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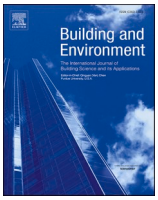

# Associations between self-reported IEQ stressors of students' homes and self-reported rhinitis, stuffy nose, migraine and headache in student profiles

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ABSTRACT

Recent studies have shown that both personal and building-related factors may affect the health and comfort of occupants in their homes. It is also known that people differ in their needs and can therefore respond differently to these stressors. Therefore, based on the large database from the survey conducted yearly from 2016 to 2020 among the first-year students of the faculty of Architecture and the Built environment at the Delft University of Technology, this study aimed to explore the associations between self-reported rhinitis/stuffy nose/migraine/headache, and the indoor environment of the students' homes, taking into account potential confounders and profiles. Two-steps cluster analysis resulted in three profiles of students based on their IEQ-related perceptions: Cluster 1 with the highest reported percentage of symptoms and the lowest reported percentage of diseases; Cluster 2 with moderate reported symptoms and diseases; and Cluster 3 with the lowest percentage of reported symptoms and the highest percentage of reported diseases. Logistic regression modelling showed that risk factors contributing to having rhinitis, stuffy nose, migraine and/or headache, differ per cluster, and showed little overlap with the all-respondents group. Moreover, when there is an overlap, the associated risk factor might increase the risk for one cluster, while for another it decreases the risk, indicating differences in response between the different clusters; and therefore, the importance of clustering instead of considering all respondents as one.

## 1. Introduction

Research has shown that staying indoors is not good for our health: we are confronted with diseases and disorders related to indoor environmental quality (IEQ) such as mental illnesses, obesity and illnesses that take longer to manifest, among which cardiovascular and chronic respiratory diseases and cancer, and more recently, COVID-19, caused by mainly airborne transmission of SARS-CoV-2 indoors [1–5]. Moreover, studies have shown that indoor environmental conditions, comprising of thermal factors (e.g. draught, temperature), lighting aspects (e.g. reflection, view, luminance ratios), air quality (e.g. odours, mould, chemical compounds, particulates, and ventilation rate) and acoustical aspects (e.g. noise and vibration), may be associated with discomfort (annoyance), building-related symptoms (e.g. headaches, nose, eyes, and skin problems, fatigue etc.), building-related illnesses (e.g. legionnaires disease), productivity loss and decrease in learning ability [6]. Studies show that the relationships between these indoor environmental conditions and those effects (diseases and disorders) are complex (e.g. homes, (e.g. homes: [1]; offices: [7]; schools [8]).

It is known that those effects are influenced by psychological, physiological, personal, social and/or environmental aspects [9], that those aspects go beyond the environmental parameters used in guidelines, and that only few studies have investigated the impact of environmental and personal factors on health [10]. For example, in a study with 396 Dutch students and their homes [11] and in a study with students from five universities in five different cities around the world in their homes, both personal and environmental factors were linked to rhinitis in young adults [12]. In a study on the risk factors causing dry eyes reported by 556 outpatient workers of six hospitals [13] and in a study of 7441 office workers in eight EU countries [14], both workplace characteristics and HVAC-system characteristics were found to be risk factors for experiencing dry eyes at the workplace. In all of these studies, occupant-related indicators (e.g. sick leave, productivity, and number of symptoms or complaints) and building-related indicators (e.g. certain measures or characteristics of a building and its components) were collected through a questionnaire and checklist(s) to associate patterns

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of building-related stressors to occupant-related indicators (health: symptoms; comfort: complaints) based on multivariate regression analysis [10]. To determine the risk factors for having a certain disease or symptom, all respondents' self-reported health and comfort was used as well as their self-reported personal characteristics and building characteristics, self-reported or gathered through an inspection of the studied scenario [15].

The outcome of these studies, patterns of risk factors that were associated with a reported disease or symptom, were based, however, on the self-reported disease or symptom of the whole group. It is known that people differ in their needs and can therefore respond differently to stressors. To cope with this individual response to environmental stressors, attempts have been made to cluster occupants according to similar self-reported preferences and/or needs [15]. For example, Two-steps cluster analysis was applied to profile 1014 office workers based on their self-reported IEQ-related complaints, resulting in three clusters and corresponding profiles [16], while the same method clustering 949 children of 45 classrooms on their self-reported IEQ-related complaints and IEQ-preferences, resulted in six profiles [17].

The question is now, do the risk factors for having a certain disease or symptom differ between different clusters in a certain scenario, and if they differ does this depend on the disease/symptom? Therefore, in this study, an attempt is made to determine whether the risk factors (patterns of stressors) for having a certain disease or symptom are different for a certain cluster of a population in a certain scenario. The selected scenario is 'first-year students and their homes'. Based on the large database from the survey conducted yearly from 2016 to 2020 among the first-year students of the faculty of Architecture and the Built environment at the Delft University of Technology, this study aimed to explore the associations between self-reported rhinitis, stuffy nose, migraine and headache, and the indoor environment of the students' homes, taking into account potential confounders and profiles.

## 2. Methods

### 2.1. Study design

In the spring of 2016, 2017, 2018, 2019, and 2020, first-year students from the faculty of Architecture and the Built Environment of the Delft University of technology in the Netherlands were recruited to participate in a survey of their health and comfort in relation to their homes. Every year, the procedure was similar. The students received an invitation by e-mail with a link to the digital on-line questionnaire applied. In the e-mail the purpose and the procedure of the survey was explained and the deadline for completing the questionnaire was given (in general one week before the lecture). All first-year registered students received an invitation. It was estimated that the questionnaire would take 30 min to complete. A participant could save the survey at any time and resume it later. Students received 0.2 points for their grade if they completed and submitted the questionnaire.

### 2.2. Data collection

The electronic-based questionnaire was voluntary, anonymous and in Dutch. It was based on the OFFICAIR questionnaire [18], including the International Positive and Negative Affect Schedule Short Form, I-PANAS-SF [19] and Emocards to self-report the emotional status at the moment of filling in the questionnaire [20], the dwelling questionnaire [21] and the HOPE checklist for homes [22]. In total, the questionnaire included a maximum of 125 questions (without skip logic questions) and one optional question about the respondents' interest in the questionnaire and ease to fill in. It included questions to collect socio-demographic data (e.g. gender, age, marital status, education level), lifestyle information (e.g. time spent inside home, work out, smoking status and alcohol habits), psycho-social aspects (e.g. mood via emo-cards, recent positive and negative events - e.g. birth, wedding, death, accident, severe illness, positive and negative affects via I-PANAS-SF), health and medical history (e.g. personal medical history, family medical history, health at home) and comfort data (e.g. overall comfort, indoor comfort perception).

Additionally, the questionnaire included questions related to the home environment of the respondent (e.g. occupants, pets and pests), outdoor pollution sources, the systems and activities conducted indoors (e.g. heating, cooling and cooking, do-it-yourself activities, cleaning activities, use of consumer products), the presence of materials, coverings and furniture (e.g. asbestos, lead, floor and wall coverings, ceiling surface, painting, new carpeting, particle board, open shelves), ventilation (window opening, air conditioning), and humidity problems (e.g. humidity signs, condensation, washer and/or drying).

The I-PANAS-SF is composed of 5-item positive affect subscales (alert, inspired, determined, attentive and active) and 5-item negative affect (upset, hostile, ashamed, nervous, and afraid) subscales. Each item is scored from 1 'never' to 5 'always'. The Emocards include illustrations of facial expression of the eight primary emotions varying from 'pleasantness' to 'arousal' (physical state of activation), for both female and male participants [19].

Concerning health data, the following question was asked for a number of diseases, including among others rhinitis and migraine: 'Have you suffered from *disease/disorder*?' With possible answers: 'Never', 'Yes, in the last 12 months', 'Yes, but not in the last 12 months'. To identify the health symptoms, the students suffered from, it was asked: 'In the past 3 months, how often have you suffered from *symptom* while you have been in your home (on average)?' Possible answers: 'every day', '3–4 days a week', '1–2 days a week', 'once every 2–3 weeks', 'less often or never'. If the answer was once every 2–3 weeks or more an additional question was asked: 'Do you think that this is because of your indoor environment?' with possible answers: 'yes', 'no', 'partly'.

### 2.3. Ethical aspects

The students were asked to give an informed consent to start the survey. Participants were able to skip any question they would not feel comfortable with. To decrease involuntary missing answers, an automatic check of completeness was performed, and missing answers were signalled to the participant at the end of each page of the questionnaire.

### 2.4. Data management and analysis

All data were digitally completed and imported from the Qualtrics XM platform to IBM SPSS statistics 26 (SPSS Inc., Chicago, IL, USA) for analysis of the data. First, the data for the respondents whose progress was less than 50% were filtered out. Responses from participants that did not answer all the questions about diseases and symptoms, were deleted as well.

#### 2.4.1. Descriptive analysis

Descriptive statistics such as percentages, range (minimum–maximum), and arithmetic mean with standard deviation (SD) were used to summarize students' and home characteristics. Since there was no overall difference between the different student groups, data were pooled for further analyses. After the cluster analysis (2.4.2), descriptive analysis was (again) performed for each cluster. Chi-square tests were conducted to compare the incidence rates of different diseases/symptoms and that of the incidence rates of different building characteristics of the different clusters.

#### 2.4.2. Cluster analysis

SPSS's Two-Step Cluster analysis was the method used to categorize respondents into potential differing groups, based only on their perception of the IEQ factors in their home environment. The Two-Step clustering method was used because it allows using simultaneously both categorical and continuous variables, and because it has been

successfully used in recent studies to cluster office workers [16,23], school children [17], and hospital staff [24].

Before conducting the Two-Step cluster analysis, it is necessary to know which variables to use. Because the IEQ perception variables did not show multicollinearity, PCA was not necessary to be performed. The variables used were related to IEQ perceptions, namely: temperature (varied vs still, cold vs hot, comfortable vs uncomfortable), air quality (smelly vs odourless, satisfied vs dissatisfied), visual (satisfied vs unsatisfied with natural light, artificial light, overall light, glare), noises (satisfied vs dissatisfied with noise from systems, outside, overall, from inside, and vibrations), and overall comfort perception (satisfied vs dissatisfied). For the cluster analysis, the Akaike information criterion (AIC) was chosen, as well as an automatic number of clusters. The model was then validated with four steps. First, the silhouette measure of cohesion was checked to be above 0.0 but preferably above 0.2. This value ensures the validity within and between cluster distances. Secondly, Chi-square tests were performed with the variables, making sure that values were statistically significant ($p < 0.05$). Third, the prediction scores of the two-step clustering variables of the model were checked to be greater than 0.02. Finally, the database was split into random halves, and the final solution model was applied to each of the halves. The output models for each half were checked and found to be similar to the main model. As these four tests for validity were successful, the final clustering model was chosen.

#### 2.4.3. Multivariate logistic regression

To identify possible risk factors for diseases/symptoms and to investigate whether these risk factors differ for different clusters, binary logistic regression analysis was conducted for diseases/symptoms, in each cluster and for all respondents, that:

- Statistically differ in incidence rates for different clusters: migraine and blocked/stuffy nose;
- Do not statistically differ in incidence rates for different clusters: rhinitis and headaches (previously analysed among students from different universities in different countries [12]).

Before developing the multivariate logistic regression model, to identify the potential independent variables for the final model, a series of univariate binary logistic regression analyses were conducted between the diseases/symptoms with every building characteristic separately. Then, potential personal factors were taken as the adjusted factors for these regression analyses. For rhinitis, adjusted factors were gender, family history of rhinitis, smoking status (yes vs. no), and psychological aspects (negative events); for blocked/stuffy nose, no adjusted factor was considered; for migraine, two adjusted factors were included: gender, and negative events; and for headaches only gender was included.

The building-related characteristics that were considered were: construction date ('after 1990' vs 'before 1990'), building location ('rural area' vs 'urban area'), outdoor pollution sources nearby (yes vs. no), type of wall/floor coverings, furniture (MDF less than one year old), presence of plants, presence of pets/pests, cleaning activities ('less than once a week' vs 'at least once a week'), use of consumer products ('less than once a week' vs 'at least once a week'), air conditioning (yes vs. no), humidity signs (yes vs. no), condensation inside window (yes vs. no), and opening of windows ('less than once a week' vs 'at least once a week').

Variables associated with a P-value of less than 0.20 in the univariate binary logistic regression analyses and personal risk factors were included in the multivariate binary logistic regression analysis. The final model was obtained by eliminating variables associated with a P-value greater than 0.20. Collinearity among variables in the model was measured by the variance inflation factor (VIF). No multicollinearity was detected (VIF<4). Results are expressed as adjusted odds ratios (OR) with their confidence intervals at 95% (95% CIs). A p-value less than 0.05 is considered as statistically significant, while a p-value less than 0.1 suggests a tendency.

## 3. Results

### 3.1. Participation rate and characteristics of the study respondents

In Table 1, the total number of respondents and the response rates per year are presented. The average response rate was 80% (range: 71–94%), which is very high. Yet expected due to the bonus points the students could receive for participating.

### 3.2. Clusters

The Two-Step cluster analysis resulted in three clusters with 1575 students (76 students were automatically excluded by the two-step cluster analysis). The silhouette measure of cohesion and separation was 0.3331, which is considered to be fair, and the predictor importance for all variables was greater than 0.02 [25]. Clusters 1 and 3 have respectively 446 and 449 students, while cluster 2 has 680. Therefore, the ratio of sizes, the largest cluster to the smallest cluster, is 1.52.

In Table 1, the characteristics of the studied population, the reported diseases that students suffered from in the past 12 months, and the reported symptoms related to staying indoors per cluster are presented. Fig. 1 presents the mood profiles, Fig. 2 shows the reported perception of the environmental conditions in the past 3 months, per cluster. Appendix A shows detailed information about the building and environment characteristics for all students, and the three clusters.

#### 3.2.1. Cluster 1 most symptoms, least diseases, and bothered by air

*3.2.1.1. Personal aspects.* Cluster 1 represents 28.3% of the total sample, is made of 52% of men with a mean age of 19 years. It has the least number of current smokers (28%), and the lowest percentage of alcohol consumers (82.5%). During completion of the questionnaire, 23% felt tense, irritated, sad or bored. It has the lowest percentages of rhinitis, eczema, migraine and depression.

*3.2.1.2. Comfort and health.* Cluster 1 has the most students dissatisfied with the air (64% air smelly; 48% air dusty; 38% air too humid; and 45% air too draughty). With regards to their health, students in cluster 1 reported the most symptoms caused by the home environment (e.g. blocked or stuffy nose, runny nose and headache).

*3.2.1.3. Building-related aspects.* Cluster 1 has the highest number of students living with their parents (66%), and they live mostly in suburban (37%) or village/rural area (22%). The Cluster 1 respondents reported the highest number of ants (11%), and the highest frequency of cleaning the floors (86%) and dusting surfaces (74%) at least once a week. Also, 84% of Cluster 1 respondents reported to have plants in their homes, and 12% claimed to have air conditioning. Students in Cluster 1 had the least problems with humidity (58%), and condensation on windows (50%).

#### 3.2.2. Cluster 2 moderate symptoms and diseases, air and temperature bothered

*3.2.2.1. Personal aspects.* Cluster 2 represents 43% of the total sample, comprises of 49% men, the mean age is 19 years, has 34% current smokers, and 88% of alcohol consumers. During completion of the questionnaire, 26% felt tense, irritated, sad or bored. With regards to percentage of reported diseases, Cluster 2 scored in between clusters 1 and 3.

*3.2.2.2. Comfort and health.* Cluster 2 had the most students dissatisfied

**Table 1**
Characteristics of the studied population per cluster.

| Characteristic | Total[a] | Cluster 1 | Cluster 2 | Cluster 3 | p-value |
|---|---|---|---|---|---|
| | n (%) | n (%) | n (%) | n (%) | |
| **Respondents (response rate)** | **1651 (100)** | **446 (28.3)** | **680 (43.2)** | **449 (28.5)** | |
| 2016 (81%) | 263 (15.9) | 64 (14.3) | 114 (16.8) | 63 (14.0) | |
| 2017 (70%) | 272 (16.5) | 72 (16.1) | 118 (17.4) | 66 (14.7) | |
| 2018 (80%) | 395 (23.9) | 99 (22.2) | 155 (22.8) | 124 (27.6) | |
| 2019 (93%) | 372 (22.5) | 112 (25.1) | 136 (20.0) | 103 (22.9) | |
| 2020 (75%) | 349 (21.1) | 99 (22.2) | 157 (23.1) | 93 (20.7) | |
| **Personal** | | | | | |
| Gender Female | 851 (52.4) | 214 (48.1) | 350 (51.5) | 262 (58.4) | **0.007** |
| Male | 774 (47.6) | 231 (51.9) | 330 (48.5) | 187 (41.6) | |
| Age mean (sd) | 19.3 (1.8) | 19.0 (1.4) | 19.3 (1.8) | 19.7 (2.1) | **< 0.001** |
| Marital status | | | | | |
| Single | 1561 (96.2) | 434 (97.3) | 656 (96.6) | 425 (95.1) | 0.185 |
| Married/living together | 62 (3.8) | 12 (2.7) | 23 (3.4) | 22 (54.9) | |
| **Lifestyle** | | | | | |
| Hours spent at home | | | | | |
| Weekday: mean (sd) | 13.8 (2.8) | 13.7 (3.2) | 13.9 (2.5) | 13.8 (2.7) | 0.377 |
| Weekend: mean (sd) | 14.9 (5.9) | 15.9 (5.2) | 14.5 (6.1) | 14.3 (6.1) | **< 0.001** |
| Work-out yes | 1525 (93.9) | 420 (94.2) | 642 (94.6) | 417 (92.9) | 0.500 |
| Smoking status | | | | | |
| Never | 914 (61.2) | 296 (71.0) | 384 (62.3) | 213 (50.5) | **< 0.001** |
| Former | 62 (4.1) | 6 (1.4) | 25 (4.1) | 31 (7.3) | |
| Current | 518 (34.7) | 115 (27.6) | 207 (33.7) | 178 (42.2) | |
| Alcohol consumer | 1295 (86.6) | 345 (82.5) | 543 (88.0) | 374 (88.6) | **0.014** |
| **Psychophysical aspects** | | | | | |
| Negative events (yes) | 576 (38.6) | 145 (34.9) | 243 (39.4) | 174 (41.2) | 0.153 |
| **Disease/disorder** | | | | | |
| Asthma | 43 (2.6) | 16 (3.6) | 12 (1.8) | 14 (3.1) | 0.139 |
| Bronchitis | 61 (3.8) | 20 (4.5) | 19 (2.8) | 18 (4.0) | 0.289 |
| Wheezing | 47 (2.9) | 10 (2.3) | 18 (2.7) | 18 (4.0) | 0.249 |
| Hay fever | 169 (10.5) | 40 (9.0) | 71 (10.5) | 51 (11.4) | 0.500 |
| *Allergic rhinitis* | 200 (12.4) | 48 (10.8) | 79 (11.7) | 64 (14.3) | 0.247 |
| Eczema | 160 (9.9) | 38 (8.6) | 65 (9.6) | 53 (11.9) | 0.239 |
| *Migraine* | 110 (6.8) | 20 (4.5) | 38 (5.6) | 49 (11.0) | **< 0.001** |
| Depression | 121 (7.5) | 21 (4.7) | 53 (7.8) | 45 (10.1) | **0.010** |
| Anxiety | 116 (7.2) | 25 (5.7) | 54 (8.0) | 36 (8.1) | 0.270 |
| **Symptoms caused by the home environment, yes and partly** | | | | | |
| Dry eyes | 202 (12.5) | 50 (11.2) | 82 (12.1) | 63 (14.1) | 0.413 |
| Itchy or watery eyes | 226 (14.0) | 55 (12.4) | 100 (14.7) | 67 (15.0) | 0.448 |
| *Blocked or stuffy nose* | 577 (34.9) | 182 (40.8) | 236 (34.7) | 138 (30.7) | **0.006** |
| Runny nose | 488 (30.2) | 155 (34.8) | 203 (30.0) | 118 (26.3) | **0.023** |
| Sneezing | 462 (28.5) | 153 (34.4) | 185 (27.2) | 106 (23.7) | **0.001** |
| Lethargy or tiredness | 571 (35.3) | 173 (38.8) | 238 (35.1) | 142 (31.7) | 0.085 |
| Itchy or dry skin | 301 (18.6) | 77 (17.3) | 123 (18.1) | 95 (21.2) | 0.275 |
| *Headache* | 508 (31.3) | 148 (33.2) | 208 (30.6) | 138 (30.7) | 0.619 |
| Breathing difficulties | 121 (7.5) | 27 (6.1) | 53 (7.8) | 37 (8.3) | 0.411 |

a: including respondents without cluster; P-values below 0.05 are in bold.

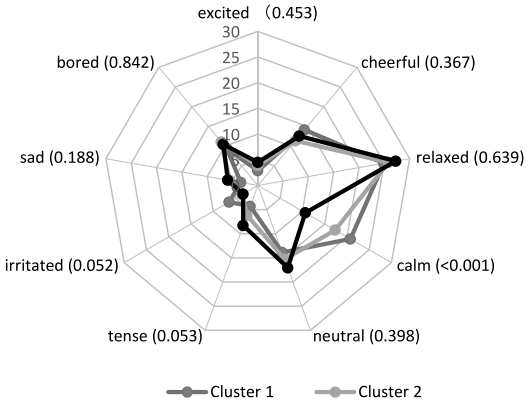


**Fig. 1.** The mood profiles of the three clusters (p-value for Chi-square of different clusters in brackets).

with thermal comfort (37% too hot; 31% too cold; 29% temperature does not vary enough; 20% temperature varied too much), and dissatisfied with air (46% air smelly; 40% air dusty; 37% air too humid; and 34% air too draughty). As far as symptoms are concerned, the scores in this cluster fall between the extreme scores of Clusters 1 and 3.

*3.2.2.3. Building-related aspects.* 35% of cluster 2 respondents lived with their parents, and they lived mostly in urban areas (mixed area (15%), city centre (21%) or town (30%)). The Cluster 2 respondents reported pests indoors (66%), cleaning the floors (81%) and dusting surfaces (65%) at least once a week, representing middle range values compared to Clusters 1 and 3.74% of Cluster 2 respondents reported to have plants in their homes, and 6% claimed to have air conditioning. Cluster 2 reported problems with humidity (68%), and condensation on windows (59%), these values were in between those of Clusters 1 and 3.

### *3.2.3. Cluster 3 least symptoms, most diseases and bothered by all aspects*

*3.2.3.1. Personal aspects.* Cluster 3 represents 28.5% of the total sample, is made of 42% men with a mean age of 20 years. It has the highest number of current smokers (42%) and the highest number of alcohol consumers (89%). During completion of the questionnaire, 28% felt tense, irritated, sad or bored. Cluster 3 reported the highest percentages of rhinitis, eczema, migraine, and depression.

*3.2.3.2. Comfort and health.* Cluster 3 has the most students dissatisfied with lighting (33%), noise (46%), air quality (36%) and general comfort (25%). More specifically, most dissatisfied with temperature (40% not comfortable; 54% too cold), air (29% air smelly; 29% air dusty; 34% dry air; 24% air too humid; and 26% air too draughty), lighting (38% artificial lighting, 40% natural lighting; noise (52% outside; 44% inside; and

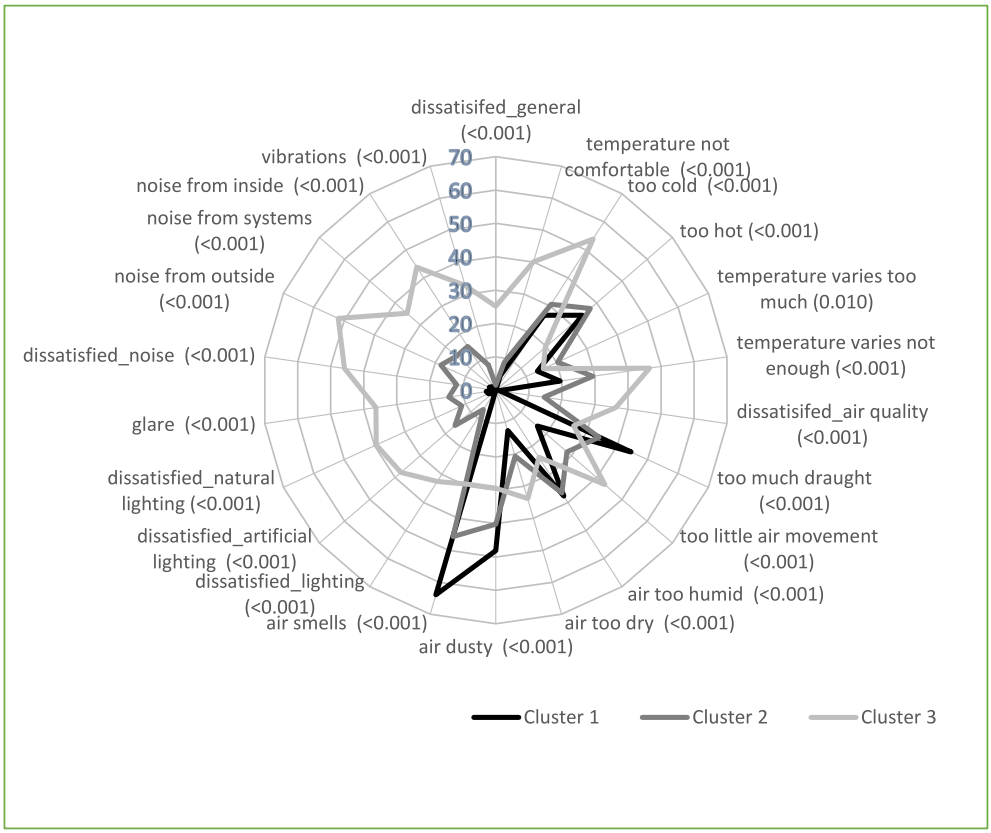


**Fig. 2.** Perception of environmental conditions in the past three months per cluster (p-value for Chi-square analysis of different clusters in brackets).

33% vibrations). Cluster 3 respondents reported the least blocked or stuffy nose, runny nose and lethargy or tiredness symptoms caused by the home environment but the highest dry eyes (14%), watery eyes (15%) and itchy, dry skin (21%).

*3.2.3.3. Building-related aspects.* Cluster 3 has the lowest number of students living with their parents (14%), they live mostly in urban area (mixed area (21%), the city centre (26%) or town (34%)). The cluster 3 respondents reported the highest number of mice (21%), silverfishes (38%) and moths (9%), and the lowest percentage of cleaning the floors (76%) and dusting surfaces (59%) at least once a week. 72% of Cluster 3 respondents reported to have plants in their homes, and 6% claimed to have air conditioning. Cluster 3 respondents had the most problems with humidity (73%), and condensation on windows (66%).

### 3.3. Multivariate logistical regression models

#### 3.3.1. Relations between rhinitis and building-related factors

Tables B1 and 2 show respectively, the binary logistic regression analysis results and the multivariate logistic regression model for

**Table 2**
Multivariate logistic regression model of the relations between rhinitis and building-related factors.

| Rhinitis | All | | Cluster 1 | | Cluster 2 | | Cluster 3 | |
|---|---|---|---|---|---|---|---|---|
| Risk factor[a] | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value |
| Gender* female vs. male | 1.66 (1.15–2.39) | **0.006** | 1.67 (0.78–3.59) | 0.184 | 1.48 (0.82–2.69) | 0.197 | 1.65 (0.89–3.07) | 0.113 |
| Family rhinitis* no vs. yes | 0.23 (0.16–0.33) | **0.000** | 0.22 (0.11–0.47) | **0.000** | 0.18 (0.10–0.33) | **0.000** | 0.26 (0.14–0.46) | **0.000** |
| Smoker* yes vs. no | 1.14 (0.79–1.65) | 0.480 | 0.74 (0.31–1.75) | 0.490 | 0.99 (0.53–1.84) | 0.965 | 1.56 (0.86–2.81) | 0.142 |
| Negative events* no vs. yes | 1.08 (0.76–1.55) | 0.667 | 1.02 (0.47–2.21) | 0.953 | 0.69 (0.39–1.23) | 0.209 | 1.03 (0.57–1.86) | 0.924 |
| Work-out yes vs. no | | | – | – | | | 0.52 (0.18–1.46) | 0.211 |
| Construction date after 1990 vs. before 1990 | | | – | – | 2.01 (1.04–3.88) | **0.038** | | |
| Location building rural & suburban vs. urban | 0.72 (0.49–1.05) | 0.090 | – | – | | | | |
| Sweeping floor less than once a week vs. at least once a week | | | 0.34 (0.14–0.79) | **0.012** | | | | |
| Hairspray less than once a week vs. at least once a week | 0.63 (0.40–1.00) | **0.049** | – | – | | | 0.50 (0.24–1.05) | 0.066 |
| Incense less than once a week vs at least once a week | | | – | – | | | 0.66 (0.36–1.21) | 0.176 |
| Do-it-yourself soldering no vs. yes | | | – | – | 0.11 (0.02–0.56) | **0.008** | | |
| Opening window in kitchen less than once a week vs. at least once a week | 0.76 (0.51–1.14) | 0.190 | | | 0.51 (0.24–1.09) | 0.081 | | |
| Opening window in bedroom less than once a week vs. at least once a week | | | 2.90 (1.18–7.12) | **0.020** | | | | |
| Air conditioning no vs. yes | 0.59 (0.32–1.08) | 0.086 | – | – | | | 0.38 (0.14–1.04) | 0.060 |

a. The second option is the reference; *adjusted variables; P-values below 0.05 are in bold; OR= Odds Ratio; CI = confidence interval.

rhinitis. For all the respondents who reported to have rhinitis, as well as in Clusters 1, 2 and 3, the outcome shows that students who have a family rhinitis history (compared with those who don't), have a higher risk for rhinitis. Among all the respondents, female students (compared to male students), and students who use hair spray at least once a week (compared to those who use it less than once a week), showed to have a higher risk for rhinitis. For Cluster 1, students who sweep their house at least once a week (compared to those who sweep less than once a week), and students who open windows in their bedroom less than once a week (compared to those who do it more than once a week), have a higher risk for rhinitis. In Cluster 2, students who live in buildings built after 1990 (compared to those living in older buildings), and students who have soldering as a hobby (compared to not), the risk was higher for rhinitis. Then, in both for all respondents and Cluster 3, students who have air conditioning showed a tendency for a higher risk for rhinitis. For all respondents, students who live in rural and suburban area (compared to those who live in urban area); in Cluster 2, students who open the window in the kitchen at least once a week; and in cluster 3, students who use hairspray at least once a week, have a tendency for a higher risk.

#### 3.3.2. Relations between stuffy nose and building-related factors

Tables B2 and 3 show respectively, the binary logistic regression analysis results and the multivariate logistic regression model for stuffy nose. Among all respondents, the students that live in a detached building, use spray deodorant at least once a week, use hair spray less than once a week and have walls other than water-based painted walls, have an increased risk for a stuffy nose. Outdoor pollution sources nearby, vacuum cleaning more than once a week and having furniture made of MDF in the kitchen that is less than one year old, gives a tendency for a reduced risk for a stuffy nose. For Cluster 1, students who have walls other than water-based painted walls have an increased risk for a stuffy nose, while being a non-smoker, the presence of plants showed, and living in a detached building showed a tendency for an increased risk for a stuffy nose. For Cluster 2, a tendency for an increased risk for a stuffy nose was found for the do-it-yourself activity use of heating oven and having walls other than water-based painted walls. For cluster 3, the use of spray deodorant at least once a week, hairspray less than once a week, and having furniture made of MDF in the kitchen that is less than one year old, increased the risk for a stuffy nose. A tendency for a decreased risk was observed in the presence of plants.

#### 3.3.3. Relations between migraine and building-related factors

Tables B3 and 4 show respectively, the binary logistic regression analysis results and the multivariate logistic regression model for migraine. Among all the respondents, students who experienced negative events recently (compared to students who did not), and students who do have painting as a hobby at home (compared to those who don't), have a higher risk for migraine. Students who have outdoor pollution sources nearby (compared to those who don't), and students who recently painted ore remodelled their home (compared to those who did not), showed a tendency for an increased risk for migraine. For cluster 1, students who were exposed to second hand smoke and students who don't have plants, have a higher risk for migraine. For Cluster 2, students who experienced a negative event recently, students who use hair spray at home at least once a week (compared to those who use it less than once a week), and students who use incense at home at least once a week (compared to those who use it less than once a week) showed an increased risk for migraine. Students who use air conditioning, showed a tendency for an increased risk for migraine. For cluster 3, students who experienced a negative event recently (compared to those who did not) and students who have painting as a hobby at home (compared to those who do not), had an increased risk for migraine. Students who recently painted or re-modelled (compared to those who did not) and students having an air conditioning system, showed a tendency of an increased risk for migraine.

#### 3.3.4. Relations between headache and building-related factors

Tables B4 and 5 show respectively, the binary logistic regression analysis results and the multivariate logistic regression model for headache. Among all the respondents, students who reported to drink alcohol (compared to those who did not), dust more than once a week (compared to those who dust less than once a week), reported to have pets (compared to those who did not), and reported to have condensation on the inside of windows, had an increased risk for having headaches. Sweeping more than once a week showed a tendency of an increased risk for headache. For Cluster 1, students who have pets showed an increased risk for headache, and being a smoker had a tendency for a reduced risk for headache. For Cluster 2, drinking alcohol and dusting the floor at least once a week, increased the risk for having headaches, while working out, opening the window in bedroom less than once a week, having no air conditioning, showed a tendency for a reduced risk. For cluster 3, recent painting or remodelling and furniture made out of MDF less than one year old in the bathroom, increased the risk for headache.

**Table 3**
Multivariate logistic regression model of the relations between stuffy nose and building-related factors.

| Stuffy nose | All | | Cluster 1 | | Cluster 2 | | Cluster 3 | |
|---|---|---|---|---|---|---|---|---|
| Risk factor[a] | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value |
| Smoker yes vs. no | | | 0.62 (0.38–1.01) | 0.054 | | | | |
| Time spent at home (weekday) 13–24 h vs. 1–12 h | | | | | | | 0.74 (0.47–1.16) | 0.184 |
| Building type detached vs. attached | 1.79 (1.25–2.58) | **0.002** | 1.74 (1.00–3.03) | 0.052 | | | 2.42 (0.83–6.99) | 0.104 |
| Outdoor pollution sources yes vs. no | 0.74 (0.55–1.00) | 0.052 | | | | | | |
| Vacuum cleaning less than once a week vs. at least once a week | 0.76 (0.56–1.01) | 0.059 | | | | | | |
| Spray deodorant less than once a week vs. at least once a week | 0.68 (0.51–0.90) | **0.008** | | | 0.70 (0.45–1.08) | 0.110 | 0.49 (0.27–0.89) | **0.019** |
| Hair spray less than once a week vs. at least once a week | 1.58 (1.12–2.23) | **0.009** | | | | | 2.14 (1.04–4.40) | **0.040** |
| Do-it-yourself use of heating oven no vs. yes | | | | | 0.62 (0.37–1.04) | 0.068 | | |
| Opening window in bedroom less than once a week vs. at least once a week | | | | | 1.44 (0.91–2.26) | 0.118 | | |
| Walls not water-based painted vs. water-based painted | 1.33 (1.05–1.68) | **0.019** | 1.94 (1.24–3.03) | **0.004** | 1.37 (0.95–1.97) | 0.092 | | |
| Furniture made out of MDF in kitchen less than one year old no vs. yes | 1.31 (0.96–1.80) | 0.087 | | | | | 1.98 (1.06–3.71) | **0.033** |
| Plants present no vs. yes | | | 0.56 (0.30–1.06) | 0.075 | | | 1.55 (0.96–2.50) | 0.070 |

a. The second option is the reference; P-values below 0.05 are in bold; OR= Odds Ratio; CI = confidence interval.

**Table 4**
Multivariate logistic regression model of the relations between migraine and building-related factors.

| Migraine | All | | Cluster 1 | | Cluster 2 | | Cluster 3 | |
|---|---|---|---|---|---|---|---|---|
| Risk factor[a] | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value |
| Gender* female vs. male | 1.38 (0.90–2.13) | 0.142 | 1.63 (0.61–4.35) | 0.331 | 1.56 (0.72–3.39) | 0.261 | 1.03 (0.52–2.05) | 0.939 |
| Negative events* no vs. yes | 0.48 (0.32–0.73) | **0.001** | 0.80 (0.29–2.19) | 0.660 | 0.45 (0.21–0.98) | **0.044** | 0.42 (0.21–0.82) | **0.011** |
| Alcohol yes vs. no | | | | | 5.21 (0.66–40.91) | 0.116 | | |
| Outdoor pollution sources yes vs. no | 1.78 (0.90–3.52) | 0.098 | 5.10 (0.64–40.63) | 0.124 | | | | |
| Vacuum cleaning less than once a week vs. at least once a week | 0.65 (0.35–1.22) | 0.182 | | | 0.31 (0.07–1.38) | 0.124 | | |
| Hairspray less than once a week vs. at least once a week | 0.65 (0.38–1.10) | 0.110 | | | 0.25 (0.11–0.59) | **0.001** | | |
| Incense less than once a week vs. at least once a week | | | | | 0.26 (0.08–0.86) | **0.028** | | |
| Do-it-yourself spray paint no vs. yes | | | 0.28 (0.05–1.51) | 0.138 | 0.42 (0.13–1.35) | 0.145 | | |
| Do-it-yourself painting no vs. yes | 0.45 (0.28–0.72) | **0.001** | 0.40 (0.10–1.55) | 0.184 | | | 0.42 (0.19–0.91) | **0.028** |
| Second hand smoke no vs. yes | | | 0.28 (0.08–1.00) | **0.050** | | | | |
| Recent painting or remodelling no vs. yes | 0.68 (0.44–1.05) | 0.081 | | | | | 0.49 (0.23–1.01) | 0.052 |
| Opening window in bedroom less than once a week vs. at least once a week | | | | | | | 2.02 (0.87–4.66) | 0.101 |
| Air conditioning no vs. yes | 0.58 (0.29–1.14) | 0.113 | | | 0.31 (0.09–1.02) | 0.055 | 0.38 (0.13–1.11) | 0.076 |
| Plants presence no vs. yes | | | 3.04 (1.02–9.05) | 0.053 | | | | |
| Condensation inside yes vs. no | | | | | 2.18 (0.78–6.10) | 0.138 | | |

aThe second option is the reference; *adjusted variables; P-values below 0.05 are in bold; OR= Odds Ratio; CI = confidence interval.

**Table 5**
Multivariate logistic regression model of the relations between headache and building-related factors.

| Headaches | All | | Cluster 1 | | Cluster 2 | | Cluster 3 | |
|---|---|---|---|---|---|---|---|---|
| Risk factor[a] | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value | Adjusted OR (95% CI) | P-value |
| Gender* female vs. male | 1.21 (0.96–1.51) | 0.102 | 1.40 (0.92–2.13) | 0.117 | 1.13 (0.78–1.64) | 0.522 | 1.18 (0.77–1.80) | 0.453 |
| Time spent at home (weekday) 13–24 h vs. 1–12 h | 1.20 (0.94–1.53) | 0.153 | | | | | | |
| Work out yes vs. no | | | | | 0.50 (0.23–1.09) | 0.082 | | |
| Smoker yes vs. no | | | 0.65 (0.40–1.06) | 0.081 | 1.36 (0.91–2.04) | 0.135 | | |
| Alcohol yes vs. no | 1.45 (1.03–2.04) | **0.035** | | | 2.46 (1.25–4.86) | **0.010** | | |
| Negative events no vs. yes | | | 0.73 (0.48–1.13) | 0.164 | | | | |
| Sweeping less than once a week vs. at least once a week | 0.80 (0.64–1.01) | 0.060 | | | | | | |
| Dusting less than once a week vs. at least once a week | 0.61 (0.38–0.98) | **0.040** | | | 0.60 (0.40–0.91) | **0.016** | | |
| Pets no vs. yes | 0.70 (0.55–0.91) | **0.006** | 0.62 (0.40–0.96) | **0.031** | | | | |
| Pests yes vs.no | | | | | 1.38 (0.92–2.06) | 0.118 | | |
| Do-it-yourself heating | | | 0.62 (0.34–1.10) | 0.104 | | | | |
| Recent painting or re-modelling no vs. yes | | | | | | | 0.61 (0.39–0.94) | **0.025** |
| Opening window in bedroom less than once a week vs. at least once a week | | | | | 0.57 (0.32–1.02) | 0.059 | | |
| Air conditioning no vs. yes | | | | | 0.51 (0.23–1.11) | 0.088 | | |
| Furniture made out of MDF in bathroom less than one year old no vs. yes | | | | | | | 0.49 (0.25–0.98) | **0.044** |
| Condensation inside yes vs. no | 1.33 (1.02–1.73) | **0.038** | – | – | – | – | – | – |

a. The second option is the reference; *adjusted variables; P-values below 0.05 are in bold; OR= Odds Ratio; CI = confidence interval.

## 4. Discussion

### 4.1. Profiles of clusters

#### 4.1.1. Comparison to other studies

In this study three profiles of students based on their IEQ-related perceptions were identified: cluster 1 with the highest reported percentage of symptoms, the lowest reported percentage of diseases and air-bothered (n = 446); cluster 2 with moderate reported symptoms and diseases, and air and temperature bothered (n = 680); and cluster 3 with the lowest percentage of reported symptoms, the highest percentage of reported diseases and bothered by all aspects (n = 449).

In a previous study on office workers, three profiles were identified as well based on their IEQ-related complaints [16]: healthy and satisfied workers (n = 379), moderate healthy and noise-bothered workers (n = 300); and unhealthy and air and temperature-bothered office workers (n = 230) (Table 6). In the last cluster, the office workers reported the highest percentage of diseases and symptoms, while in the first the reported the lowest percentage of diseases and symptoms. The outcome of the office study showed that cluster 1 was by far the healthiest. Significant higher risks for building-related symptoms such as dry eyes, dry skin, and watering, itchy eyes were identified for the unhealthy group (cluster 3) than the moderate healthy group (cluster 2).

The most reported disease was rhinitis for the students (All: 12%; Cluster 1: 11%; Cluster 2: 12%; Cluster 3: 14%) (Table 1), while for the office workers this was allergy (All: 23%; Cluster 1: 23%; Cluster 2: 17%; Cluster 3: 30%). For the IE-related symptoms, dry eyes were more common among the office workers (31% office workers vs. 13% students), while blocked/stuffy nose scores higher among the students (35% students vs. 17% office workers). While the reported percentage of headaches showed a statistically significant difference among the clusters of the office workers (Cluster 1: 5%; Cluster 2: 21%; Cluster 3: 29%), for the students this was not the case (Cluster 1: 33%; Cluster 2: 31%; Cluster 3: 31%). The reported percentage of migraines, however, was for

**Table 6**
Characteristics of the three identified clusters of office workers [16].

| Characteristic | Total[a] n (%) | Cluster 1 n (%) | Cluster 2 n (%) | Cluster 3 n (%) | p-value |
|---|---|---|---|---|---|
| **Respondents** | 1014 | 379 | 300 | 230 | |
| gender: Female | 503 (49.6) | 123 (32.5) | 157 (52.3) | 169 (73.5) | < **0.001** |
| Male | 511 (50.4) | 256 (67.5) | 143 (47.7) | 61 (26.5) | |
| Age mean (sd) | 43.8 (10.1) | | | | |
| **Disease/disorder** | | | | | |
| Asthma | 93 (9.2) | 30 (7.9) | 28 (9.3) | 27 (11.7) | 0.479 |
| *High blood pressure* | 111 (10.9) | 34 (8.9) | 31 (10.3) | 27 (11.7) | 0.790 |
| *Allergy* | 229 (22.5) | 88 (23.2) | 51 (17) | 69 (30) | **0.004** |
| Eczema | 111 (10.9) | 35 (9.2) | 35 (11.6) | 33 (14.3) | 0.280 |
| Migraine | 81 (8) | 22 (5.8) | 22 (7.3) | 30 (13) | **0.011** |
| Depression | 38 (3.7) | 10 (2.6) | 11 (3.7) | 13 (5.6) | 0.301 |
| Anxiety | 16 (1.6) | 4 (1) | 5 (1.7) | 7 (3) | 0.348 |
| **Symptoms caused by the home environment, yes and partly** | | | | | |
| Dry eyes | 312 (30.8) | 50 (12.4) | 92 (30.8) | 140 (60.7) | < **0.001** |
| Itchy or watery eyes | 104 (10.3) | 16 (4.1) | 29 (9.8) | 48 (21) | < **0.001** |
| Blocked or stuffy nose | 176 (17.4) | 34 (8.9) | 49 (16.3) | 72 (31.4) | < **0.001** |
| Runny nose | 74 (7.3) | 16 (4.1) | 26 (8.5) | 25 (10.9) | < **0.001** |
| Sneezing | 143 (14.1) | 36 (9.5) | 45 (14.9) | 45 (19.7) | < **0.001** |
| Lethargy or tiredness | 83 (8.2) | 7 (1.9) | 32 (10.8) | 30 (13.1) | < **0.001** |
| Itchy or dry skin | 234 (23.1) | 34 (8.9) | 64 (21.4) | 110 (48) | < **0.001** |
| Headache | 165 (16.3) | 17 (4.6) | 62 (20.7) | 67 (29.3) | < **0.001** |

both groups statistically different among the clusters and for both, Cluster 3 scored the highest. Besides the differences in indoor environment, differences in age and gender distribution of the clusters, might explain the differences in reported diseases and IE-related symptoms.

#### 4.1.2. Rhinitis and stuffy nose

Rhinitis is a worldwide health problem (symptoms of the upper airways such as runny or stuffy nose) with negative impacts on quality of life [26]. In this study 12% of the respondents reported to suffer from rhinitis in the past year (Table 1). Compared to other studies, this group of students falls in the lower range of the estimated range of 10–25% by Dykewicz and Hamilos for the Western population [27]. In cluster 1, 2 and 3, respectively, 11%, 12%, and 14% reported to suffer from rhinitis in the past year (no statistical difference).

Nasal congestion or stuffy/blocked nose is next to the common cold, a common symptom in rhinitis [28]. 76% reported to suffer from stuffy nose at least every 2–3 weeks, while 35% reported indoor environment-related stuffy nose at least once every 2–3 weeks. Per cluster, the numbers for IE-related stuffy nose were 41%, 35% and 31%, respectively for Clusters 1, 2 and 3 (statistical different; $p = 0.006$) (Table 1).

From the Chi-square analysis, statistically significant relationships between having rhinitis and stuffy nose were found in all the clusters except for cluster 1 (Fig. 3). The percentage of people who suffered from rhinitis among those who suffered from a stuffy nose was significantly higher (about twice as) than the percentage among people who did not suffer from a stuffy nose. From the students who reported to have a stuffy nose at least once every 2–3 weeks (related or not to IE), respectively 14%, 13%, 13%, and 16% for all respondents, Cluster 1, Cluster 2 and Cluster 3, reported to also suffer from rhinitis in the past year (Table 1).

#### 4.1.3. Migraine and headache

Headache disorders are the most common disorders of the nervous system, including migraine, tension-type headache (most common), and cluster headache [29]. Globally, it has been estimated that the prevalence among adults of headache disorder (symptomatic at least once within the last year) is about 50%. Half to three quarters of adults aged 18–65 years in the world have had a headache in the last year and, among those individuals, 30% or more reported having migraine [29].

Migraine is a neurovascular disorder that affects over 1 billion people worldwide [30]. Studies worldwide show on average that active headaches are present in 52% of the population studied (female: 58%; male: 44%) and migraines are present in 14% (female: 17%; Male: 9%) [31]. In the current study, 7% of the respondents reported to suffer from

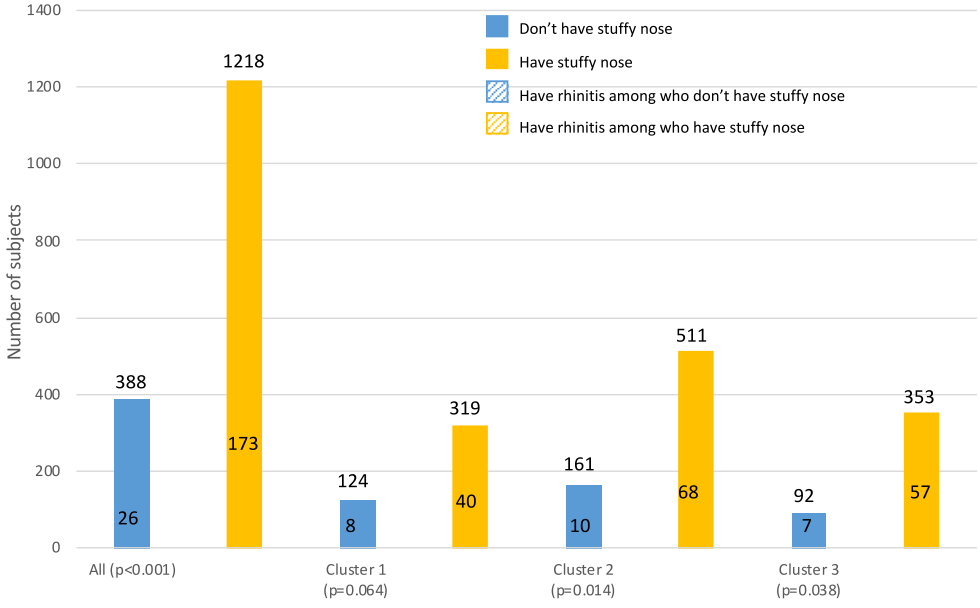


**Fig. 3.** Relationships between the prevalence of rhinitis and stuffy nose (no matter whether it's related to IE) among all and among different clusters.

migraine in the past year, and respectively 59% reported to suffer from headaches at least once every 2–3 weeks. 31% reported IE-related headaches at least every 2–3 weeks. These numbers for IE-related headaches were 33%, 31% and 31% for Clusters 1,2 and 3, respectively (with no statistical difference). In Clusters 1, 2 and 3, respectively, 5%, 6% and 11% reported to suffer from migraine in the past year (statistical different; $p < 0.001$) (Table 1).

From the Chi-square analysis, statistically significant relationships between having migraine and headache were found in all the clusters except for cluster 1 (Fig. 4). The percentage of people who suffered from migraines among those who suffered from headaches was significantly higher (more than three times as) than the percentage among people who did not suffer from headaches. From the students who reported to have headaches at least every 2–3 weeks (related or not to IE), respectively 10%, 6%, 9%, and 15% for all respondents, Cluster 1, Cluster 2 and Cluster 3, reported to also suffer from migraine in the past year (Table 1).

### 4.2. Patterns of stressors

#### 4.2.1. Rhinitis and stuffy nose

From previous studies with students [11,12], rhinitis was found to be a multifactorial disease, as both personal and building-related factors were linked to this disease in students. In the current study, again personal factors (e.g. gender and family rhinitis) and building-related factors were linked to having rhinitis (e.g. use of hairspray) for all respondents (Table 2). Per cluster, however, the building-related risk factors varied: while in Clusters 1 and 2, two risk factors (Cluster 1: sweeping floor and opening window in bedroom; Cluster 2: construction date building and do-it-yourself soldering) were found to be associated with having rhinitis, in cluster 3 no building-related factors at all were found to be associated. Moreover, the only common risk factor for all clusters was family rhinitis. Considering a tendency of a risk, the model of Cluster 3 showed an overlap with the model for all respondents (Table 2).

A stuffy nose can not only occur through a viral infection, but also through the same triggers causing rhinitis: that is indoor allergens such as dust mites, moulds, insects and animal dander; and non-allergic conditions such as chemical, physical and emotional factors [32]. Nevertheless, with regards to overlap in risk factors for rhinitis and stuffy nose, only one overlap is observed: the use of hairspray by all respondents and Cluster 3 (Tables 2 and 3). In the current study, for all respondents no personal factors were linked to having an IE-related stuffy nose, while several environmental factors (building type, use of spray deodorant, use of hair spray and surface type of walls) were linked (Table 3). Interestingly, stuffy nose in Cluster 3 was linked to three building-related factors (use of spray deodorant, use of hair spray and furniture made of MDF in kitchen less than one year old), Cluster 2 to none, and Cluster 1 to one building-related factor (surface type of walls). Also, an overlap with the model for all respondents was seen for cluster 1 and 3 (Table 3).

#### 4.2.2. Migraine and headache

The exact cause of migraines is unknown, but a number of migraine triggers have been suggested [33]: hormonal changes, emotional (e.g. stress, anxiety, depression), physical (e.g. poor-quality sleep, tiredness), dietary (e.g. alcohol, coffee, dehydration), environmental (e.g. bright lights, loud noises, smoking, strong smells) and medicinal factors. The same triggers are common causes of headaches.

From previous studies with students [12] and hospital staff [13], both personal-related as well as building-related factors were found to be associated with headaches. In the current study, the same is found for both migraine (negative events, do-it-yourself painting) and headache (alcohol consumption, dusting, having pets, condensation inside windows) for all respondents (Tables 4 and 5, respectively). For both headache and migraine, no correlations were found between students reporting migraines/having headaches at least once every 2–3 weeks (related to IE) and dissatisfaction with glare, for all respondents and for the students in the three clusters. Only migraine for all respondents showed a tendency with reported glare dissatisfaction ($p = 0.090$) (Table 4).

An overlap in risk factors for migraine and headache is observed for recent painting or re-modelling in Cluster 3 and air conditioning in Cluster 2. For migraine, the group with all respondents, Clusters 2 and 3 show a link between the same personal-related factor (negative events) (Table 4), while for headache only the group with all respondents and Cluster 2 do (alcohol consumption) (Table 5). With regards to building-related factors, Cluster 1 has one factor (having pets) linked to headache for all respondents. Cluster 2 has one factor (dusting) linked to headache for all respondents. Cluster 3 has one building-related factor (do-it-

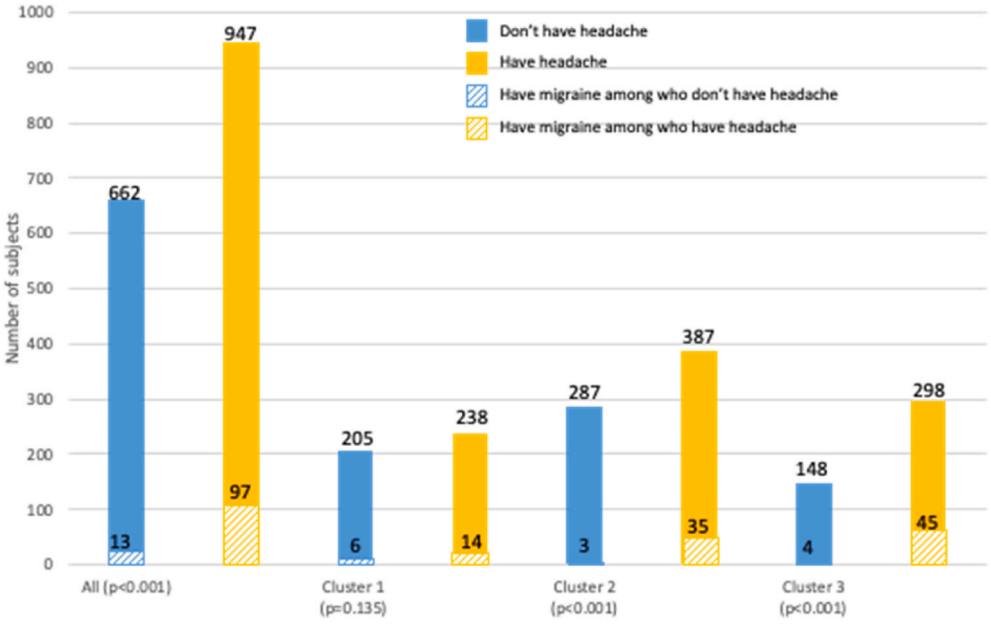


**Fig. 4.** Relationships between the prevalence of migraine and headache (no matter whether it's related to IE) among all and among different clusters.

yourself painting) linked to migraine for all respondents.

#### 4.2.3. Opposite and contradicting effects

With regards to an overlap in risk factors between rhinitis and stuffy nose, only the use of hairspray was found, with an opposite outcome: while hairspray seemed to decrease the risk for a stuffy nose in the all-respondents' group (and a tendency for a decreased risk in Cluster 3) (Table 3), it increased the risk for rhinitis in the all-respondents' group (and a tendency for an increased risk in Cluster 3) (Table 2). A similar effect is observed for stuffy nose and furniture made of MDF in cluster 3. Previous studies on rhinitis showed that less than one-year old furniture made of MDF in the bedroom had an increased risk for rhinitis [11]. Both ingredients of hairspray and formaldehyde can cause irritation of the eyes, nose, throat and skin. They can also cause allergic reactions like sneezing. Short-term effects of exposure to low levels of formaldehyde include among others headache and runny nose [34]. It could well be that both formaldehyde and hair spray stimulate the mucous production (runny nose) and open-up the sinuses with some people, and therefore decrease a blocked or stuffy nose.

An interesting finding of the current study is that the presence of plants at home had the tendency to increase the risk for of rhinitis in cluster 1 while the opposite effect was found in cluster 3 (Table 2). This might be explained by two facts. First, the effect of plants on air purification largely depends on the type of plants [35–37]. For example, some plant species have significant effects on removing VOC [35] or benzene [36] from air, while some species that produce pollen or emit gaseous substances might have an adverse effect on IAQ [37], and some pollens emitted by plants could cause allergic rhinitis [38]. Second, this finding further indicates the difference between people. The impact of the same factor/item might be positive to some people but negative to the others. Therefore, studies that treating all participants as a whole might produce inaccurate results.

Another interesting finding is the tendency for a decreased risk of headaches from being a smoker in cluster 1 (Table 5). The same tendency is seen in cluster 1 for stuffy nose (Table 3). While most studies indicate that smoking contributes to headache [39–41], some report that nicotine has antinociceptive effects [42], so it might help to relief a headache. Additionally, 'smoking' to some young adults in the Netherlands might be similar to 'inhaling weed/marijuana', which has been found to decrease headache frequency [43]. Cannabis products can help to balance the body's immune system and alleviate allergies [44]. Moreover, inhaling cannabis products could offer faster relief than eating these products [45]. So, possibly this can explain the decreased tendency of headache in students who smoke in cluster 1 (Table 5). With regards to stuffy nose (Table 3), a similar explanation as for hairspray and MDF could be that smoke (including among others formaldehyde) causes irritation of nose (runny nose), opens up the sinuses with some people, and therefore decrease a blocked or stuffy nose.

In Cluster 2, opening window in bedroom less than once a week shows a tendency of a decreased risk for headaches (Table 5); and opening window in kitchen less than once a week shows a tendency of a decreased risk for rhinitis (Table 2). In fact, the opposite effect is expected: opening windows less than once a week is expected to cause an increased risk, except if outdoor pollution sources are present that could cause rhinitis and/or headaches. Indeed, for rhinitis in Cluster 2, although the risk factor outdoor pollution sources disappeared in the final model, the binary logistic regression analysis showed an increased risk for rhinitis (OR = 0.51 (0.26–0.93); p = 0.044) for students who live close to outdoor pollution sources (Table B1). For headaches in cluster 2, the binary logistic regression analysis was, however, not statistical relevant (p = 0.554) (Table B4), and therefore was not applied in the multivariate analysis. Additionally, in Cluster 2, people who have rhinitis/headache were more likely to open windows whether there are outdoor pollution sources or not (although the correlation is not statistically significant) (Figs. 5 and 6). In other words, almost all students who have rhinitis/headache open their windows at least once a week, especially the bedroom and kitchen windows, and 19–33% of them live close to outdoor pollution sources (these percentages were higher than those who do not have rhinitis/headache in most cases). So, this behaviour (opening windows) might trigger their rhinitis/headache.

A similar tendency that seems contrary to common sense was found between the presence of outdoor pollution sources and stuffy nose in all respondents: having outdoor pollution pollutant sources nearby shows a tendency of a decreased risk for a stuffy nose (Table 3). This tendency can be explained by the statistically significant relationship between the presence of outdoor pollution sources and the frequency of opening bedroom windows identified in all respondents. According to the Chi-square tests (p = 0.024), among the people who live close to pollutant sources, the percentage (83%) of them who open windows in their bedroom at least once a week was significantly lower than the percentage (89%) among the people who don't have outdoor pollution sources nearby. Therefore, having outdoor pollution pollutant sources

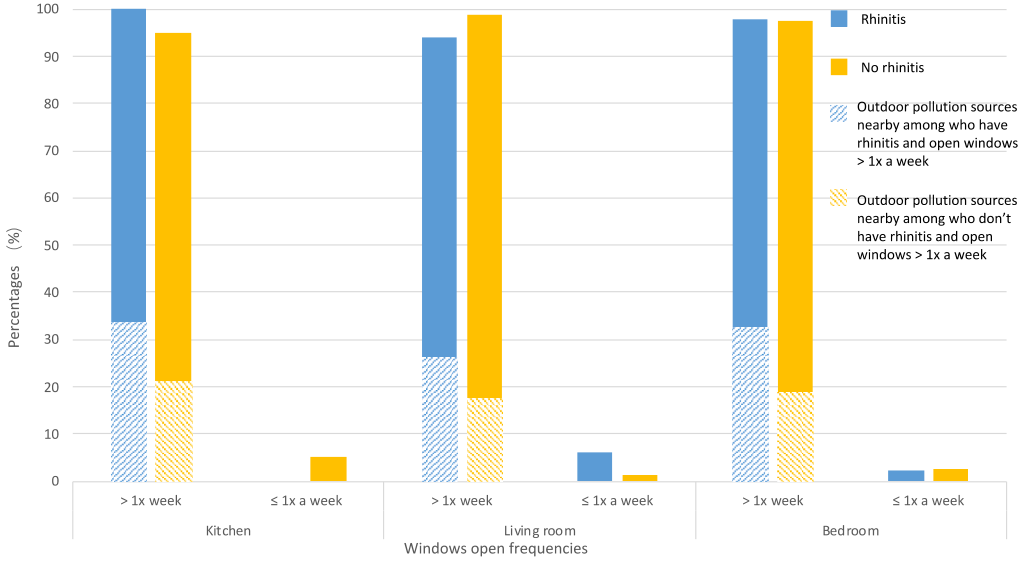


**Fig. 5.** Relationships between the occurrence of outdoor pollution sources nearby and rhinitis among students who open windows at least once a week in kitchen/living room/bedroom in Cluster 2.

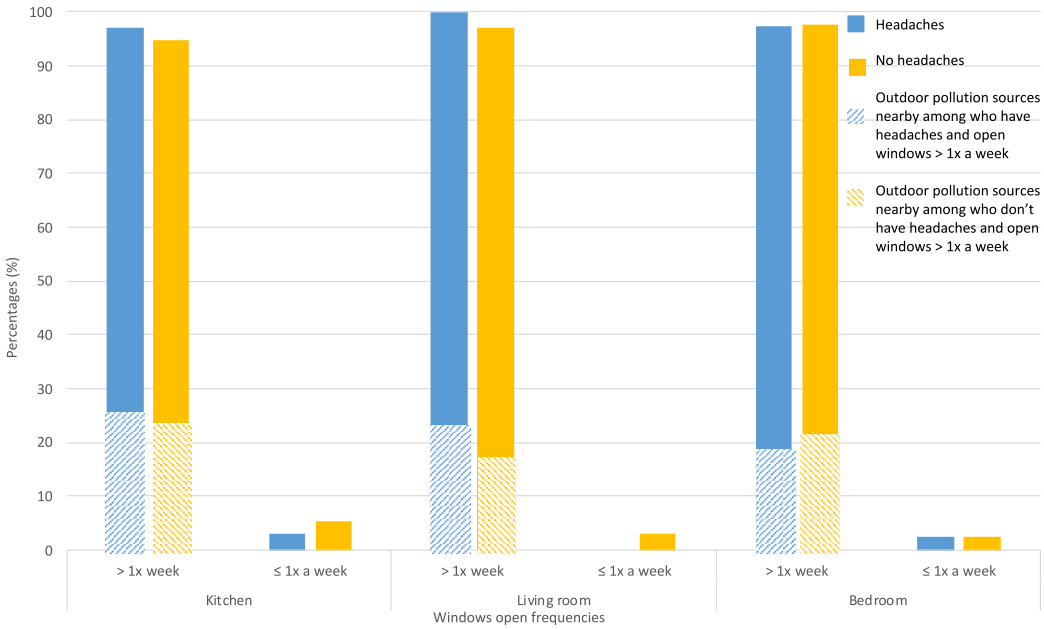


**Fig. 6.** Relationships between the occurrence of outdoor pollution sources nearby and headaches among students who open windows at least once a week in kitchen/living room/bedroom in Cluster 2.

nearby decreases the frequency of opening windows in bedrooms, which might decrease the risk for a stuffy nose.

## 5. Conclusions and recommendations

The current study is a first attempt to identify pattern of stressors for different profiles of students based on self-reported health, comfort perception and building-related characteristics of their home environments. In this study three profiles of students based on their IEQ-related perceptions were identified: Cluster 1 with the highest reported percentage of symptoms and the lowest reported percentage of diseases; Cluster 2 with moderate reported symptoms and diseases; and Cluster 3 with the lowest percentage of reported symptoms and the highest percentage of reported diseases.

The analysis of the different personal and building-related risk factors for statistically different incidence rates for the different clusters (migraine and stuffy nose) and not statistically different incidence rates for the different clusters (rhinitis and headache), showed that this statistical difference does not seem to matter. While for rhinitis no common building-related risk factor was found, headache did show an overlap in building-related factors between the all-respondents model and the models of Clusters 1 and 2. While for stuffy nose no personal-related risk factors were found, for migraine negative events showed an overlap between the all-respondents model and the models of Clusters 2 and 3.

The multivariate logistic regression analysis showed that risk factors contributing to having rhinitis, stuffy nose, migraine and/or headache, differ per cluster, and showed little overlap with the all-respondents group. Moreover, when there is an overlap, the associated risk factor might increase the risk for one cluster, while for another decreases the risk, indicating the differences between the way people in different clusters respond; and therefore, the importance of clustering instead of considering all respondents as one.

The analysis further showed that although in the literature a clear overlap in risk factors for rhinitis & stuffy nose and migraine and headache exist, little overlap in risk factors for the different clusters was seen. Moreover, the same building-related risk factor could result in an opposite effect.

Based on these findings, it is recommended that future studies focusing on the relationship between building-related risk factors and the prevalence of diseases and symptoms caused by staying indoors, should apply cluster analysis in combination with multi-variate analysis for each disease or symptom separately. Moreover, personal risk factors are also important and should be taken into account.

While this study focused on students in their home environment, in particular bachelor students of the faculty of Architecture and the Built Environment, future studies should expand to other population groups (e.g. office workers, elderly, children, teenagers), and other scenarios (e.g. offices, schools, etc.). In this way, a database with patterns of stressors for different diseases and symptoms of different occupants and profiles in different scenarios can be created, which can help to better explain the complex relationships between the indoor environments and the effects we are dealing with.

## CRediT authorship contribution statement

**Philomena M. Bluyssen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Dadi Zhang:** Writing – review & editing, Writing – original draft, Formal analysis. **Marco Ortiz:** Writing – review & editing, Writing – original draft, Formal analysis.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The data that has been used is confidential.

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## Appendix A. Building and environment characteristics for all students, and the clusters

| | Total[a] 1651 n (%) | Cluster 1 446 n (%) | Cluster 2 680 n (%) | Cluster 3 449 n (%) | p |
|---|---|---|---|---|---|
| **Tenure** | | | | | |
| Owner | 214 (13.3) | 105 (23.7) | 85 (12.6) | 19 (4.2) | **< 0.001** |
| Renter | 1046 (64.9) | 155 (35.0) | 459 (67.8) | 400 (89.5) | |
| Others | 352 (21.8) | 183 (41.3) | 133 (19.6) | 28 (6.3) | |
| **Home** | | | | | |
| Students' resident | 1011 (62.4) | 151 (34.0) | 439 (64.8) | 383 (85.9) | **< 0.001** |
| Parents' home | 610 (37.6) | 293 (66.0) | 238 (35.2) | 63 (14) | |
| **Building type** | | | | | **< 0.001** |
| Apartment complex | 398 (25.3) | 85 (19.1) | 75 (25.7) | 138 (30.7) | |
| Gallery complex | 125 (7.9) | 14 (3.1) | 61 (9.0) | 50 (11.1) | |
| Row-house | 568 (35.9) | 147 (33.0) | 256 (37.6) | 162 (36.1) | |
| Semi-detached house | 248 (15.7) | 96 (21.5) | 97 (14.3) | 55 (12.2) | |
| Detached house | 137 (8.7) | 69 (15.5) | 51 (7.5) | 17 (3.8) | |
| Other | 69 (4.4) | 25 (5.6) | 24 (3.5) | 20 (4.5) | |
| **Construction date** | | | | | **< 0.001** |
| Before 1945 | 393 (25.0) | 83 (18.6) | 181 (26.6) | 129 (28.7) | |
| 1945–1965 | 231 (14.7) | 44 (9.9) | 85 (12.5) | 102 (22.7) | |
| 1966–1981 | 334 (21.2) | 81 (18.2) | 160 (23.5) | 93 (20.7) | |
| 1982–1990 | 120 (7.6) | 44 (9.7) | 49 (7.2) | 27 (6.0) | |
| 1991–1999 | 119 (7.6) | 65 (14.6) | 44 (6.5) | 10 (2.2) | |
| 2000 or later | 229 (14.5) | 102 (22.9) | 93 (13.7) | 34 (7.6) | |
| I don't know | 149 (9.5) | 27 (6.1) | 68 (10.0) | 54 (12.0) | |
| **Building location** | | | | | **< 0.001** |
| Mixed area (industrial, commercial, residential) | 246 (15.6) | 51 (11.4) | 99 (14.6) | 96 (21.4) | |
| City centre, densely packed housing | 305 (19.4) | 47 (10.5) | 141 (20.8) | 117 (26.1) | |
| Town, with no or small gardens | 443 (28.2) | 86 (19.3) | 205 (30.2) | 152 (33.9) | |
| Suburban, with larger gardens | 379 (24.1) | 166 (37.2) | 146 (21.5) | 67 (15.0) | |
| Village or rural area | 199 (12.7) | 96 (21.5) | 87 (12.8) | 16 (3.6) | |
| **Outdoor pollution sources** | | | | | |
| None | 228 (14.5) | 91 (20.4) | 93 (13.7) | 44 (9.8) | **< 0.001** |
| Cars parked close to building | 295 (18.7) | 57 (12.8) | 118 (17.4) | 120 (26.7) | **< 0.001** |
| Attached garage | 186 (11.8) | 66 (14.8) | 77 (11.3) | 43 (9.6) | **0.047** |
| Direct access from basement or roof car park | 88 (5.6) | 21 (4.7) | 39 (5.7) | 28 (6.2) | 0.595 |
| Busy road | 816 (51.8) | 182 (40.8) | 363 (53.4) | 271 (60.4) | **< 0.001** |
| Industry | 115 (7.3) | 23 (5.2) | 42 (6.2) | 50 (11.1) | **0.001** |
| Power station | 20 (1.3) | 5 (1.1) | 6 (0.9) | 9 (2.0) | 0.243 |
| Construction site | 214 (13.6) | 46 (10.3) | 85 (12.5) | 83 (18.5) | **0.001** |
| Waste management site | 43 (2.7) | 7 (1.6) | 22 (3.2) | 14 (3.1) | 0.205 |
| Agricultural sources | 87 (5.5) | 29 (6.5) | 37 (5.4) | 21 (4.7) | 0.486 |
| Railway station | 188 (11.9) | 34 (7.6) | 84 (12.4) | 70 (15.6) | **0.001** |
| **OCCUPANTS AND ACTIVITIES** | | | | | |
| **Pets in your home** | | | | | |
| None | 1179 (75.0) | 289 (64.8) | 510 (75.1) | 380 (84.8) | **< 0.001** |
| Dog | 119 (7.6) | 56 (12.6) | 49 (7.2) | 14 (3.1) | **< 0.001** |
| Cat | 146 (9.3) | 58 (13.0) | 60 (8.8) | 28 (6.2) | **0.002** |
| Rabbit/hamster/guinea pig | 29 (1.8) | 7 (1.6) | 17 (2.5) | 5 (1.1) | 0.209 |
| Bird | 21 (1.3) | 5 (1.1) | 11 (1.6) | 5 (1.1) | 0.692 |
| Other | 30 (1.9) | 12 (2.7) | 11 (1.6) | 7 (1.6) | 0.357 |
| **Pests in your home** | | | | | |
| None | 526 (33.4) | 157 (35.2) | 229 (33.7) | 140 (31.2) | 0.434 |
| Cockroaches | 5 (0.3) | 1 (0.2) | 2 (0.3) | 2 (0.4) | 0.833 |
| Ants | 106 (6.7) | 47 (10.5) | 40 (5.9) | 19 (4.2) | **< 0.001** |
| Mice | 245 (15.6) | 49 (11.0) | 101 (14.9) | 95 (21.2) | **< 0.001** |
| Rats | 17 (1.1) | 5 (1.1) | 7 (1.0) | 5 (1.1) | 0.986 |
| Ladybugs | 86 (5.5) | 33 (7.4) | 34 (5.0) | 19 (4.2) | 0.089 |
| Silverfishes | 595 (37.8) | 178 (39.9) | 246 (36.2) | 171 (38.1) | 0.444 |
| Moths | 103 (6.5) | 23 (5.2) | 41 (6.0) | 39 (8.7) | 0.079 |
| Other | 78 (5.0) | 24 (5.4) | 30 (4.4) | 24 (5.3) | 0.689 |
| **Exposure to second hand tobacco smoke** | | | | | |
| Yes | 186 (11.8) | 26 (5.8) | 82 (12.1) | 78 (17.4) | **< 0.001** |
| **Do-it-yourself activities** | | | | | |
| None | 575 (53.6) | 169 (55.4) | 254 (52.3) | 152 (54.1) | 0.678 |
| Welding | 17 (1.1) | 8 (1.8) | 3 (0.4) | 6 (1.3) | 0.082 |
| Spray paint | 74 (4.7) | 19 (4.3) | 30 (4.4) | 25 (5.6) | 0.584 |
| Heating | 184 (11.7) | 57 (12.8) | 78 (11.5) | 49 (10.9) | 0.668 |
| Model glues | 208 (13.2) | 49 (11.0) | 80 (11.8) | 79 (17.6) | **0.005** |
| Woodworking | 90 (5.7) | 29 (6.5) | 39 (5.7) | 22 (4.9) | 0.586 |
| Soldering | 45 (2.9) | 22 (4.9) | 13 (1.9) | 10 (2.2) | **0.008** |
| Paint | 225 (14.3) | 64 (14.3) | 86 (12.6) | 75 (16.7) | 0.162 |
| Other | 13 (0.8) | 6 (1.3) | 5 (0.7) | 2 (0.4) | 0.312 |
| **Recent painting, renovation within the last year** | | | | | |
| Yes | 829 (52.7) | 207 (46.4) | 358 (52.8) | 264 (58.9) | **0.001** |

(*continued on next page*)

(*continued*)

| | | | | | |
|---|---|---|---|---|---|
| **Cleaning activities (at least once a week)** | | | | | |
| Floors/carpets swept/vacuumed | 1267 (80.6) | 382 (85.8) | 546 (80.5) | 339 (75.7) | **0.001** |
| Smooth floors washed | 865 (55.2) | 247 (55.6) | 384 (56.7) | 234 (52.3) | 0.344 |
| Surfaces dusted | 1031 (65.7) | 329 (73.9) | 439 (64.8) | 263 (58.7) | **< 0.001** |
| **Use of consumer products (at least once a week)** | | | | | |
| Air fresheners | 603 (39.2) | 174 (39.5) | 266 (40.2) | 163 (37.3) | 0.614 |
| Spray deodorant | 1255 (80.3) | 366 (82.6) | 535 (79.5) | 354 (79.2) | 0.345 |
| Roller deodorant | 493 (32.1) | 131 (30.0) | 200 (30.3) | 162 (36.7) | **0.044** |
| Insecticides | 22 (1.4) | 6 (1.4) | 5 (0.8) | 11 (2.5) | 0.055 |
| Disinfectants | 464 (30.3) | 116 (26.4) | 210 (31.9) | 138 (31.7) | 0.108 |
| Window cleaners | 196 (12.7) | 53 (12.1) | 87 (13.1) | 56 (12.8) | 0.883 |
| Spray on oven cleaners | 138 (9.0) | 29 (6.6) | 55 (8.3) | 54 (12.4) | **0.009** |
| Nail polish removers | 124 (8.0) | 35 (8.0) | 55 (8.3) | 34 (7.7) | 0.950 |
| Hair sprays | 203 (13.2) | 70 (15.9) | 74 (11.2) | 59 (13.5) | 0.074 |
| Incense sticks | 84 (5.4) | 19 (4.3) | 34 (5.1) | 31 (7.1) | 0.180 |
| Pesticides | 13 (0.8) | 2 (0.5) | 4 (0.6) | 7 (1.6) | 0.120 |
| **Opening of windows in winter (more than once a week)** | | | | | |
| Kitchen | 1008 (69.5) | 270 (65.2) | 444 (71.7) | 294 (70.5) | 0.073 |
| Living room | 955 (65.5) | 257 (62.4) | 416 (65.9) | 282 (68.0) | 0.231 |
| Bedroom | 1179 (83.9) | 338 (83.9) | 520 (84.3) | 321 (83.4) | 0.931 |
| **FURNISHING AND FURNITURE** | | | | | |
| **Main floor covering** | | | | | |
| Carpet | 178 (11.3) | 38 (8.5) | 89 (13.2) | 51 (11.4) | **< 0.001** |
| Wood | 710 (45.2) | 227 (50.9) | 300 (44.4) | 183 (40.8) | |
| Stone/ceramic | 131 (8.3) | 43 (9.6) | 52 (7.7) | 36 (8.0) | |
| Synthetic smooth floorcovering | 426 (27.1) | 92 (20.6) | 181 (26.8) | 153 (34.2) | |
| Exposed concrete | 17 (1.1) | 4 (0.9) | 8 (1.2) | 5 (1.1) | |
| Other | 108 (6.9) | 42 (9.4) | 46 (6.8) | 20 (4.5) | |
| **Main wall covering** | | | | | **0.001** |
| Wall paper | 292 (18.6) | 77 (17.3) | 139 (20.6) | 76 (17.0) | |
| Wood/sealed cork | 14 (0.9) | 3 (0.7) | 7 (1.0) | 4 (0.9) | |
| Stone/tile | 14 (0.9) | 1 (0.2) | 5 (0.7) | 8 (1.8) | |
| Exposed concrete/plaster | 409 (26.1) | 126 (28.3) | 165 (24.4) | 118 (26.4) | |
| Enamel/gloss paint | 296 (18.9) | 66 (14.8) | 126 (18.7) | 104 (23.3) | |
| Dispersion/emulsion paint | 507 (32.4) | 155 (34.8) | 222 (32.9) | 130 (29.1) | |
| Porous fabric incl. Textiles | 9 (0.6) | 1 (0.2) | 5 (0.7) | 3 (0.7) | |
| Other | 26 (1.7) | 16 (3.5) | 6 (0.9) | 4 (0.9) | |
| **Main ceiling surface** | | | | | |
| Exposed concrete/plaster | 727 (46.5) | 229 (51.5) | 306 (45.5) | 192 (46.5) | **0.001** |
| Synthetic material | 49 (3.1) | 5 (1.1) | 29 (4.3) | 15 (3.4) | |
| Wood fibre tiles | 42 (2.7) | 8 (1.8) | 16 (2.4) | 18 (4.0) | |
| Mineral fibre tiles | 22 (1.4) | 1 (0.2) | 9 (1.3) | 12 (2.7) | |
| Paint | 604 (38.6) | 174 (39.1) | 260 (38.6) | 170 (38.0) | |
| Wood | 75 (4.8) | 13 (2.9) | 34 (5.1) | 28 (6.3) | |
| Other | 46 (2.9) | 15 (3.4) | 19 (2.8) | 12 (2.7) | |
| **Furniture made out of MDF (yes, at least < 1 year)** | | | | | |
| Bedroom | 373 (24.3) | 87 (20.0) | 168 (25.4) | 118 (27.0) | 0.120 |
| Kitchen | 233 (15.1) | 50 (11.4) | 101 (15.2) | 82 (18.7) | **0.005** |
| Bathroom | 114 (7.5) | 20 (4.7) | 57 (8.7) | 37 (8.6) | 0.062 |
| Living room | 277 (18.2) | 73 (16.8) | 118 (17.9) | 86 (19.9) | **0.003** |
| **Natural decorative plants** | | | | | |
| Yes | 1202 (76.4) | 374 (83.9) | 506 (74.4) | 322 (71.9) | **< 0.001** |
| **SYSTEMS** | | | | | |
| **Air conditioning** | | | | | |
| Yes | 118 (7.5) | 51 (11.5) | 40 (5.9) | 27 (6.1) | **0.001** |
| **Ventilation** | | | | | |
| Operable windows | 1484 (98.7) | 410 (97.9) | 647 (98.9) | 427 (99.3) | 0.141 |
| Ventilation grille | 438 (29.1) | 176 (42.0) | 174 (26.6) | 88 (20.5) | **< 0.001** |
| Other natural ventilation | 135 (9.0) | 49 (11.7) | 57 (8.7) | 29 (6.7) | 0.251 |
| Mechanical ventilation | 204 (13.6) | 79 (18.9) | 88 (13.5) | 37 (8.6) | **< 0.001** |
| **HUMIDITY** | | | | | |
| **Signs of humidity problems** | | | | | |
| Water leakage or water damage indoors in walls, floor, ceiling | 451 (28.6) | 96 (21.5) | 193 (28.4) | 162 (36.1) | **< 0.001** |
| Bubbles or yellow discoloration on plastic covering or black discoloration on a parquet floor | 25 (1.6) | 1 (0.2) | 10 (1.5) | 14 (3.1) | **0.002** |
| Visible mould growth indoors on walls, floor, ceiling | 273 (17.3) | 39 (8.7) | 119 (17.5) | 115 (25.6) | **< 0.001** |
| The smell of mould in one or more rooms (excl. basement) | 48 (3.0) | 3 (0.7) | 25 (3.7) | 20 (4.5) | **< 0.001** |
| None | 524 (33.3) | 188 (42.2) | 214 (31.5) | 122 (27.2) | **< 0.001** |
| **Condensation on windows** | | | | | |
| Yes, on outside | 96 (6.1) | 19 (4.3) | 39 (5.7) | 38 (8.5) | **0.028** |
| Yes, on inside | 359 (22.8) | 77 (17.3) | 136 (20.0) | 146 (32.5) | **< 0.001** |
| Yes, in between glazing | 34 (2.2) | 4 (0.9) | 20 (2.9) | 10 (2.2) | 0.069 |
| No | 653 (41.5) | 222 (49.8) | 279 (41.0) | 152 (33.9) | **< 0.001** |
| **Clothes drying method** | | | | | |
| **0.019** | | | | | |
| Hanging indoors | 1038 (66.3) | 276 (61.9) | 450 (66.7) | 312 (70.1) | |
| In the dryer | 436 (27.8) | 133 (29.8) | 186 (27.6) | 117 (26.3) | |
| **Dryer vented to outdoors** | | | | | |
| No | 331 (41.4) | 95 (41.9) | 157 (44.0) | 79 (36.6) | **< 0.001** |

a: including the respondents without cluster; n can vary because of missing data (not completed).

## Appendix B. Binary logistic regression analysis

### *B1. Binary logistic regression analysis for rhinitis*

| Factor | Cluster 1<br>P | Cluster 2<br>P | Cluster 3<br>P | Total<br>P |
|---|---|---|---|---|
| **Personal** | | | | |
| Gender Male vs. female | / | / | / | / |
| **Life style** | | | | |
| Time spent at home (weekday) 1–12 h vs. 13–24 h | 0.972 | 0.497 | 0.901 | 0.658 |
| Time spent at home (weekday) 1–12 h vs. 13–24 h | 0.576 | 0.969 | 0.507 | 0.696 |
| Work out no vs. yes | 0.998 | 0.638 | **0.154** | 0.620 |
| Smoking no vs. yes | / | / | / | / |
| Alcohol no vs. yes | 0.917 | 0.906 | 0.620 | 0.849 |
| **Psychophysical aspects** | | | | |
| Negative events yes vs.no | / | / | / | / |
| **Building** | | | | |
| Building type<br>Attached vs. detached | 0.986 | 0.980 | 0.581 | 0.569 |
| Construction date<br>Before 1990 vs. after 1990 | 0.811 | **0.102** | 0.249 | 0.984 |
| Building location<br>Urban vs. rural & suburban | 0.451 | 0.402 | 0.512 | **0.109** |
| Outdoor pollution sources yes vs. no | 0.837 | **0.044**[a] | 0.917 | **0.130** |
| **Cleaning activities** | | | | |
| Vacuuming: At least 1x/week vs less than 1x/week | 0.903 | 0.709 | **0.192** | 0.456 |
| Sweeping: At least 1x/week vs less than 1x/week | **0.100** | 0.477 | **0.100** | **0.039** |
| Dusting: At least 1x/week vs less than 1x/week | 0.978 | 0.645 | 0.473 | 0.815 |
| **Consumer products** | | | | |
| Nail polish: At least 1x/week vs less than 1x/week | 0.801 | 0.949 | 0.877 | 0.883 |
| Hairspray: At least 1x/week vs less than 1x/week | 0.690 | 0.397 | **0.029** | **0.042** |
| Incense: At least 1x/week vs less than 1x/week | 0.999 | 0.686 | **0.134** | 0.699 |
| **Occupants and activities** | | | | |
| **Pets** | | | | |
| Pets: Yes vs no | 0.755 | 0.836 | 0.349 | 0.977 |
| **Pests** | | | | |
| Presence of pests: No vs yes | 0.854 | **0.193** | 0.991 | 0.864 |
| **DIY activities** | | | | |
| Welding: Yes vs no | 0.999 | 0.999 | 0.807 | 0.393 |
| Spray paint: Yes vs no | 0.976 | 0.471 | 0.943 | 0.737 |
| Heating oven: Yes vs no | 0.821 | 0.803 | 0.841 | 0.853 |
| Model glue: Yes vs no | 0.996 | 0.449 | **0.096** | **0.078** |
| Woodworking: Yes vs no | 0.291 | 0.686 | **0.109** | 0.221 |
| Soldering: Yes vs no | 0.998 | **0.035** | 0.999 | 0.815 |
| Paint: Yes vs no | 0.524 | 0.987 | 0.803 | 0.831 |
| Other DIY<br>Yes vs no | 0.999 | 0.999 | / | 0.999 |
| **SHS exposure** | | | | |
| Yes vs no | 0.575 | 0.374 | 0.533 | 0.421 |
| **Recent painting or remodelling**<br>Yes vs no | 0.652 | 0.731 | **0.174** | 0.322 |
| **Window opening** | | | | |
| Kitchen<br>At least 1x/week vs less than once a week | 0.681 | **0.041** | 0.415 | **0.078** |
| Living room<br>At least 1x/week vs less than once a week | 0.401 | 0.263 | **0.107** | **0.101** |
| Bedroom<br>At least 1x/week vs less than once a week | **0.089** | **0.175** | 0.226 | 0.474 |
| **Air conditioning**<br>Yes vs no | **0.075** | 0.851 | **0.165** | **0.067** |
| **Surface coverings** | | | | |
| Floors: Carpet vs others | **0.122** | 0.327 | 0.572 | 0.762 |
| Walls: Water-based paint vs others | 0.325 | 0.291 | 0.505 | 0.482 |
| Ceilings: Paint vs others | 0.976 | 0.747 | 0.973 | 0.785 |
| **MDF less than 1 year** | | | | |
| Kitchen: Yes vs no | 0.362 | 0.266 | 0.946 | 0.566 |
| Bedroom: Yes vs no | 0.427 | **0.067** | 0.630 | 0.444 |
| Bathroom: Yes vs no | 0.774 | 0.328 | 0.502 | 0.949 |
| Living room: Yes vs no | 0.520 | 0.313 | 0.654 | 0.575 |
| **Open bookshelves**<br>Yes vs no | 0.775 | **0.109** | 0.799 | 0.419 |
| **Humidity problems**<br>No vs Yes | **0.137** | **0.009** | 0.813 | **0.011** |
| **Condensation inside** yes vs. no | **0.106** | 0.681 | 0.943 | 0.965 |

a: OR = 0.51 (0.26–0.93) increased risk for rhinitis for students who live close to outdoor pollution sources.Note: Adjusted factors: gender, family rhinitis history, smoker, negative events.

*B2. Binary logistic regression analysis for stuffy nose*

| Factor | Cluster 1<br>P | Cluster 2<br>P | Cluster 3<br>P | Total<br>P |
|---|---|---|---|---|
| **Personal** | | | | |
| Gender: male vs. female | 0.212 | 0.813 | 0.256 | 0.397 |
| **Life style** | | | | |
| Time spent at home (weekday) 1–12 h vs. 13–24 h | 0.745 | 0.513 | **0.090** | 0.772 |
| Time spent at home (weekend) 1–12 h vs. 13–24 h | 0.325 | 0.688 | 0.727 | 0.406 |
| Work out no vs. yes | **0.144** | **0.013** | 0.740 | 0.416 |
| Smoking no vs. yes | **0.016** | 0.323 | 0.248 | **0.100** |
| Alcohol no vs. yes | 0.291 | **0.006** | **0.102** | 0.225 |
| **Psychophysical aspects** | | | | |
| Negative events yes vs.no | 0.300 | **0.053** | 0.330 | 0.622 |
| **Building** | | | | |
| Building type<br>Attached vs. detached | **0.009** | **0.189** | **0.146** | **<0.001** |
| Construction date<br>Before 1990 vs. after 1990 | 0.205 | 0.413 | **0.181** | 0.501 |
| Building location<br>Urban vs. rural & suburban | 0.546 | 0.747 | 0.230 | 0.303 |
| Outdoor pollution sources yes vs. no | **0.102** | 0.383 | 0.870 | **0.028** |
| **Cleaning activities** | | | | |
| Vacuuming; At least 1x/week vs less than 1x/week | **0.113** | **0.070** | 0.707 | **0.023** |
| Sweeping: At least 1x/week vs less than 1x/week | 0.577 | 0.501 | 0.385 | 0.744 |
| Dusting: At least 1x/week vs less than 1x/week | 0.484 | **0.541** | 0.998 | 0.257 |
| **Consumer products** | | | | |
| Spray deodorant: At least 1x/week vs less than 1x/week | 0.531 | **0.162** | **0.030** | **0.010** |
| Nail polish: At least 1x/week vs less than 1x/week | 0.609 | 0.520 | 0.799 | 0.899 |
| Hairspray: At least 1x/week vs less than 1x/week | **0.127** | 0.257 | **0.100** | **0.019** |
| Incense: At least 1x/week vs less than 1x/week | 0.692 | 0.817 | 0.286 | **0.170** |
| **Occupants and activities** | | | | |
| **Pets** | | | | |
| Pets Yes vs no | 0.554 | 0.327 | 0.558 | **0.067** |
| **Pests** | | | | |
| Presence of pests No vs yes | 0.851 | 0.554 | 0.512 | 0.865 |
| **DIY activities** | | | | |
| Spray paint Yes vs no | 0.406 | 0.872 | 0.305 | 0.936 |
| Heating oven Yes vs no | 0.716 | **0.135** | 0.984 | 0.457 |
| Model glue Yes vs no | 0.999 | 0.419 | 0.847 | 0.756 |
| Woodworking Yes vs no | 0.745 | 0.233 | 0.718 | 0.653 |
| Soldering Yes vs no | **0.192** | 0.386 | **0.194** | 0.754 |
| Paint Yes vs no | 0.561 | 0.655 | 0.795 | 0.544 |
| **SHS exposure** | | | | |
| Yes vs no | 0.509 | 0.267 | 0.565 | **0.028** |
| **Recent painting or remodelling** Yes vs no | 0.388 | 0.325 | 0.278 | **0.191** |
| **Window opening** | | | | |
| Kitchen: At least 1x/week vs less than 1x/week | 0.680 | 0.658 | 0.988 | 0.519 |
| Living room: At least 1x/week vs less than 1x/week | 0.829 | **0.124** | 0.406 | **0.059** |
| Bedroom: At least 1x/week vs less than 1x/week | 0.205 | **0.174** | 0.479 | 0.381 |
| **Air conditioning** | | | | |
| Yes vs no | 0.212 | 0.470 | 0.327 | 0.264 |
| **Surface coverings** | | | | |
| Floors; Carpet vs others | 0.865 | 0.464 | 0.819 | 0.516 |
| Walls: Water-based paint vs others | **0.015** | **0.099** | 0.674 | **0.026** |
| Ceilings: Paint vs others | 0.218 | 0.840 | 0.816 | 0.774 |
| **MDF less than 1 year** | | | | |
| Kitchen: Yes vs no | 0.632 | 0.343 | **0.017** | **0.038** |
| Bedroom: Yes vs no | 0.884 | 0.251 | 0.899 | 0.296 |
| Bathroom: Yes vs no | 0.611 | **0.174** | 0.204 | **0.049** |
| Living room: Yes vs no | 0.230 | 0.572 | 0.250 | **0.063** |
| **Natural plants**<br>Yes vs no | **0.002** | 0.418 | **0.063** | **0.177** |
| **Open bookshelves**<br>Yes vs no | 0.476 | 0.867 | 0.978 | 0.566 |
| **Humidity problems**<br>No vs Yes | 0.656 | 0.361 | 0.206 | 0.561 |
| **Condensation inside windows** Yes vs no | 0.914 | 0.233 | 0.368 | 0.797 |

Adjusted factors: none.

*B3. Binary logistic regression analysis for migraine*

| Factor | Cluster 1<br>P | Cluster 2<br>P | Cluster 3<br>P | Total<br>P |
|---|---|---|---|---|
| **Personal** | | | | |
| Gender: male vs. female | / | / | / | / |

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| | | | | |
|---|---|---|---|---|
| **Life style** | | | | |
| Time spent at home (weekday) 1–12 h vs. 13–24 h | 0.799 | 0.493 | 0.814 | 0.535 |
| Time spent at home (weekend) 1–12 h vs. 13–24 h | **0.121** | 0.782 | 0.742 | 0.429 |
| Work out: no vs. yes | 0.439 | 0.684 | 0.445 | **0.170** |
| Smoking: no vs. yes | 0.957 | 0.446 | 0.972 | 0.832 |
| Alcohol: no vs. yes | 0.379 | **0.198** | 0.318 | 0.990 |
| **Psychophysical aspects** | | | | |
| Negative events: yes vs.no | / | / | / | / |
| **Building** | | | | |
| Building type<br>Attached vs. detached | 0.482 | 0.705 | 0.631 | 0.296 |
| Construction date<br>Before 1990 vs. after 1990 | 0.330 | 0.718 | 0.223 | 0.710 |
| Building location<br>Urban vs. rural & suburban | **0.137** | **0.066** | 0.737 | 0.548 |
| Outdoor pollution sources yes vs. no | **0.104** | 0.989 | 0.329 | **0.093** |
| **Cleaning activities** | | | | |
| Vacuuming: At least 1x/week vs less than 1x/week | 0.322 | **0.079** | 0.769 | **0.167** |
| Sweeping: At least 1x/week vs less than 1x/week | 0.725 | 0.456 | 0.789 | 0.974 |
| Dusting: At least 1x/week vs less than 1x/week | 0.507 | **0.154** | 0.995 | 0.768 |
| **Consumer products** | | | | |
| Spray deodorant: At least 1x/week vs less than 1x/week | 0.715 | 0.463 | 0.429 | 0.216 |
| Nail polish: At least 1x/week vs less than 1x/week | 0.763 | 0.188 | 0.670 | 0.612 |
| Hairspray: At least 1x/week vs less than 1x/week | 0.607 | **<0.001** | 0.790 | **0.033** |
| Incense: At least 1x/week vs less than 1x/week | 0.998 | **0.066** | 0.810 | 0.311 |
| **Occupants and activities** | | | | |
| **Pets** | | | | |
| Pets: Yes vs no | 0.375 | 0.238 | **0.128** | 0.694 |
| **Pests** | | | | |
| Presence of pests: No vs yes | 0.216 | **0.081** | 0.933 | 0.661 |
| **DIY activities** | | | | |
| Welding: Yes vs no | **0.026** | 0.999 | 0.604 | **0.162** |
| Spray paint: Yes vs no | **0.004** | **0.129** | 0.437 | **0.006** |
| Heating oven: Yes vs no | **0.113** | 0.853 | 0.278 | 0.138 |
| Model glue: Yes vs no | **0.074** | 0.797 | **0.192** | **0.029** |
| Woodworking: Yes vs no | **0.025** | 0.590 | 0.431 | **0.064** |
| Soldering: Yes vs no | **0.049** | 0.832 | 0.822 | 0.338 |
| Paint: Yes vs no | **0.021** | 0.778 | **0.005** | **0.004** |
| **SHS exposure**<br>Yes vs no | **0.010** | **0.180** | 0.918 | 0.720 |
| **Recent painting or remodelling:** Yes vs no | **0.062** | 0.364 | **0.157** | **0.134** |
| **Window opening** | | | | |
| Kitchen: At least 1x/week vs less than 1x/week | 0.568 | 0.798 | 0.731 | 0.469 |
| Living room: At least 1x/week vs less than 1x/week | 0.877 | 0.920 | 0.217 | 0.487 |
| Bedroom: At least 1x/week vs less than 1x/week | 0.325 | 0.214 | **0.167** | 0.850 |
| **Air conditioning**<br>Yes vs no | 0.394 | **0.018** | **0.065** | **0.073** |
| **Surface coverings** | | | | |
| Floors: Carpet vs others | 0.681 | 0.986 | 0.368 | 0.618 |
| Walls: Water-based paint vs others | **0.063** | 0.540 | **0.136** | 0.211 |
| Ceilings: Paint vs others | 0.445 | 0.492 | 0.671 | 0.550 |
| **MDF less than 1 year** | | | | |
| Kitchen: Yes vs no | 0.385 | 0.638 | 0.908 | 0.937 |
| Bedroom: Yes vs no | 0.547 | 0.632 | **0.175** | **0.090** |
| Bathroom: Yes vs no | 0.998 | 0.528 | **0.033** | **0.099** |
| Living room: Yes vs no | 0.312 | 0.601 | 0.793 | 0.234 |
| **Natural plants**<br>Yes vs no | **0.047** | 0.901 | 0.503 | 0.429 |
| **Open bookshelves**<br>Yes vs no | 0.785 | 0.314 | 0.651 | 0.662 |
| **Humidity problems** yes vs. no | 0.233 | 0.753 | **0.143** | 0.235 |
| **Condensation problems** | | | | |
| Condensation inside windows<br>Yes vs no | 0.343 | **0.124** | 0.355 | 0.476 |

Adjusted factors are gender and negative event.

### *B4. Binary logistic regression analysis for headaches*

| Factor | Cluster 1<br>P | Cluster 2<br>P | Cluster 3<br>P | Total<br>P |
|---|---|---|---|---|
| **Personal** | | | | |
| Gender: male vs. female | / | / | / | / |
| **Life style** | | | | |
| Time spent at home (weekday) 1–12 h vs. 13–24 h | 0.815 | 0.502 | **0.184** | **0.191** |
| Time spent at home (weekend) 1–12 h vs. 13–24 h | 0.729 | **0.172** | 0.797 | 0.543 |
| Work out: no vs. yes | 0.773 | **0.182** | 0.910 | 0.364 |

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| | | | | |
|---|---|---|---|---|
| Smoking: no vs. yes | **0.093** | **0.175** | 0.758 | 0.911 |
| Alcohol: no vs. yes | 0.964 | **0.015** | 0.214 | **0.034** |
| **Psychophysical aspects** | | | | |
| Negative events: yes vs.no | **0.179** | 0.703 | 0.441 | 0.433 |
| **Building** | | | | |
| Building type: Attached vs. detached | 0.472 | 0.408 | 0.328 | **0.140** |
| Construction date Before 1990 vs. after 1990 | 0.507 | 0.423 | 0.474 | 0.512 |
| Building location Urban vs. rural & suburban | 0.425 | 0.095 | 0.366 | **0.080** |
| Outdoor pollution sources yes vs. no | 0.798 | 0.554 | 0.605 | 0.503 |
| **Cleaning activities** | | | | |
| Vacuuming: At least 1x/week vs less than 1x/week | 0.479 | 0.789 | 0.668 | 0.562 |
| Sweeping: At least 1x/week vs less than 1x/week | **0.193** | **0.051** | 0.914 | **0.028** |
| Dusting: At least 1x/week vs less than once a week | 0.884 | **0.053** | 0.878 | **0.064** |
| **Consumer products** | | | | |
| Spray deodorant: At least 1x/week vs less than 1x/week | 0.436 | **0.133** | 0.430 | 0.324 |
| Nail polish: At least 1x/week vs less than 1x/week | 0.776 | 0.690 | 0.934 | 0.818 |
| Hairspray: At least 1x/week vs less than 1x/week | 0.226 | **0.134** | 0.353 | 0.263 |
| Incense: At least 1x/week vs less than 1x/week | 0.415 | **0.162** | **0.197** | **0.074** |
| **Occupants and activities** | | | | |
| **Pets** | | | | |
| Pets: Yes vs no | **0.005** | 0.314 | 0.253 | **0.002** |
| **Pests** | | | | |
| Presence of pests: No vs yes | 0.727 | **0.157** | 0.647 | 0.337 |
| **DIY activities** | | | | |
| Spray paint: Yes vs no | 0.515 | 0.738 | 0.823 | 0.965 |
| Heating oven: Yes vs no | **0.077** | 0.576 | 0.491 | 0.295 |
| Model glue: Yes vs no | 0.066 | 0.903 | 0.410 | 0.734 |
| Woodworking: Yes vs no | 0.886 | 0.491 | 0.528 | 0.983 |
| Soldering: Yes vs no | 0.669 | 0.244 | 0.511 | 0.986 |
| Paint: Yes vs no | 0.454 | 0.860 | 0.738 | 0.766 |
| **SHS exposure** Yes vs no | 0.824 | 0.462 | 0.916 | 0.507 |
| **Recent painting or remodelling:** Yes vs no | 0.791 | 0.702 | **0.049** | 0.661 |
| **Window opening** | | | | |
| Kitchen: At least 1x/week vs less than 1x/week | 0.215 | 0.695 | 0.830 | 0.653 |
| Living room: At least 1x/week vs less than 1x/week | 0.356 | **0.177** | 0.883 | 0.601 |
| Bedroom: At least 1x/week vs less than 1x/week | 0.806 | **0.071** | 0.862 | **0.157** |
| **Air conditioning** Yes vs no | 0.553 | **0.095** | 0.474 | 0.311 |
| **Surface coverings** | | | | |
| Floors: Carpet vs others | 0.394 | 0.578 | 0.480 | 0.525 |
| Walls: Water-based paint vs others | 0.983 | 0.253 | 0.649 | 0.422 |
| Ceilings: Paint vs others | 0.870 | 0.359 | 0.773 | 0.788 |
| **MDF less than 1 year** | | | | |
| Kitchen: Yes vs no | 0.716 | 0.627 | 0.416 | 0.840 |
| Bedroom: Yes vs no | 0.324 | 0.874 | 0.815 | 0.713 |
| Bathroom: Yes vs no | 0.500 | 0.437 | **0.046** | 0.288 |
| Living room: Yes vs no | **0.198** | 0.525 | 0.407 | 0.475 |
| **Natural plants** Yes vs no | 0.485 | 0.668 | 0.434 | 0.587 |
| **Open bookshelves** Yes vs no | 0.435 | 0.582 | 0.795 | 0.273 |
| **Humidity problems** No vs Yes | 0.359 | 0.526 | 0.439 | 0.697 |
| **Condensation problems** | | | | |
| Condensation inside windows Yes vs no | 0.360 | 0.244 | 0.513 | **0.116** |

Note: adjusted factor is gender.

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