin". Respondents with self-reported atopy were also grouped together. "Atopy" in this study refers to at least one symptom from the questions "Have or have you ever had asthma, eczema or hay fever".

2.4 Statistical analyses

The statistical package PIA (www.amap.no) was used for the multiple logistic regression analysis. As a measure of Pseudo R^2, McFadden adjusted R^2 and Nagelkerkes R^2 were applied. To test the stability of the database, random samples with 50 % of the material were first tested five times for selected variables against the symptom group "General symptoms".

Secondly, the factors were tested for multicollinearity in order to check for intercorrelations among the independent variables as a part of an Ordinary Least Square (OLS) Multiple Regression Analysis.

Selected variables were then tested versus the groups "General symptoms", "Mucous symptoms" and "Skin symptoms" respectively. After the first run of the analysis, variables that were not significant were removed from the model and the material analyzed again until only significant factors remained in order to follow the principle of parsimony. Excluding variables generally led to more individuals in the test, since one question not answered led to exclusion of all the answers from that individual.

Another run tested only indoor environment variables against the three symptom groups.

2.5 Interpreting the results

A few notes on how to interpret tables 1-6. In each table heading the number of values included in the analysis are reported. In all the runs a few thousand values were missing from the original 18293 values. This was due to some of the questions being unanswered in the

forms. The frequency table shows how many of the respondents that answered “Yes” and “No” to the questions in the survey. The frequency table was only applicable to the dichotomized factors, hence the absence of frequency values for the continuous variables. The possible answers to the dichotomized questions were “Yes” or “No”. When looking at the Odds ratio for the factors, the “No” answer is set to a baseline of 1, while the difference in Odds ratio can be seen in the “Yes” answer of the question. For instance, when looking at the factor “Draught” in table 1, 1283 respondents answered “Yes, often” to the question “Have you been bothered during the last three months by any of the following factors at your work place?” and 9968 answered “Yes, sometimes” or “No, never” (the three possible answers were dichotomized to a “Yes” group and a “No” group as described in “Material and methods”). The individuals in the “No” group is the baseline population and the Odds ratio is set to 1. The Odds ratio 1.21 describes the individuals in the “Yes” group that consequently has a 21 % higher risk of perceived general symptoms. In other words, when the Odds ratio is above 1 for the dichotomized factors, it means that the probability for symptoms increases. On the other hand, when the Odds ratio is below 1, it means that the probability for symptoms decreases. Following the Odds ratio is the 95 % confidence interval given in parenthesis. If stars follow the confidence interval the relation between the factor and the outcome is statistical significant. One star means that $p < 0.05$, two stars mean that $p < 0.01$ and three stars that $p < 0.001$.

2.6 Ethics

This was a non-invasive study. The questions in the survey were not controversial and the participation was voluntary and anonymous. A letter also accompanied the questionnaire with an inquiry about participation. The answers were treated with secrecy and analyzed at a group level. However, it is possible that certain groups may feel singled out, if the results e g show that a specific group have one type of symptoms. It is important to be able to use these kinds of databases in research. It could be argued that it is one of the main reasons why large databases exist. Apart from the general interest of investigating how symptoms may be related to buildings, this study has several other potential benefits. First of all it gives us a map of possible causes to the perceived symptoms in the office stock of the Örebro region. Knowing the causes is the first step of prevention and in a longer perspective a study like this may help in cutting the costs of sick leave. Another potential outcome of the study is the improvement of the Örebro questionnaire. If some of the questions in the survey appear to be either more or

less important, it is possible to either broaden the scope of the important questions or remove the ones that are not important. In conclusion, taken together the anonymous, voluntary and non-invasive nature of the material and the potential positive effects of the study, it is hard to find any reasonable objection against the study.

3. Results

3.1 Stability test

The stability test, using five randomly selected 50% portions of the data base, resulted in stable significance in all the five runs. All of the variables maintained significance or were not significant during all of the runs.

3.2 Multicollinearity test

The test for multicollinearity showed dependency for the factors "Time at present work" and "Work interesting and stimulating", both with a variance inflation factor (VIF) over 10. However, testing for multicollinearity was carried out as a part of a multiple regression analysis, since this test is not ideal with logistic factors. The continuous factor "Time at present work" showed the largest VIF and was omitted in the following analysis.

3.3 Factors tested versus symptom groups

Tables 1-3 show the results from the multiple logistic regression analysis with selected variables tested versus "General symptoms", "Mucous symptoms" and "Skin symptoms" respectively. When removing the variables that were not significant in the first run, the remaining variables maintained their significance in the second run, except for the factors "Help from fellow workers" and "Worried that work situation will change" when tested versus "Skin symptoms". These factors were removed and a third run was performed for significant factors versus symptom group "Skin symptoms". Table 4-6 show only the significant factors tested versus the three symptom groups.

The results in table 1 - 6 show that more factors were significant when tested versus "General symptoms" than when tested versus "Mucous symptoms" and "Skin symptoms". All the psychosocial factors, all the indoor environment variables except "Room temperature too low", the factor "Education" and the factor "Work with computer/day" were significant when

tested versus “General symptoms”. The factors “Dry air” “Unpleasant odor”, “Static electricity, often causing shocks”, “Dust and dirt”, “Work interesting and stimulating”, “Age”, “Gender”, “Easy irritated in eyes or respiratory airways”, “Frequent colds or other infections” and “Atopy” were significant in all the runs. The variable “Stuffy “bad” air” was significant when tested versus “Mucous symptoms” and “General symptoms”, but not when tested versus “Skin symptoms”. The factors “Static electricity, often causing shocks”, “Noise” and “Position” were significant when tested versus “Skin symptoms” and “General symptoms”, but not when tested versus “Mucous symptoms”. The variable “Snus” (orally applied tobacco) was only significant when tested versus “Mucous symptoms”, while the variable “Smoker” was only significant when tested versus “Skin symptoms”. “Eye lenses” was not tested significant in any of the runs.

3.4 Indoor environment factors tested versus the symptom groups

When testing only the indoor environment factors, all the variables came out significant versus the group “General symptoms”. Testing versus “Mucous symptoms” and “Skin symptoms”, all the variables yielded significance except “Room temperature too high” and “Varying room temperature”.

Table 1. Multiple logistic regression analysis. Selected variables tested versus symptom group "General symptoms" (*N* 11250). Pseudo R^2: Nagelkerkes: 0.1833, McFadden Adj: 0.1511

	Frequency	OR (95 % CI)
INDOOR ENVIRONMENT		
Draught	1283	1.21 (1.05 - 1.39) **
- No	9968	1
Room temperature too high	1316	1.17 (1.02 - 1.35)*
- No	9934	1
Varying room temperature	1823	1.31 (1.16 - 1.483) ***
- No	9428	1
Room temperature too low	2081	1.08 (0.96 - 1.21)
- No	9169	1
Stuffy "bad" air	3825	1.70 (1.53 - 1.90) ***
- No	7425	1
Dry air	3893	1.58 (1.42 - 1.75) ***
- No	7358	1
Unpleasant odor	1035	1.36 (1.17 - 1.58) ***
- No	10215	1
Static electricity, often causing shocks	428	1.56 (1.25 - 1.94) ***
- No	10823	1
Noise	1474	1.73 (1.53 - 1.97) ***
- No	9776	1
Light that is dim or causes glare and/or reflections	1035	1.43 (1.23 - 1.65) ***
- No	10215	1
Dust and dirt	1609	1.16 (1.03 - 1.32) *
- No	9641	1
PSYCHOSOCIAL		
Work interesting and stimulating	10991	0.56 (0.42 - 0.74) ***
- No	259	1
Too much work to do	9394	1.30 (1.15 - 1.46) ***
- No	1856	1
Opportunity to influence working conditions	9484	0.71 (0.63 - 0.80) ***
- No	1766	1
Help from fellow workers	10575	0.65 (0.54 - 0.77) ***
- No	675	1
Worried that work situation will change	3398	1.50 (1.37 - 1.65) ***
- No	7853	1
BACKGROUND		
Age		0.99 (0.98 - 0.99) ***
Man	3983	0.61 (0.55 - 0.67) ***
- Woman	7268	1
Atopic (have/have had asthma, eczema or hay fever)	4748	1.22 (1.11 - 1.33) ***
- Not atopic	6503	1
Smoker	878	1.17 (0.99 - 1.37)
- Non smoker	10373	1
Snus	1181	1.07 (0.92 - 1.24)
- No snus	10069	1
Education		1.20 (1.10 - 1.31) ***
Work with computer/day		1.13 (1.05 - 1.22) ***
Eye lenses	1755	0.94 (.83 - 1.06)
- No eye lenses	9495	1
Position (Supervisor/head)	1688	0.76 (0.67 - 0.87) ***
- Other	9563	1
SENSITIVITY/IMMUNITY		
Easy irritated in eyes or respiratory airways	3150	1.38 (1.25 - 1.52) ***
- No	8100	1
Frequent colds or other infections	1778	2.01 (1.79 - 2.25) ***
- No	9473	1

Table 2. Multiple logistic regression analysis. Selected variables tested versus symptom group "Mucous symptoms" (*N* 11250). Pseudo R^2: Nagelkerkes: 0.1963, McFadden Adj: 0.1844.

	Frequency	OR (95 % CI)
INDOOR ENVIRONMENT		
Draught	1283	1.09 (0.94 - 1.27)
- No	9968	1
Room temperature too high	1316	0.97 (0.84 - 1.12)
- No	9934	1
Varying room temperature	1823	1.09 (0.96 - 1.25)
- No	9428	1
Room temperature too low	2081	1.09 (0.95 - 1.24)
- No	9169	1
Stuffy "bad" air	3825	1.31 (1.16 - 1.47) ***
- No	7425	1
Dry air	3893	3.80 (3.40 - 4.25) ***
- No	7358	1
Unpleasant odor	1035	1.69 (1.44 - 1.97) ***
- No	10215	1
Static electricity, often causing shocks	428	1.50 (1.20 - 1.88) ***
- No	10823	1
Noise	1474	1.11 (0.97 - 1.28)
- No	9776	1
Light that is dim or causes glare and/or reflections	1035	1.14 (0.97 - 1.33)
- No	10215	1
Dust and dirt	1609	1.36 (1.19 - 1.55) ***
- No	9641	1
PSYCHOSOCIAL		
Work interesting and stimulating	10991	0.69 (0.51 - 0.94) *
- No	259	1
Too much work to do	9394	0.90 (0.79 - 1.03)
- No	1856	1
Opportunity to influence working conditions	9484	0.89 (0.78 - 1.01)
- No	1766	1
Help from fellow workers	10575	0.86 (0.70 - 1.05)
- No	675	1
Worried that work situation will change	3398	0.96 (0.86 - 1.06)
- No	7853	1
BACKGROUND		
Age		1.02 (1.01 - 1.02) ***
Man	3983	0.72 (0.64 - 0.80) ***
- Woman	7268	1
Atopic (have/have had asthma, eczema or hay fever)	4748	1.55 (1.40 - 1.71) ***
- Not atopic	6503	1
Smoker	878	1.13 (0.94 - 1.34)
- Non smoker	10373	1
Snus	1181	1.20 (1.02 - 1.42) *
- No snus	10069	1
Education		1.02 (0.93 - 1.11)
Work with computer/day		1.01 (0.93 - 1.10)
Eye lenses	1755	0.94 (0.83 - 1.08)
- No eye lenses	9495	1
Position (Supervisor/head)	1688	0.92 (0.79 - 1.06)
- Other	9563	1
SENSITIVITY/IMMUNITY		
Easy irritated in eyes or respiratory airways	3150	1.72 (1.55 - 1.91) ***
- No	8100	1
Frequent colds or other infections	1778	2.26 (2.00 - 2.55) ***
- No	9473	1

Table 3. Multiple logistic regression analysis. Selected variables tested versus symptom group "Skin symptoms" (*N* 11250). Pseudo R^2: Nagelkerkes: 0.1155, McFadden Adj: 0.1275.

	Frequency	OR (95 % CI)
INDOOR ENVIRONMENT		
Draught	1283	1.07 (0.91 - 1.26)
- No	9968	1
Room temperature too high	1316	1.11 (0.95 - 1.29)
- No	9934	1
Varying room temperature	1823	1.11 (0.97 - 1.28)
- No	9428	1
Room temperature too low	2081	1.06 (0.93 - 1.22)
- No	9169	1
Stuffy "bad" air	3825	1.09 (0.96 - 1.24)
- No	7425	1
Dry air	3893	2.47 (2.18 - 2.80) ***
- No	7358	1
Unpleasant odor	1035	1.22 (1.03 - 1.43) *
- No	10215	1
Static electricity, often causing shocks	428	1.69 (1.36 - 2.11) ***
- No	10823	1
Noise	1474	1.18 (1.02 - 1.37) *
- No	9776	1
Light that is dim or causes glare and/or reflections	1035	1.21 (1.03 - 1.43) *
- No	10215	1
Dust and dirt	1609	1.40 (1.22 - 1.60) ***
- No	9641	1
PSYCHOSOCIAL		
Work interesting and stimulating	10991	0.65 (0.48 - 0.90) **
- No	259	1
Too much work to do	9394	1.06 (0.91 - 1.23)
- No	1856	1
Opportunity to influence working conditions	9484	1.12 (0.97 - 1.30)
- No	1766	1
Help from fellow workers	10575	0.80 (0.65 – 1.00) *
- No	675	1
Worried that work situation will change	3398	1.13 (1.01 - 1.26) *
- No	7853	1
BACKGROUND		
Age		0.99 (0.99 – 1.00) ***
Man	3983	0.59 (0.51 - 0.67) ***
- Woman	7268	1
Atopic (have/have had asthma, eczema or hay fever)	4748	2.55 (2.29 - 2.85) ***
- Not atopic	6503	1
Smoker	878	1.27 (1.05 - 1.54) *
- Non smoker	10373	1
Snus	1181	1.10 (0.91 - 1.33)
- No snus	10069	1
Education		1.02 (0.92 - 1.13)
Work with computer/day		1.02 (0.92 - 1.12)
Eye lenses	1755	0.97 (0.84 - 1.12)
- No eye lenses	9495	1
Position (Supervisor/head)	1688	0.77 (0.65 - 0.92) ***
- Other	9563	1
SENSITIVITY/IMMUNITY		
Easy irritated in eyes or respiratory airways	3150	1.18 (1.05 - 1.33) ***
- No	8100	1
Frequent colds or other infections	1778	1.20 (1.06 - 1.38) **
- No	9473	1

Table 4. Multiple logistic regression analysis. Significant variables tested versus symptom group "General symptoms" (*N* 12375). Pseudo R^2: Nagelkerkes: 0.1822, McFadden Adj: 0.1510.

	Frequency	OR (95 % CI)
INDOOR ENVIRONMENT		
Draught	1398	1.24 (1.09 - 1.41) ***
- No	10977	1
Room temperature too high	1460	1.18 (1.04 - 1.35) *
- No	10915	1
Varying room temperature	2005	1.32 (1.18 - 1.48) ***
- No	10370	1
Stuffy "bad" air	4220	1.68 (1.52 - 1.86) ***
- No	8155	1
Dry air	4282	1.61 (1.46 - 1.77) ***
- No	8093	1
Unpleasant odor	1139	1.37 (1.19 - 1.58) ***
- No	11237	1
Static electricity, often causing shocks	470	1.57 (1.27 - 1.94) ***
- No	11905	1
Noise	1621	1.72 (1.53 - 1.94) ***
- No	10754	1
Light that is dim or causes glare and/or reflections	1126	1.43 (1.24 - 1.65) ***
- No	11249	1
Dust and dirt	1745	1.18 (1.05 - 1.33) **
- No	10630	1
PSYCHOSOCIAL		
Work interesting and stimulating	12078	0.55 (0.42 - 0.72) ***
- No	297	1
Too much work to do	10346	1.28 (1.14 - 1.44) ***
- No	2030	1
Opportunity to influence working conditions	10420	0.71 (0.64 - 0.80) ***
- No	1955	1
Help from fellow workers	11633	0.65 (0.55 - 0.77) ***
- No	743	1
Worried that work situation will change	3737	1.49 (1.36 - 1.63) ***
- No	8638	1
BACKGROUND		
Age		0.99 (0.98 - 0.99) ***
Man	4443	0.59 (0.54 - 0.65) ***
- Woman	7932	1
Atopic (have/have had asthma, eczema or hay fever)	5198	1.24 (1.14 - 1.35) ***
- Not atopic	7178	1
Education		1.19 (1.10 - 1.29) ***
Work with computer/day		1.15 (1.07 - 1.24) ***
Position (Supervisor/head)	1844	0.78 (0.69 - 0.89) ***
- Other	10531	1
SENSITIVITY/IMMUNITY		
Easy irritated in eyes or respiratory airways	3428	1.30 (1.18 - 1.42) ***
- No	8947	1
Frequent colds or other infections	1968	1.99 (1.78 - 2.22) ***
- No	10407	1

Table 5. Multiple logistic regression analysis. Significant variables tested versus symptom group "Mucous symptoms" (*N* 15268). Pseudo R^2: Nagelkerkes: 0.1957, McFadden Adj: 0.1844.

	Frequency	OR (95 % CI)
INDOOR ENVIRONMENT		
Stuffy "bad" air	5390	1.31 (1.19 - 1.45) ***
- No	9878	1
Dry air	5496	3.80 (3.46 - 4.18) ***
- No	9772	1
Unpleasant odor	1466	1.66 (1.46 - 1.89) ***
- No	13802	1
Static electricity, often causing shocks	611	1.46 (1.21 - 1.76) ***
- No	14657	1
Dust and dirt	2214	1.49 (1.34 - 1.66) ***
- No	13054	1
PSYCHOSOCIAL		
Work interesting and stimulating	14917	0.63 (0.49 - 0.81) ***
- No	351	1
BACKGROUND		
Age		1.01 (1.01 - 1.02) ***
Man	5298	0.73 (0.66 - 0.80) ***
- Woman	9970	1
Atopic (have/have had asthma, eczema or hay fever)	6443	1.63 (1.50 - 1.77) ***
- Not atopic	8825	1
Snus	1618	1.16 (1.01 - 1.33) *
- No snus	13650	1
SENSITIVITY/IMMUNITY		
Easy irritated in eyes or respiratory airways	4397	1.68 (1.54 - 1.84) ***
- No	10871	1
Frequent colds or other infections	2428	2.28 (2.05 - 2.53) ***
- No	12840	1

Table 6. Multiple logistic regression analysis. Significant variables tested versus symptom group "Skin symptoms" (*N* 14264). Pseudo R^2: Nagelkerkes: 0.1081, McFadden Adj: 0.1218.

	Frequency	OR (95 % CI)
INDOOR ENVIRONMENT		
Dry air	5121	2.65 (2.40 - 2.92) ***
- No	9143	1
Unpleasant odor	1355	1.22 (1.06 - 1.40) **
- No	12909	1
Static electricity, often causing shocks	571	1.79 (1.48 - 2.17) ***
- No	13693	1
Noise	1840	1.25 (1.10 - 1.42) ***
- No	12424	1
Light that is dim or causes glare and/or reflections	1298	1.20 (1.04 - 1.39) *
- No	12966	1
Dust and dirt	2068	1.37 (1.21 - 1.54) ***
- No	12196	1
PSYCHOSOCIAL		
Work interesting and stimulating	13936	0.69 (0.52 - .92) *
- No	328	1
BACKGROUND		
Age		0.99 (0.99 - 0.99) ***
Man	4907	0.65 (0.58 - 0.73) ***
- Woman	9357	1
Atopic (have/have had asthma, eczema or hay fever)	5977	2.48 (2.25 - 2.73) ***
- Not atopic	8287	1
Smoker	1327	1.17 (1.00 - 1.37) *
- Non smoker	12937	1
Position (Supervisor/head)	2083	0.77 (0.66 - 0.90) ***
- Other	12181	1
SENSITIVITY/IMMUNITY		
Easy irritated in eyes or respiratory airways	4037	1.21 (1.10 - 1.34) ***
- No	10227	1
Frequent colds or other infections	2239	1.26 (1.12 - 1.41) ***
- No	12025	1

4. Discussion

This study is part of an attempt to understand cause and effect in a complex environment. To be able to reduce symptoms it is paramount that we understand the causes behind them. This study investigated possible explanations to the perceived symptoms. Is it meaningful to renovate problematic buildings or improve building techniques? Or is it more appropriate to improve the psychosocial environment in the office? A higher degree of prevalence of symptoms leads to a higher degree of sick leave. To understand the relationship between certain factors and symptoms in problematic buildings and to ameliorate them with appropriate measures could mean a revolution in terms of cutting costs for loss of work and health care. Another important outcome of this study could be to further improve the Örebro-questionnaire. Removing irrelevant questions from the questionnaire and further elaborating the important ones could help the questionnaire to maintain its position as a modern and precise tool for investigating office environments.

Multiple logistic regression analysis has been used to investigate building related symptoms in several studies. Factors that have been tested range from technical measurements [15] to answers from various questionnaires [16]. Part of the data used in this report has been analyzed with multiple logistic regression analysis before [13]. To get a measurement of the symptoms, some studies use examinations by physicians [17], while others rely on perceived symptoms taken from questionnaires. The perceived symptoms may be lumped together in the analysis [17] or divided, focusing on e g skin symptoms [18]. In other words, the methods and the variables included in the analyses vary, which possibly makes a comparison difficult. However, some common trends seem to be discernible.

Looking at table 1 - 6 in the results, the tendency was that more variables were significant when tested versus “General symptoms” than when tested versus “Mucous symptoms” or “Skin symptoms”. General symptoms such as concentration difficulties, dizziness and headache were diffuse and might be of a more multifactorial origin, depending on a wider range of variables. A higher prevalence of general symptoms in general does not affect the significance in the statistical analysis. The model only tests the statistical correlation between the factors and the outcome.

Among the indoor environment variables, several factors describing air quality ("Dry air", "Unpleasant odor" and "Dust and dirt") were significant in all the tests and may be important in developing the symptoms in all the symptom groups. On the other hand, the temperature variables appeared to have less influence on the development of mucous and skin symptoms, while the variables "Room temperature too high" and "Varying room temperature" yielded significance when tested versus "General symptoms".

The variable "Static electricity, often causing shocks", was significant in all the runs. The possible symptom causing mechanism is hard to explain. Possibly the static electricity acts as a proxy of another factor in the environment that causes the symptoms. The frequency of respondents having problem with static electricity was also quite low, compared with the ones that did not. This imbalance between the two groups makes the result more unstable. The relation between static electricity and symptoms is inconclusive in other studies [19, 20].

All the psychosocial variables were significant when tested versus "General symptoms" while only one psychosocial variable ("Work interesting and stimulating") was significant when tested versus "Mucous symptoms" or "Skin symptoms". Consequently, symptoms such as dizziness or tiredness can be explained in part by psychosocial factors, while it is less likely that the mucous and skin symptoms can be explained by these variables. However, an interesting and stimulating work seems to decrease the probability of developing any of the symptoms. Several studies have shown a relation between psychosocial factors and the development of SBS symptoms [21, 22].

Other variables, apart from the ones already mentioned, that were significant through all the runs were "Age", "Gender", "Easy irritated in eyes or respiratory airways", "Frequent colds or other infections" and "Atopy". Women reported symptoms more often than men in this study and in several others [18, 23]. In this study older individuals reported fewer symptoms than younger persons. However, this relation is inconclusive in other studies [21]. Even though the correlation between age and symptoms was significant in this study the odds ratio is close to 1, which means that the effect of age was weak. In the way the tables are presented it is uncertain if the odds ratio gives any useful information when considering the continuous variables. Atopic individuals were more sensitive to changes in the indoor environment and reported more symptoms accordingly. This relation has been shown in several other studies [8, 24]. It is important to remember though, that the atopy was self reported in this study.

“Easy irritated in eyes or respiratory airways” and “Frequent colds or other infections” could be considered as variables describing a higher degree of sensitivity and poorer immunity respectively. They were both significant in all the runs. However, it is possible that at least the variable “Easy irritated in eyes or respiratory airways” interact with the variable “Atopy”.

The use of eye lenses was never significant. The cause of the symptoms is probably not found in this factor.

Pseudo R^2 is a measure of how much of the outcome that can be explained by the statistical model. However, pseudo R^2 is not an equivalent to the R^2 value in an ordinary multiple regression analysis. It is generally lower [25]. Pseudo R^2 can be calculated in several ways and there is some dispute over which value to use and how to interpret them [25]. Mcfadden’s adjusted R^2 and Nagelkerkes R^2 were used in this report. Pseudo R^2 never rose above 20 % in any of the runs in this study. The pseudo R^2 value should be interpreted with caution, but it is obvious that all factors that affected the symptoms were not included in the analysis.

As already mentioned, the data used in this report comes from office buildings with suspected indoor environmental problems. One way to proceed with the investigation would be to perform a multiple logistic regression analysis on a large database with answers from office buildings without problems and then compare that analysis with the one performed in this study. Another multivariate technique often linked to multiple logistic regression is discriminant analysis (DA). It would be interesting to also apply DA and compare it to the results in this study. This could possibly lead to a better insight into possible causal relations between the symptoms and the independent variables.

Another interesting sequel to this study would be to test the factors for interaction effects. Does e g the variable “Easy irritated in eyes or respiratory airways” interact with the variable “Atopy”?

It would also be interesting to do a longitudinal study, where the same questions are asked some time later in the same environment. This would yield more information and could solidify the results.

This study used information from self reported questionnaires, which obviously was a limitation. The information collected was based on *perceived* indoor environment and *perceived* symptoms and was not verified objectively. However, the nature of the relation between indoor environment and symptoms is diffuse. That does not mean that the symptoms do not exist. While waiting for more sophisticated technical methods for measuring the indoor climate and symptoms objectively, the questionnaires offer one way to investigate the problem.

Criticism has been raised against the possibility to study the relation between indoor environment and bad health epidemiologically at all [26]. Both the factors and the symptoms are too diffuse and subjective. Moreover, the results from the studies are too inconclusive and depend too much on the study design [26]. As already mentioned, the use of questionnaires has its limitations, but so do the alternatives. Since it is not possible to measure neither the environmental factors nor the symptoms objectively in a good way, one is left with a more qualitative approach, which cost more time and is not possible to execute on a larger scale.

It is important to remember that the statistical analysis does not imply a causal relation between the factors and the outcome. The analysis only estimates the probability that the factors and the outcome are related by pure coincidence. If this probability is sufficiently low, a relationship is assumed. The results from this study showed that the measured relation between perceived symptoms and several of the selected factors unlikely occurred by chance. But even if a relationship was statistically significant, it is not necessarily biologically or medically significant. Nor does it give the mechanism behind the relation. The result may e g be influenced by the respondents desire to seek causes and mechanisms to the perceived symptoms. It should also be stressed that using very large sample sizes increase the possibility to find statistically significant relationships also when the influence from an independent variable is very small and trivial from a medical point of view. Significant results can also be due to biases of various kinds.

The symptoms experienced in a poor indoor environment are probably truly multifactorial. The statistical analysis does not give us the whole truth, but it may give us part of the truth.

5. Conclusion

Almost all of the variables were significant when tested versus “General symptoms”. This may imply that the group “General symptoms” is of a more multifactorial origin than the two other symptom groups.

All the symptom groups appeared to be affected by factors describing air quality, “Gender” and sensitivity factors.

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