Indoor Air 2015; 25: 499–511
wileyonlinelibrary.com/journal/ina

INDOOR AIR
doi:10.1111/ina.12158

Prevalence and risk factors associated with nonspecific building-related symptoms in office employees in Japan: relationships between work environment, Indoor Air Quality, and occupational stress

Abstract A nationwide cross-sectional study of 3335 employees was conducted in 320 offices in Japan to estimate the prevalence of building-related symptoms (BRSs) and determine the risk factors related to work environment, Indoor Air Quality, and occupational stress. Data were collected through self-administered questionnaires. The prevalences of general symptoms, eye irritation, and upper respiratory symptoms were 14.4%, 12.1%, and 8.9%, respectively. Multiple logistic regression analyses revealed that eye irritation was significantly associated with carpeting [odds ratio (OR), 1.73; 95% confidence interval (CI), 1.24–2.41], coldness perception (OR, 1.28; 95% CI, 1.13–1.45), and air dryness perception (OR, 1.61; 95% CI, 1.42–1.82). General symptoms were significantly associated with unpleasant odors (OR, 1.37; 95% CI, 1.13–1.65), amount of work (OR, 1.24; 95% CI, 1.06–1.45), and interpersonal conflicts (OR, 1.44; 95% CI, 1.23–1.69). Upper respiratory symptoms were significantly associated with crowded workspaces (OR, 1.36; 95% CI, 1.13–1.63), air dryness perception (OR, 2.07; 95% CI, 1.79–2.38), and reported dustiness on the floor (OR, 1.39; 95% CI, 1.16–1.67). Although psychosocial support is important to reduce and control BRSs, maintaining appropriate air-conditioning and a clean and uncrowded workspace is of equal importance.

K. Azuma[1], K. Ikeda[2], N. Kagi[3], U. Yanagi[4], H. Osawa[5]

[1]Department of Environmental Medicine and Behavioral Science, Kinki University Faculty of Medicine, Osakasayama, Osaka, Japan, [2]Department of Architecture, College of Science and Technology, Nihon University, Chiyoda-ku, Tokyo, Japan, [3]Department of Mechanical and Environmental Informatics, Graduate School of Information Science and Engineering, Tokyo Institute of Technology, Meguro-ku, Tokyo, Japan, [4]Department of Architecture, School of Architecture, Kogakuin University, Shinjuku-ku, Tokyo, Japan, [5]National Institute of Public Health, Wako, Saitama, Japan

Key words: Epidemiology; Building-related symptoms; Indoor Air Quality; Sick Building Syndrome; Work environment; Occupational stress.

Kenichi Azuma
Department of Environmental Medicine and Behavioral Science
Kinki University Faculty of Medicine
377-2 Ohnohigashi
Osakasayama
Osaka 589-8511
Japan
Tel.: +81-72-366-0221
Fax: +81-72-368-1192
e-mail: kenazuma@med.kindai.ac.jp

Received for review 18 May 2014. Accepted for publication 11 September 2014.

Practical Implications

Building-related symptoms (BRSs) were common in this nationwide sample, accounting for 25% of respondents. The associations between BRSs and poor physical environmental conditions remained even after controlling job stressors. These findings support current argument for psychosocial support to reduce and control BRSs. However, these findings also indicate that improvements are needed to the physical environmental conditions in many office buildings, and maintaining appropriate air-conditioning and a clean and uncrowded workspace is of equal importance.

Introduction

Since the early 1970s, nonspecific building-related symptoms (BRSs), commonly called Sick Building Syndrome, have emerged as an occupational and environmental health issue (Redlich et al., 1997). BRSs comprise respiratory (stuffy and irritated nose, rhinitis, cough, sore throat, and shortness of breath), ocular, skin, and general (fatigue, headache, and fever) symptoms that are temporally related to working in particular buildings (Burge, 2004; Finnegan et al., 1984). Various factors are reportedly associated with BRSs. These include personality traits (Runeson et al., 2004), work stress (Chao et al., 2003; Hansen et al., 2008; Marmot et al., 2006; Runeson and Norbäck, 2013; Runeson et al., 2006), female sex (Norbäck et al., 1990; Runeson et al., 2006), thermal comfort (Norbäck and Nordström, 2008), dust (Marmot et al., 2006; Niven et al., 2000; Norbäck et al., 1990), volatile organic compounds (Apter et al., 1994; Norbäck et al., 1990), molds (Ruotsalainen et al., 1995; Teeuw et al., 1994), poorly maintained ventilation systems, and poor humidification systems (Fisk et al., 2009; Mendell et al., 2008).

In Japan, the Law for Maintenance of Sanitation in Buildings was enacted in 1970. The Building Sanitation Management Standards were also established by the Ministry of Health and Welfare, which dictated the control of Indoor Air Quality, water supply and sewage management, cleaning, and rodent and insect control (Building Management Education Center, 2007). This law applies to specific buildings in Japan used as offices, stores, hotels, entertainment facilities, assembly halls, libraries, and museums, whose total floor areas exceed 3000 m^2, and for schools, whose total floor areas exceed 8000 m^2. The standards for Indoor Air Quality provide permissible indoor air concentrations of carbon dioxide, carbon monoxide, suspended particles, formaldehyde, and regulate temperature, relative humidity, and airflow requirements (Azuma et al., 2011, 2012). This law may have prevented serious BRS epidemics in Japan (MHLW, 2002; Nakazawa et al., 2005). However, the scientific evidence has not been indicated. Furthermore, the ratio of buildings that do not conform to the standards of relative humidity, room temperature, and carbon dioxide has increased in the last decade in Japan (Azuma et al., 2011, 2012). Additionally, failing to conform to outcomes in temperature, relative humidity, and carbon dioxide has been significantly associated with the installation of individual air-conditioning systems in buildings compared with central air-conditioning systems (Azuma et al., 2011).

It has also been hypothesized that psychosocial factors in the work environment have a significant role in explaining BRSs (Marmot et al., 2006). However, BRSs are also associated with the conditions of the physical environment, including Indoor Air Quality. For example, the development of eye irritation is associated with visual display unit work (i.e., computer-related job), particularly in workplaces with low humidity (Wolkoff, 2008, 2010), and there are increased incidences of BRSs in buildings with dampness and mold (Fisk et al., 2007; WHO, 2009; Zhang et al., 2012). Recently, the development of upper airway inflammation and oxidative stress has been associated with exposure to particles emitted from photocopiers or laser printers used in the workplace (Bai et al., 2010; Khatri et al., 2013; Könczöl et al., 2013). There is a clear need for a nationwide survey on the possible risk factors associated with BRSs in employees working in office buildings as well as identifying the factors that are significantly associated with BRSs.

Therefore, this study aimed to estimate the prevalence of BRSs among office workers in Japan. The primary objective of this study was to examine the possible risk factors associated with the work environment, Indoor Air Quality, and occupational stress.

Methods

Study design and population

We conducted a nationwide cross-sectional study to examine the association between the possible risk factors in office workplaces for BRSs, based on reports by office employees in Japan. The Japan Building Maintenance Association has 2882 member companies nationwide that belong to the 47 local prefectural associations. The Japan Building Maintenance Association recommended 489 companies and 4–50 offices (average, 10.4) per prefectural association based on the number of member companies in a given association. This ensured an even representation across all prefectures. Each company office was selected from a different building.

To examine the associations between the health status of employees and their work and office environments, we focused on the office space in each building. Two questionnaires were prepared, one for the office managers and the other for the employees working in the office. The employees who worked in their offices for relatively long periods per day during the daytime, such as managers, planning and administrative staff, communication engineers, and designers, were selected as participants within the office; however, those who were engaged in cleaning the building or measuring Indoor Air Quality were excluded. The scales of the member company offices in a building were small overall, and these criteria limited the selection of participant employees. We therefore relied on the office managers to select all employees when 10 or less employees in their office met our selection criteria.

Otherwise, managers arbitrarily selected 15 employees at a maximum that met the criteria. Each office manager received a questionnaire to complete and distributed an additional 15 questionnaires to be completed by their employees. The surveys were conducted from January 2012 to March 2012.

Questionnaires

The office managers were asked to provide basic information about their offices and the buildings in which they were sited, including total floor area of the building and its age, using our previously described questionnaire (Azuma et al., 2011). The employees were asked about their gender, age, job category, smoking status, contact lens use, specific symptoms, the frequency of symptoms, the association of symptoms with the building, and their perception of the work environment, Indoor Air Quality, and occupational stress. The employee questionnaire comprised the United States Environmental Protection Agency (USEPA) Questionnaire for indoor environmental quality survey (USEPA, 2003), the Indoor Air Questionnaire (MM-40) (Andersson, 1998), and the Brief Job Stress Questionnaire (Ozaki et al., 2012; Shimomitsu et al., 2000; Wada et al., 2013). We added items regarding installed office equipment, such as printers, copiers, exterior windows, and doors, as well as items regarding the use of fragrances, air fresheners, and insect repellents. In addition, mold odor in workplace and pet ownership at home were included.

In the work environment questionnaire, we asked participants the following: the number of people working in the room in which workstation of respondent is located, the condition of their workstation (carpeting, lighting, experience of reflection or glare in the field of vision, table comfort, and chair comfort), computer use, frequency odorous chemical use, any change within 5 m of their workstation within the last 3 months (new carpeting, painted walls, furniture, partitions, wall covering, or water damage), the equipment within 2 m of the workstation (laser printer, bubble jet printer, copier, exterior window, and door), and indoor workplace installations (fragrance, air freshener, and repellent). In the questionnaire about specific symptoms, we presented a page-long table of symptoms. For each symptom, respondents chose how often the symptom had occurred while working in the building in the last 4 weeks (frequency) and whether the symptom had improved after they left work (work relatedness). In the questionnaire about the perception of Indoor Air Quality, questions were also presented in a page-long table. For each question, respondents chose how often the condition had been experienced while working in the building during the last 4 weeks.

The job stressor scale comprised 17 general items related to job stress that were rated on a 4-point Likert scale ranging from yes (1) to no (4). Responses related to amount of work, mental workload, physical overload, interpersonal conflict, environmental stress, job control, skill utilization, job suitability, and work satisfaction were converted to job stressors using a score translation table (Shimomitsu et al., 2000). Environmental stress was not included in the following analyses because it is related to other environmental variables such as work environment and perception of Indoor Air Quality.

BRS groups

Analyses used BRS outcomes, defined as specific symptoms experienced in the building at least 1 day per week in the last 4 weeks that improved when away from the building (Chao et al., 2003; Mendell et al., 2008). The symptom groups were determined according to the categories commonly used in previous investigations (Chao et al., 2003; Mendell et al., 2008; Redlich et al., 1997). Therefore, the outcomes of interest were eye irritation, general symptoms, upper respiratory symptoms, lower respiratory symptoms, and skin symptoms.

The eye irritation group included dry or irritated eyes and tired eyes. The general symptom group included headache, unusual tiredness, tension, difficulty concentrating or remembering things, dizziness, feeling depressed, and nausea. The upper respiratory symptom group included sore or dry throat, sinus congestion, cough, and sneezing. The lower respiratory symptom group included wheezing, chest tightness, and shortness of breath. The skin symptom group included dryness, itching, and irritation of the skin. A symptom group was considered present if a participant reported at least one BRS in that group.

Statistical analyses

We examined correlations among the variables (personal factors, work environment, Indoor Air Quality, and job stressors) for multicollinearity by creating a correlation matrix and scanning for highly correlated variables ($\geq$0.7). To prevent multicollinearity, highly correlated variables are not included in the multiple logistic regression model (Dormann et al., 2013; Nafiu and Onyewuche, 2014). Univariate associations between BRSs and the potential risk factors were examined, and factors with $P < 0.2$ were selected for multiple logistic regression analysis.

First, personal factors and job stressors were tested using multiple logistic regression analyses to determine the potential risk factors associated with BRSs (Model 1). Second, we analyzed the associations between BRSs and the work environment, adjusting for personal and job stressors (Model 2). Third, we analyzed the associa-

tions between BRSs and the workplace conditions in the last 4 weeks, adjusting for personal factors and job stressors (Model 3). Finally, the selected potential risk factors were included in a stepwise logistic regression analysis (forward selection with Wald statistics) to identify the independent risk factors for BRSs (Model 4). The *P*-values for entry and removal of variables in the stepwise logistic regression model were 0.05 and 0.1, respectively. Goodness of fit was measured with the chi-square test and Hosmer and Lemeshow tests (Hosmer et al., 1997). We used $P < 0.05$ to indicate statistical significance. Odds ratios (ORs) and 95% confidence intervals (CIs) were determined for the univariate and multivariate associations. All data analyses were performed using IBM SPSS version 22 for Windows (IBM Corp, Armonk, NY, USA).

Ethics

The Ethics Committee for Human Research at the National Institute of Public Health (Wako, Japan) (NIPH-IBRA #12003) approved this study. Furthermore, the study was completed in accordance with the Declaration of Helsinki.

Results

Participants

Of the original 489 offices, 320 offices provided employee responses (response rate, 65.4%) and 315 provided responses from office managers (response rate, 64.4%). Five offices provided responses from their employees but not from the managers. Questionnaire responses were obtained from 3335 employees, with an average of 10.4 (s.d. = 3.7) participant employees per office.

Participant characteristics are shown in Table 1. The mean age was 44.9 years (range, 19–80 years), 35.6% were women, and most participants had planning or administrative jobs. The mean duration of employment was long, averaging 7.8 years (s.d., 7.2 years). The proportions of building by age were 9.6%, 21.8%, 17.7%, 33.9%, and 17.0%, for 1950–1969, 1970–1979, 1980–1989, 1990–1999, and ≥2000, respectively. Approximately 51% of the participant buildings were built after 1990. The proportions of building by total floor area were 43.1%, 20.8%, 8.6%, 10.9%, 12.1%, and 4.5% for <1000 m^2, 1000 to <3000 m^2, 3000 to <5000 m^2, 5000 to <10,000 m^2, 10,000 to <50,000 m^2, and ≥50,000 m^2, respectively. The total floor area of approximately 40% of the participant buildings was <1000 m^2.

Table 1 Participant characteristics ($N = 3335$)

Characteristic	Mean ± s.d. or *n*/*N* (%)[a]
Gender	
Male	2130/3306 (64.4)
Female	1176/3306 (35.6)
Age group	
10–19	4/3295 (0.1)
20–29	351/3295 (10.7)
30–39	883/3295 (26.8)
40–49	830/3295 (25.2)
50–59	745/3295 (22.6)
≥60	482/3295 (14.6)
Job categories	
Managerial	797/3266 (24.4)
Professional	158/3266 (4.8)
Technical	443/3266 (13.6)
Sales	397/3266 (12.2)
Planning/administrative	1267/3266 (38.8)
Secretarial/clerical	7/3266 (0.2)
Other	197/3266 (6.0)
Smoking status	
Never	1374/3306 (41.6)
Former	844/3306 (25.5)
Current/sometime	113/3306 (3.4)
Current/everyday	975/3306 (29.5)
Mean year working in the building ($n = 3290$)	7.8 ± 7.2

[a]Data for some characteristics were missing for some participants.

Prevalence of BRSs

The prevalence of 19 health symptoms related to the work environments is shown in Table 2. The left column (weekly) shows the prevalence of BRSs, defined as a participant experienced the symptom at least 1 day per week in last 4 weeks and felt better when away from work. Thus, the associations between health

Table 2 Prevalence of health symptoms related to work environments ($N = 3335$)

Symptoms	Weekly[a] *n*/*N* (%)[b]	Monthly[c] *n*/*N* (%)[b]
Tension, irritability, or nervousness	278/3171 (8.8)	227/3171 (7.2)
Tired or strained eyes	250/3128 (8.0)	130/3128 (4.2)
Dry, itching, or irritated eyes	232/3247 (7.1)	97/3247 (3.0)
Sore or dry throat	182/3201 (5.7)	106/3201 (3.3)
Feeling depressed	163/3184 (5.1)	144/3184 (4.5)
Unusual tiredness, fatigue, or drowsiness	152/3230 (4.7)	127/3230 (3.9)
Dry or flushed facial skin	103/3234 (3.2)	54/3234 (1.7)
Headache	76/3228 (2.4)	124/3228 (3.8)
Sneezing	57/3126 (1.8)	82/3126 (2.6)
Stuffy or runny nose, or sinus congestion	54/3157 (1.7)	60/3157 (1.9)
Cough	49/3155 (1.6)	67/3155 (2.1)
Difficulty remembering things or concentration	46/3174 (1.4)	93/3174 (2.9)
Hands dry, Itching, red skin	46/3212 (1.4)	32/3212 (1.0)
Scaling/itching scalp or ears	33/3257 (1.0)	21/3257 (0.6)
Nausea or upset stomach	28/3253 (0.9)	54/3253 (1.7)
Dizziness or lightheadedness	24/3248 (0.7)	50/3248 (1.5)
Chest tightness	17/3294 (0.5)	35/3294 (1.1)
Shortness of breath	9/3274 (0.3)	21/3274 (0.6)
Wheezing	7/3301 (0.2)	14/3301 (0.4)
Total[d]	724/2904 (24.9)	1049/2961 (35.4)

[a]A participant experienced the symptom at least one day per week in last 4 weeks and felt better when away from work.

[b]Data for some characteristics were missing for some participants.

[c]A participant experienced the symptom at least one day in last 4 weeks and felt better when away from work.

[d]At least 1 of 19 symptoms reported by participants.

symptoms and work environment are strong. The right column (monthly) shows the prevalence that a participant experienced the symptom at least 1 day in last 4 weeks and felt better when away from work. Thus, the associations between health symptoms and work environment are weak.

In the BRS groups, the prevalences of eye irritation, general symptoms, upper respiratory symptoms, lower respiratory symptoms, and skin symptoms (weekly) strongly related to the work environment were 12.1%, 14.4%, 8.9%, 0.8%, and 4.5%, respectively. The prevalence of those symptom (weekly), irrespective of whether the symptoms improved when away from work, were 25.6%, 23.6%, 24.5%, 2.8%, and 16.0%, respectively. Thus, general symptoms were the most work-related (proportion, 61.0%), while skin symptoms were the least work-related (proportion, 28.1%). In the BRSs, the prevalence of lower respiratory symptoms was very low, so this symptom group was excluded from subsequent modeling.

Risk factors associated with BRSs

We examined the correlations among 53 variables (seven personal factors, 22 work environment factors, 16 Indoor Air Quality factors, and eight job stressors). No highly correlated variables (correlation ≥ 0.7) existed. The correlation between job suitability and work satisfaction was 0.619. All other correlations were <0.6. Accordingly, no variable was excluded from the multiple logistic regression models. The univariate associations between BRSs and all personal and other variables are listed in Table 3. The numbers of cases by variable factors for weekly building-related symptoms listed in Table 3 are presented in Table S1. The subsequent results of multiple logistic regression analysis models for the association with BRSs are shown in Tables 4–7.

In most models, all BRSs were significantly increased in females than in males (Tables 4–7). Younger age significantly increased the possibility of reported general symptoms and upper respiratory symptoms. A significant association was found between current smoking and increased upper respiratory symptoms, and skin symptoms. Contact lens use was significantly related to eye irritation, upper respiratory symptoms, and skin symptoms.

In the associations between job stressors and BRSs, many stressors were significantly associated with general symptoms such as excessive work, high mental workload, strong interpersonal conflict, low job suitability, and low work satisfaction. Strong interpersonal conflict was significantly associated with upper respiratory symptoms, low work satisfaction was significantly associated with skin symptoms, and adequate skill utilization and high physical overload significantly decreased the reporting of eye irritation. High physical overload described any job activity with more physical activity and less deskwork. High mental workload and strong interpersonal conflict were significantly associated with eye irritation and general symptoms in Model 1 (Table 4), and less physical overload was significantly associated with general symptoms. However, the associations did not persist after adjusting for other variables (Table 7). Therefore, the associations with those job stressors may not be strong.

In the associations between the work environment and BRSs, a crowded workplace was significantly associated with both general and upper respiratory symptoms. Eye irritation was significantly associated with carpeting, poor lighting, uncomfortable seating, and use of odorous chemicals. In the univariate analyses, recent (in the last 3 months) changes in the workplace within 5 m of a workstation were not significant. Some office equipments were significantly associated with eye irritation and upper respiratory symptoms (Table 3). However, after adjusting for other variables in multivariate models, the associations became insignificant except for the association between the bubble jet printer and upper respiratory symptoms (Tables 5 and 7). Reflection or glare in vision and the use of uncomfortable tables were significantly associated with eye irritation and general symptoms in Model 2 (Table 5). Uncomfortable seating and the use of odorous chemicals were also significantly associated with general symptoms, upper respiratory symptoms, and skin symptoms. In addition, poor lighting was also significantly associated with upper respiratory symptoms. However, none of these associations persisted after adjusting for other variables (Table 7). Therefore, the associations with those work environments may not be strong.

Concerning the association between the workplace conditions in the last 4 weeks and BRSs, multivariate analyses revealed that all symptoms were significantly associated with the air-conditioning factors (Tables 6 and 7). These included too little air movement, varying room temperatures, and the air being too cold, too dry, or excessive airflow from air conditioner. Particularly, dryness was significantly associated with eye irritation, general symptoms, upper respiratory symptoms, and skin symptoms. Varying room temperature was significantly associated with general symptoms and skin symptoms. Although mold and tobacco smoke odors had univariate correlations with BRSs (Table 3), the relationships did not persist after adjusting for other variables (Table 7).

The indoor pollutant factors—dust and dirt—were significantly associated with eye irritation, general symptoms, upper respiratory symptoms, and skin symptoms. Unpleasant odors (e.g., body odor, food odor, or perfume) were significantly associated with general symptoms and upper respiratory symptoms. Additionally, noise was significantly associated with general symptoms and skin symptoms.

Table 3 Univariate analysis for the association with weekly building-related symptoms

Variable factors	Eye irritation OR (95% CI)	General symptoms OR (95% CI)	Upper respiratory OR (95% CI)	Skin symptoms OR (95% CI)
Personal				
Gender (female)	3.40 (2.72–4.24)**	3.07 (2.49–3.77)**	4.85 (3.68–6.38)**	9.47 (6.15–14.58)**
Age				
10–19	–	–	–	–
20–29	4.41 (2.65–7.33)**	5.04 (3.24–7.84)**	8.99 (4.52–17.90)**	4.94 (2.22–11.02)**
30–39	3.47 (2.17–5.55)**	2.81 (1.86–4.25)**	4.58 (2.34–8.93)**	3.63 (1.71–7.72)**
40–49	2.85 (1.77–4.58)**	2.37 (1.56–3.61)**	3.52 (1.78–6.96)**	2.66 (1.22–5.77)*
50–59	2.01 (1.26–3.42)**	1.42 (0.91–2.24)	4.03 (2.03–7.98)**	1.93 (0.85–4.34)
≥60	Ref.	Ref.	Ref.	Ref.
P for trend	< 0.001	< 0.001	< 0.001	< 0.001
Job categories				
Managerial	Ref.	Ref.	Ref.	Ref.
Professional	0.56 (0.24–1.25)	0.76 (0.41–1.41)	0.97 (0.37–2.56)	0.95 (0.27–3.31)
Technical	0.82 (0.51–1.31)	0.76 (0.50–1.15)	1.63 (0.92–2.89)	1.26 (0.58–2.74)
Sales	0.94 (0.59–1.50)	0.89 (0.59–1.15)	1.19 (0.62–2.27)	1.01 (0.43–2.37)
Planning/administrative	3.04 (2.25–4.11)**	2.25 (1.72–2.95)**	5.11 (3.35–7.80)**	4.12 (2.41–7.05)**
Secretarial/clerical	4.70 (0.16–0.90)	–	17.90 (2.87–111.74)**	11.81 (1.25–111.69)*
Other	0.38 (0.16–0.90)*	1.01 (0.60–1.70)	1.11 (0.48–2.61)	1.83 (0.74–4.51)
Smoking				
Never	Ref.	Ref.	Ref.	Ref.
Former	0.55 (0.41–0.73)**	0.64 (0.49–0.83)**	0.45 (0.32–0.64)**	0.37 (0.23–0.61)**
Current/sometime	0.83 (0.46–1.49)	0.84 (0.47–1.47)	0.64 (0.31–1.35)	1.02 (0.46–2.27)
Current/everyday	0.63 (0.48–0.81)**	0.68 (0.53–0.86)**	0.60 (0.44–0.81)**	0.53 (0.35–0.80)**
Contact lens use	2.87 (2.28–3.62)**	1.81 (1.44–2.28)**	2.83 (2.17–3.70)**	3.19 (2.25–4.51)**
Pet ownership at home				
Dog	0.97 (0.72–1.30)	0.96 (0.73–1.27)	0.83 (0.58–1.20)	0.74 (0.45–1.22)
Cat	0.99 (0.67–1.48)	0.92 (0.63–1.35)	1.42 (0.93–2.15)	1.14 (0.63–2.04)
Work environment				
No. of people in office[a]	1.47 (1.30–1.66)**	1.37 (1.22–1.53)**	1.59 (1.38–1.83)**	1.39 (1.15–1.66)**
Work station				
Floor carpet (with)	1.78 (1.36–2.34)**	1.27 (1.00–1.60)*	1.38 (1.02–1.87)*	1.79 (1.16–2.76)**
Lighting[b]	0.67 (0.52–0.86)**	0.78 (0.61–0.99)*	0.58 (0.44–0.76)**	0.58 (0.41–0.84)**
Reflection or glare in vision[c]	1.47 (1.29–1.67)**	1.51 (1.34–1.70)**	1.43 (1.23–1.65)**	1.31 (1.08–1.60)**
Table comfort[d]	1.66 (1.40–1.96)**	2.01 (1.72–2.34)**	1.87 (1.55–2.26)**	1.88 (1.47–2.41)**
Chair comfort[d]	1.72 (1.46–2.02)**	1.95 (1.67–2.28)**	1.84 (1.53–2.21)**	1.80 (1.41–2.29)**
Work with computer	4.54 (2.40–8.61)**	2.19 (1.40–3.43)**	2.92 (1.53–5.56)**	1.19 (0.65–2.18)
Use of odorous chemicals[e]	1.15 (1.07–1.23)**	1.20 (1.13–1.28)**	1.27 (1.18–1.38)**	1.34 (1.21–1.48)**
Change in workplace[f]				
New carpeting	0.73 (0.37–1.47)	0.87 (0.47–1.61)	0.70 (0.31–1.63)	1.16 (0.46–2.90)
Painted wall	0.39 (0.14–1.06)	0.60 (0.27–1.31)	0.59 (0.22–1.64)	0.85 (0.26–2.73)
New furniture	1.08 (0.62–1.88)	0.91 (0.52–1.58)	1.10 (0.58–2.08)	1.62 (0.77–3.39)
New partitions	1.10 (0.52–2.32)	0.89 (0.42–1.88)	0.80 (0.29–2.22)	0.35 (0.05–2.56)
New wall covering	0.16 (0.02–1.13)	1.05 (0.47–2.37)	0.48 (0.12–2.00)	0.93 (0.22–3.88)
Water damage	0.67 (0.32–1.39)	1.39 (0.81–2.37)	1.15 (0.57–2.32)	0.93 (0.34–2.57)
Equipment/installation				
Laser printer[g]	1.29 (1.03–1.62)*	1.21 (0.97–1.50)	1.50 (1.16–1.95)**	1.01 (0.70–1.46)
Bubble jet printer[g]	1.16 (0.92–1.46)	0.95 (0.76–1.18)	1.37 (1.05–1.78)*	0.87 (0.60–1.26)
Copier[g]	1.11 (0.88–1.40)	1.10 (0.89–1.37)	1.17 (0.90–1.53)	1.28 (0.90–1.82)
Exterior window[g]	0.77 (0.62–0.96)*	0.95 (0.77–1.17)	0.88 (0.68–1.14)	0.76 (0.54–1.09)
Door[g]	0.78 (0.61–0.99)*	0.81 (0.65–1.01)	0.81 (0.61–1.07)	0.79 (0.54–1.15)
Fragrance[h]	0.80 (0.53–1.20)	0.88 (0.60–1.28)	1.01 (0.65–1.58)	0.79 (0.41–1.52)
Air freshener[h]	1.11 (0.81–1.52)	1.22 (0.91–1.63)	1.58 (1.13–2.21)**	1.52 (0.97–2.37)
Repellent[h]	0.97 (0.63–1.48)	0.95 (0.63–1.42)	0.72 (0.41–1.26)	1.39 (0.77–2.50)
Workplace conditions in last 4 weeks[i]				
Too much air movement	1.57 (1.23–2.00)**	1.80 (1.44–2.25)**	2.10 (1.67–2.63)**	1.08 (0.67–1.73)
Too little air movement	2.03 (1.84–2.23)**	2.18 (1.99–2.38)**	2.38 (2.14–2.64)**	2.41 (2.12–2.75)**
Too hot	1.59 (1.40–1.81)**	1.57 (1.39–1.77)**	1.83 (1.61–2.09)**	1.88 (1.60–2.22)**
Varying room temperature	1.80 (1.62–2.00)**	1.97 (1.78–2.18)**	1.90 (1.69–2.13)**	2.07 (1.80–2.39)**
Too cold	1.80 (1.63–1.98)**	1.85 (1.69–2.03)**	1.90 (1.70–2.11)**	1.87 (1.62–2.14)**
Air too humid	1.42 (1.01–2.00)*	1.73 (1.28–2.33)**	1.81 (1.29–2.54)**	1.23 (0.70–2.18)
Air too dry	2.29 (2.09–2.51)**	1.94 (1.78–2.10)**	2.72 (2.44–3.04)**	3.03 (2.59–3.53)**
Static electricity	1.88 (1.70–2.08)**	1.73 (1.57–1.91)**	1.97 (1.77–2.20)**	1.92 (1.67–2.20)**

Table 3 Continued

Variable factors	Eye irritation OR (95% CI)	General symptoms OR (95% CI)	Upper respiratory OR (95% CI)	Skin symptoms OR (95% CI)
Noise	1.56 (1.34–1.83)**	2.13 (1.85–2.45)**	1.94 (1.67–2.26)**	2.23 (1.88–2.65)**
Airflow from air conditioner	1.70 (1.53–1.90)**	1.46 (1.31–1.63)**	1.59 (1.41–1.79)**	1.77 (1.53–2.04)**
Odors from air conditioner	2.13 (1.71–2.66)**	2.52 (2.01–3.16)**	2.54 (2.04–3.16)**	2.78 (2.18–3.55)**
Mold odor	1.68 (1.27–2.22)**	2.51 (1.93–3.28)**	2.15 (1.67–2.77)**	2.34 (1.76–3.12)**
Dust and dirt	2.00 (1.77–2.27)*	2.41 (2.13–2.73)**	2.45 (2.16–2.78)**	2.44 (2.10–2.83)**
Tobacco smoke odor	1.59 (1.43–1.78)**	1.67 (1.51–1.84)**	1.80 (1.61–2.01)**	1.70 (1.47–1.96)**
Unpleasant chemical odor	1.63 (1.16–2.29)**	2.28 (1.66–3.13)**	2.44 (1.74–3.42)**	1.84 (1.22–2.78)**
Unpleasant other odor[j]	1.91 (1.67–2.19)**	2.42 (2.13–2.76)**	2.31 (2.01–2.65)**	2.28 (1.94–2.68)**
Job stressors				
Amount of work[k]	1.08 (0.97–1.20)	1.35 (1.22–1.48)**	1.13 (1.00–1.28)*	0.96 (0.82–1.13)
Mental workload[k]	1.19 (1.06–1.33)**	1.33 (1.19–1.48)**	1.21 (1.06–1.38)**	1.09 (0.91–1.30)
Physical overload[l]	0.60 (0.53–0.69)**	0.77 (0.69–0.86)**	0.67 (0.58–0.78)**	0.74 (0.61–0.90)**
Interpersonal conflict[k]	1.34 (1.19–1.51)**	1.93 (1.72–2.17)**	1.49 (1.29–1.71)**	1.31 (1.09–1.57)**
Job control[k]	0.91 (0.81–1.02)	0.68 (0.62–0.76)**	0.85 (0.74–0.97)*	0.84 (0.71–1.01)
Skill utilization[m]	0.74 (0.65–0.85)**	0.72 (0.63–0.82)**	0.78 (0.66–0.91)**	0.64 (0.52–0.78)**
Job suitability[n]	0.86 (0.77–0.96)**	0.67 (0.60–0.74)**	0.85 (0.75–0.97)*	0.75 (0.63–0.90)**
Work satisfaction[n]	0.79 (0.71–0.88)**	0.60 (0.53–0.67)**	0.72 (0.63–0.82)**	0.62 (0.52–0.74)**

Values are expressed as crude odds ratios (95% CI) for participants with complete data. Ref. = referent. Significant at * $P < 0.05$, ** $P < 0.01$. Text in parentheses reflects case groups.

[a]Number of people working in the room in which workstation of respondent is located. Six levels are (i) 1 person, (ii) 2–3 persons, (iii) 4–7 persons, (iv) 8–20 persons, (v) 21–50 persons, and (vi) ≥51 persons.

[b]Five levels are (i) much too dim, (ii) a little too dim, (iii) just right, (iv) a little too bright, and (v) much too bright.

[c]Five levels are (i) rarely, (ii) occasionally, (iii) sometimes, (iv) fairly often, and (v) very often.

[d]Four levels are (i) very comfortable, (ii) reasonably comfortable, (iii) somewhat uncomfortable, and (iv) very uncomfortable.

[e]Five levels are (i) never, (ii) less than 3 times/week, (iii) 3–4 times a week, (iv) about once a week, and (v) several times a day, with cleanser, glue, correction fluid, or other odorous chemicals.

[f]Change taken place within 5 m of workstation in last 3 months.

[g]Within 2 m of workstation.

[h]In workplace indoors.

[i]Four levels are (i) never, (ii) 1–3 days, (iii) 1–3 days per week, and (iv) every or almost every workday.

[j]For example, body odor, food odor, or perfume.

[k]Five levels are (i) less/low, (ii) somewhat less/low, (iii) medium, (iv) somewhat more/high, and (v) more/high.

[l]Four levels are (i) somewhat less/low, (ii) medium, (iii) somewhat more/high, and (iv) more/high.

[m]Four levels are (i) less/low, (ii) somewhat less/low, (iii) medium, and (iv) somewhat more/high.

[n]Four levels are (i) less/low, (ii) somewhat less/low, (iii) medium, and (iv) more/high.

Discussion

To the best of our knowledge, this is the first nationwide population-based cross-sectional study to estimate the prevalence of BRSs in Japan. General symptoms had the highest prevalence, followed by eye irritation and upper respiratory symptoms, whereas lower respiratory symptoms had the lowest prevalence. The Building Assessment Survey Evaluation (BASE) study estimated the prevalence of BRSs in 100 office buildings in the United States in the 1990s (Brightman et al., 2008). The study included 4326 employees, and identified the three most prevalent BRSs as 'tired or strained eyes' (22%), 'dry, itching, or irritated eyes' (19%), and 'pain or stiffness in the back, shoulders, or neck' (17%). The lowest prevalence was associated with 'shortness of breath and wheezing' (2%). In our study, the three most prevalent BRSs were 'tension, irritability, or nervousness' (8.8%), 'tired or strained eyes' (8.0%), and 'dry, itching, or irritated eyes' (7.1%), whereas 'wheezing' (0.2%) had the lowest prevalence. In both BASE and this study, the prevalence of BRSs followed approximately the same rank ordering: eye symptoms were the most prevalent, and wheezing was the least prevalent. However, compared with the BASE study, all prevalences were lower in this study, with 24.9% of participants reporting at least 1 of 19 symptoms; thus, one in four people had some evidence of BRSs. The enactment of the Law for Maintenance of Sanitation in Buildings in 1970 may have prevented serious BRS epidemics in Japan. Nevertheless, our results demonstrate that BRSs remain a widespread issue in society and present a major health concern to people working in office buildings.

In this study, significantly more women than men reported BRSs. This effect of sex on BRSs is characteristic of previous studies (Norbäck et al., 1990; Ooi et al., 1998; Reijula and Sundman-Digert, 2004; Runeson et al., 2006). Our finding of a positive association with smoking habits was also supported by a large-scale survey of 11154 employees in Finland (Reijula and Sundman-Digert, 2004). We also found that younger age significantly increased the rate of both general and upper respiratory symptoms, which is consistent with the work by Ooi et al. (1998) among younger employees in a Singapore-based survey of 2856 office

Table 4 The association of weekly building-related symptoms with personal factors and job stressors (Model 1)

Variable factors	Eye irritation OR (95% CI)	General symptoms OR (95% CI)	Upper respiratory OR (95% CI)	Skin symptoms OR (95% CI)
Personal				
Gender (female)	2.11 (1.48–3.03)**	3.24 (2.29–4.57)**	3.74 (2.42–5.76)**	13.62 (7.38–25.15)**
Age				
10–19	–	–	–	–
20–29	1.97 (1.09–3.53)*	3.07 (1.81–5.20)**	4.91 (2.10–11.45)**	1.95 (2.22–11.02)
30–39	1.77 (1.04–3.01)*	1.71 (1.06–2.77)*	2.68 (1.18–6.11)*	2.05 (1.71–7.72)
40–49	1.39 (0.81–2.38)	1.20 (0.74–1.95)	1.99 (0.87–4.56)	1.44 (1.22–5.77)
50–59	1.25 (0.72–2.16)	0.92 (0.56–1.52)	3.26 (1.44–7.39)**	1.28 (0.85–4.34)
≥60	Ref.	Ref.	Ref.	Ref.
P for trend	0.128	< 0.001	< 0.001	0.410
Job categories				
Managerial	Ref.	Ref.	Ref.	Ref.
Professional	0.56 (0.24–1.28)	0.47 (0.23–0.98)	0.85 (0.31–2.34)	0.59 (0.16–2.18)
Technical	0.86 (0.50–1.48)	0.78 (0.49–1.26)	1.78 (0.95–3.32)	1.28 (0.55–2.97)
Sales	0.73 (0.44–1.22)	0.62 (0.39–0.98)	1.00 (0.50–1.99)	0.81 (0.33–2.01)
Planning/administrative	1.28 (0.85–1.94)	0.85 (0.57–1.26)	1.87 (1.09–3.20)*	0.63 (0.32–1.25)
Secretarial/clerical	1.85 (0.33–10.43)	–	5.56 (0.80–38.56)	0.93 (0.09–10.18)
Other	0.49 (0.20–1.21)	1.10 (0.59–2.03)	0.94 (0.35–2.51)	0.57 (0.19–1.74)
Smoking				
Never	Ref.	Ref.	Ref.	Ref.
Former	1.04 (0.73–1.46)	1.18 (0.86–1.63)	1.09 (0.73–1.63)	1.02 (0.59–1.76)
Current/sometime	1.46 (0.75–2.86)	1.35 (0.70–2.58)	1.43 (0.64–3.21)	2.15 (0.88–5.24)
Current/everyday	1.32 (0.94–1.85)	1.24 (0.90–1.70)	1.73 (1.17–2.56)**	1.75 (1.06–2.87)*
Contact lens use	1.71 (1.30–2.26)**	0.92 (0.69–1.21)	1.52 (1.11–2.08)**	1.57 (1.06–2.33)*
Job stressors				
Amount of work[a]	0.99 (0.85–1.15)	1.23 (1.06–1.41)**	1.07 (0.90–1.28)	
Mental workload[a]	1.23 (1.05–1.44)*	1.24 (1.06–1.44)**	1.15 (0.96–1.38)	
Physical overload[b]	0.77 (0.65–0.91)**	0.81 (0.69–0.95)**	0.89 (0.73–1.09)	1.05 (0.81–1.35)
Interpersonal conflict[a]	1.31 (1.13–1.51)**	1.71 (1.49–1.96)**	1.50 (1.27–1.78)**	1.15 (0.81–1.35)
Job control[a]	1.00 (0.86–1.16)	0.86 (0.75–0.98)*	0.96 (0.81–1.14)	0.94 (0.75–1.17)
Skill utilization[c]	0.83 (0.71–0.98)*	0.98 (0.84–1.14)	0.98 (0.81–1.18)	0.83 (0.66–1.05)
Job suitability[d]	1.01 (0.86–1.18)	0.93 (0.80–1.08)	1.03 (0.86–1.23)	0.97 (0.76–1.23)
Work satisfaction[d]	0.92 (0.79–1.07)	0.76 (0.65–0.88)**	0.87 (0.73–1.04)	0.74 (0.59–0.94)*

Values are expressed as adjusted odds ratios (95% CI) for participants with complete data. Variables with $P < 0.2$ in univariate analyses are included in a multivariate logistic regression analysis (Model 1). Ref. = referent. Significant at $*P < 0.05$, $**P < 0.01$. Text in parentheses reflects case groups.

[a]Five levels are (i) less/low, (ii) somewhat less/low, (iii) medium, (iv) somewhat more/high, and (v) more/high.

[b]Four levels are (i) somewhat less/low, (ii) medium, (iii) somewhat more/high, and (iv) more/high.

[c]Four levels are (i) less/low, (ii) somewhat less/low, (iii) medium, and (iv) somewhat more/high.

[d]Four levels are (i) less/low, (ii) somewhat less/low, (iii) medium, and (iv) more/high.

workers. Recent studies have suggested that younger workers with higher job stress have greater risk for headache (Santos et al., 2014) and depression (Ogasawara et al., 2011). In our study, younger participants with low job suitability and low work satisfaction were at greater risk for general symptoms (chi-square test, data not shown). After starting their careers, some young workers may feel stressed because the first job is unsuitable for them. But, some young workers may have to continue to work to earn the money needed to live. This may be dependent on the community structure or economic status of the society.

Concerning the work environment factors, our results indicated that having more number of people in an office was positively related to general symptoms and upper respiratory symptoms, which is consistent with previous findings (Chao et al., 2003; Zweers et al., 1992). With more people in an office, there is a greater risk of infectious disease transmission, possibly resulting in BRSs. In addition, as the number of people increases, the carbon dioxide concentration may also increase, possibly resulting in BRSs, as suggested by previous studies (Apte et al., 2000; Erdmann and Apte, 2004; Norbäck and Nordström, 2008).

When considering the workplace conditions over the previous 4 weeks, many air-conditioning factors were positively associated with the development of BRSs in this study, as reported in previous epidemiological studies (Jaakkola et al., 1989; Ooi et al., 1998). Our results suggest that adequate maintenance and management of air-conditioning may be important for decreasing the risk of BRSs. Unfortunately, nonconformance to the relative humidity, room temperature, and carbon dioxide standards has increased in the last decade in Japan (Azuma et al., 2011, 2012); therefore, improving the compliance rate is important.

Table 5 Associations between weekly building-related symptoms and the work environment (Model 2)

Variable factors	Eye irritation OR (95% CI)	General symptoms OR (95% CI)	Upper respiratory OR (95% CI)	Skin symptoms OR (95% CI)
No. of people in office[a]		1.24 (1.07–1.44)**	1.54 (1.29–1.84)**	1.33 (1.06–1.65)*
Work station				
Floor carpet (with)	1.87 (1.36–2.58)**	1.11 (0.83–1.48)	1.21 (0.85–1.74)	1.47 (0.91–2.38)
Lighting[b]	0.65 (0.49–0.86)**	0.90 (0.68–1.17)	0.72 (0.52–0.99)*	0.82 (0.55–1.23)
Reflection or glare in vision[c]	1.20 (1.02–1.40)*	1.24 (1.06–1.49)**	1.15 (0.95–1.38)	1.03 (0.81–1.32)
Table comfort[d]	1.27 (1.01–1.61)*	1.27 (1.01–1.59)*	1.22 (0.92–1.60)	1.25 (0.88–1.78)
Chair comfort[d]	1.32 (1.05–1.66)*	1.37 (1.10–1.70)**	1.36 (1.04–1.77)*	1.47 (1.05–2.06)*
Work with computer	1.89 (0.77–4.64)	1.99 (0.84–4.69)	1.66 (0.58–4.72)	
Use of odorous chemicals[e]	1.11 (1.02–1.21)*	1.09 (1.00–1.18)*	1.14 (1.04–1.26)**	1.16 (1.03–1.31)*
Equipment/installation				
Laser printer[f]	0.97 (0.74–1.26)		1.06 (0.77–1.46)	
Bubble jet printer[f]			1.43 (1.03–1.97)*	
Air freshener[g]		1.04 (0.71–1.44)	1.25 (0.81–1.93)	

Values are expressed as adjusted odds ratios (95% CI) for participants with complete data. Variables with P < 0.2 in univariate analyses were included in a multivariate logistic regression analysis (Model 2). Ref. = referent. Significant at * $P < 0.05$, ** $P < 0.01$. Text in parentheses reflects case groups.

[a]Number of people working in the room in which workstation of respondent is located. Six levels are (i) 1 person, (ii) 2–3 persons, (iii) 4–7 persons, (iv) 8–20 persons, (v) 21–50 persons, and (vi) ≥51 persons.

[b]Five levels are (i) much too dim, (ii) a little too dim, (iii) Just right, (iv) a little too bright, and (v) much too bright.

[c]Five levels are (i) rarely, (ii) occasionally, (iii) sometimes, (iv) fairly often, and (v) very often.

[d]Four levels are (i) very comfortable, (ii) reasonably comfortable, (iii) somewhat uncomfortable, and (iv) very uncomfortable.

[e]Five levels are (i) never, (ii) less than 3 times/week, (iii) 3–4 times a week, (iv) about once a week, and (v) several times a day, with cleanser, glue, correction fluid, or other odorous chemicals.

[f]Within 2 m of workstation.

[g]In workplace indoors.

Table 6 Association between weekly building-related symptoms and workplace conditions in the last 4 weeks (Model 3)

Variable factors[a]	Eye irritation OR (95% CI)	General symptoms OR (95% CI)	Upper respiratory OR (95% CI)	Skin symptoms OR (95% CI)
Too much air movement	1.01 (0.73–1.38)	1.29 (0.95–1.76)	1.37 (0.98–1.91)	
Too little air movement	1.11 (0.97–1.28)	1.30 (1.13–1.49)**	1.15 (0.98–1.34)	1.14 (0.94–1.38)
Too hot	1.06 (0.89–1.25)	0.93 (0.78–1.11)	1.19 (0.98–1.43)	1.10 (0.88–1.38)
Varying room temperature	1.10 (0.95–1.28)	1.26 (1.09–1.46)**	1.04 (0.88–1.22)	1.26 (1.04–1.55)*
Too cold	1.22 (1.07–1.40)**	1.18 (1.03–1.34)*	1.16 (0.99–1.35)	1.04 (0.86–1.26)
Air too humid	0.64 (0.39–1.07)	0.61 (0.39–0.95)*	0.67 (0.40–1.12)	
Air too dry	1.56 (1.36–1.78)**	1.14 (1.00–1.30)	1.87 (1.60–2.20)**	2.07 (1.66–2.58)**
Static electricity	1.21 (1.06–1.39)**	1.10 (0.96–1.26)	1.14 (0.97–1.33)	0.98 (0.81–1.20)
Noise	0.85 (0.68–1.07)	1.28 (1.05–1.56)*	1.02 (0.81–1.28)	1.41 (1.10–1.80)**
Airflow from air conditioner	1.31 (1.13–1.50)**	1.03 (0.89–1.20)	0.96 (0.81–1.14)	1.21 (0.99–1.47)
Odors from air conditioner	1.16 (0.80–1.68)	0.91 (0.63–1.33)	1.34 (0.93–1.94)	1.27 (0.84–1.93)
Mold odor	0.58 (0.36–0.95)*	0.99 (0.63–1.55)	0.55 (0.35–0.86)**	0.68 (0.41–1.13)
Dust and dirt	1.24 (1.02–1.50)*	1.34 (1.12–1.61)**	1.30 (1.06–1.59)*	1.28 (1.01–1.61)*
Tobacco smoke odor	1.09 (0.94–1.27)	1.00 (0.86–1.16)	1.08 (0.91–1.28)	0.81 (0.65–1.01)
Unpleasant chemical odor	0.97 (0.60–1.55)	0.95 (0.62–1.44)	1.34 (0.84–2.12)	0.73 (0.42–1.25)
Unpleasant other odor[b]	1.13 (0.93–1.37)	1.40 (1.17–1.67)**	1.26 (1.03–1.55)*	1.24 (0.98–1.58)

Values are expressed as adjusted odds ratios (95% CI) for participants with complete data. Variables with P < 0.2 in univariate analyses were included in a multivariate logistic regression analysis (Model 3). Ref. = referent. Significant at * $P < 0.05$, ** $P < 0.01$. Text in parentheses reflects case groups.

[a]Four levels are (i) never, (ii) 1–3 days, (iii) 1–3 days per week, and (iv) every or almost every workday.

[b]For example, body odor, food odor, or perfume.

Building-related symptoms (BRSs) were significantly associated with indoor pollutants, including floor dust, unpleasant odors, and carpet. In this study, dust was significantly associated with general symptoms, upper respiratory symptoms, and skin symptoms, which is consistent with a previous report on general symptoms and skin symptoms (Niven et al., 2000). Additionally, the authors reported that noise was significantly associated with general symptoms and skin symptoms (Niven et al., 2000), which is consistent with the findings of Ooi et al. (1998). However, observational data were not available for indoor pollutants and noise in the present study. Future observational research should consider the environmental risk factors and health outcomes to confirm and clarify the reported relationships. Particularly, the association between

Table 7 Final models for the association between weekly building-related symptoms and all variables (Model 4)

Variable factors	Eye irritation OR (95% CI)	General symptoms OR (95% CI)	Upper respiratory OR (95% CI)	Skin symptoms OR (95% CI)
Personal				
Gender (female)	–	1.63 (1.21–2.19)**	2.21 (1.47–3.33)**	4.01 (2.28–7.02)**
Age				
10–19	–	–	–	–
20–29	–	2.50 (1.41–4.44)**	4.20 (1.64–10.76)**	–
30–39	–	1.53 (0.90–2.59)	2.51 (1.01–6.21)*	–
40–49	–	1.19 (0.70–2.05)	1.88 (0.75–4.71)	–
50–59	–	0.80 (0.45–1.42)	3.26 (1.31–8.14)*	–
≥60	–	Ref.	Ref.	–
P for trend	–	< 0.001	0.005	–
Smoking				
Never	–	–	Ref.	Ref.
Former	–	–	0.92 (0.58–1.44)	0.71 (0.38–1.32)
Current/sometime	–	–	1.27 (0.53–3.04)	2.35 (0.88–6.28)
Current/everyday	–	–	1.82 (1.18–2.81)**	2.16 (1.26–3.71)**
Contact lens use	2.04 (1.53–2.72)**	–	1.46 (1.02–2.08)*	1.74 (1.14–2.65)**
Work environment				
No. of people in office[a]		1.16 (1.00–1.34)*	1.36 (1.13–1.63)**	
Work station				
Floor carpet (with)	1.73 (1.24–2.41)**	–	–	–
Lighting[b]	0.70 (0.52–0.94)*	–	–	–
Chair comfort[c]	1.26 (1.03–1.54)*	–	–	–
Use of odorous chemicals[d]	1.10 (1.01–1.19)*	–	–	–
Equipment/installation[e]				
Bubble jet printer			1.42 (1.02–1.98)*	
Workplace conditions in last 4 weeks[f]				
Too little air movement	–	1.31 (1.14–1.51)**	–	–
Varying room temperature	–	1.25 (1.08–1.45)**	–	1.25 (1.05–1.50)*
Too cold	1.28 (1.13–1.45)**	1.20 (1.05–1.37)**	–	–
Air too humid	0.53 (0.32–0.89)*	0.62 (0.40–0.96)*	–	
Air too dry	1.61 (1.42–1.82)**	1.19 (1.04–1.35)*	2.07 (1.79–2.38)**	2.06 (1.69–2.51)**
Static electricity	1.28 (1.11–1.46)**	–	–	–
Noise	–	1.29 (1.05–1.59)*	–	1.45 (1.14–1.83)**
Airflow from air conditioner	1.32 (1.16–1.51)**	–	–	1.25 (1.04–1.49)*
Dust and dirt	1.22 (1.02–1.45)*	1.32 (1.09–1.59)**	1.39 (1.16–1.67)**	1.26 (1.02–1.55)*
Unpleasant other odor[g]	–	1.37 (1.13–1.65)**	1.36 (1.13–1.65)**	–
Job stressors				
Amount of work[h]	–	1.24 (1.06–1.45)**	–	
Mental workload[h]	–	1.19 (1.00–1.40)*	–	
Physical overload[i]	0.80 (0.68–0.95)**	–	–	–
Interpersonal conflict[h]	–	1.44 (1.23–1.69)**	1.34 (1.13–1.60)**	–
Skill utilization[j]	0.77 (0.65–0.91)**	–	–	–
Job suitability[k]	–	0.82 (0.69–0.98)*	–	–
Work satisfaction[k]	–	0.81 (0.69–0.96)*	–	0.80 (0.66–0.98)*

Values are expressed as adjusted odds ratio (95% CI) for participants with complete data. Personal factors, work environment, workplace conditions in the last 4 weeks, and job stressors with $P < 0.2$ in univariate analyses are included in multivariate stepwise logistic regression analysis (Model 4) (forward, Wald). Ref. = referent. Significant at * $P < 0.05$, ** $P < 0.01$. Horizontal lines are expressed as the variable included in models.

[a]Number of people working in the room in which workstation of respondent is located. Six levels are (i) 1 person, (ii) 2–3 persons, (iii) 4–7 persons, (iv) 8–20 persons, (v) 21–50 persons, and (vi) ≥51 persons.

[b]Five levels are (i) much too dim, (ii) a little too dim, (iii) Just right, (iv) a little too bright, and (v) much too bright.

[c]Four levels are (i) very comfortable, (ii) reasonably comfortable, (iii) somewhat uncomfortable, and (iv) very uncomfortable.

[d]Five levels are (i) never, (ii) less than 3 times/week, (iii) 3–4 times a week, (iv) about once a week, and (v) several times a day, with cleanser, glue, correction fluid, or other odorous chemicals.

[e]Within 2 m of workstation.

[f]Four levels are (i) never, (ii) 1–3 days, (iii) 1–3 days per week, and (iv) every or almost every workday.

[g]For example, body odor, food odor, or perfume.

[h]Five levels are (i) less/low, (ii) somewhat less/low, (iii) medium, (iv) somewhat more/high, and (v) more/high.

[i]Four levels are (i) somewhat less/low, (ii) medium, (iii) somewhat more/high, and (iv) more/high.

[j]Four levels are (i) less/low, (ii) somewhat less/low, (iii) medium, and (iv) somewhat more/high.

[k]Four levels are (i) less/low, (ii) somewhat less/low, (iii) medium, and (iv) more/high.

general symptoms and lung-related inflammatory potency of surface dust in office buildings has been suggested (Allermann et al., 2007), while an association between mucosal symptoms similar to BRSs and phosphates in indoor house dust has been suggested (Kanazawa et al., 2010). Clarifying the etiological role of these agents in BRSs is necessary.

Notably, the association with tobacco smoke odor was not significant in multivariate models in this study. A previous study suggested an association between BRSs and environmental tobacco smoke (ETS) (Mizoue et al., 2000). The Health Promotion Act, which includes regulation to protect public health from ETS, has been enforced since May 2003 in Japan. Our results may reflect the decreasing influence of ETS on BRSs after the enforcement of this law.

Many job stressors were significantly associated with general symptoms, but there were few associations with other symptoms. These factors might influence psychological health perception or increase physical susceptibility to environmental exposure. Furthermore, the physical environment of workstations and office buildings affect BRSs less than the psychosocial work environment, including high job demands and low support (Marmot et al., 2006). In the present study, the associations between BRSs and poor physical environmental conditions remained in all BRS groups, even after controlling for job stressors. Although psychosocial support is important to reduce and control BRSs, improving poor physical environments can be beneficial for eye irritations, general symptoms, upper respiratory symptoms, and skin symptoms.

Our study had several limitations. First, we used a nationwide cross-sectional survey to examine the association between the possible office-based risk factors and BRSs self-reported by employees. The cross-sectional nature limits any causal inferences and may be subject to recall bias. Second, the office managers selected all employees when 10 or less employees in their office met our selection criteria, but otherwise, managers arbitrarily selected 15 employees at a maximum that met the criteria. The proportion of participants that worked in offices with no more than 20 employees was 72.6%. Although employees who met the exclusion criteria will have been included in that number, we cannot exclude selection bias. Thus, it might be likely that employees with symptoms rather than those without symptoms tended to be selected as the participant employees by the managers, and vice versa. The prevalence of BRSs obtained in this study would include such uncertainty. However, it is probably less likely that the selection bias has severely influenced the strength of the associations between BRSs and the possible risk factors. Third, the survey was conducted from January 2012 to March 2012, which corresponds to winter in Japan. The summer season may cause different thermal conditions and different results. Further investigation of the seasonal differences in the risk factors for BRSs is needed. Fourth, this study was based on a self-reported questionnaire survey. Several environmental reports from respondents are subjective, and the resulting inaccuracies may have resulted in bias. This is also true of the subjective, self-reported health outcome assessments used in this study. Fifth, employees suffering from BRSs may avoid working overtime, which may have underestimated the prevalence and risks of extensive overtime. Finally, we analyzed mass variable factors that could introduce a systematic statistical bias. We therefore performed a number of statistical analyses (four models, two stepwise procedures of Wald and likelihood ratio) based on the specific assumptions of those tests. However, the results were similar for the different models used, so it is less likely that the overall results are affected because of a particular statistical model, or because of the relatively large number of statistical tests performed.

In conclusion, BRSs were common in this nationwide survey, with one in four people having at least one BRS. Furthermore, BRSs were associated with multiple factors, including work environment, Indoor Air Quality, and occupational stress. The associations between BRSs and poor physical environmental conditions remained in all BRS groups, even after controlling for job stressors. We noted that improvements in the physical environment are important when controlling eye irritations, general symptoms, upper respiratory symptoms, and skin symptoms, although psychosocial support remains critical. Finally, improving the physical office environment appears to be important for the health of employees, and it may be best achieved by providing appropriate air-conditioning and a clean and uncrowded workspace.

Acknowledgements

This study was financially supported by a Grant-in-Aid for Health and Labour Sciences Research Grant (H23-health/crisis-009) provided by the Japanese Ministry of Health, Labour and Welfare. We would like to extend our sincere thanks to Takayuki Nakamura, Tomoko Shimodaira, and the staff of the Japan Building Maintenance Association for their help in conducting the survey. We thank Daichi Takano and Yuma Nakagawa (formerly of the Department of Architecture, College of Science and Technology, Nihon University) for their assistance in the laboratory. We also thank all participants for their collaboration.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Number of cases by variable factors for weekly building-related symptoms.

References

Allermann, L., Pejtersen, J., Gunnarsen, L. and Poulsen, O.M. (2007) Building-related symptoms and inflammatory potency of dust from office buildings, *Indoor Air*, **17**, 458–467.

Andersson, K. (1998) Epidemiological approach to indoor air problems, *Indoor Air*, **8**(Suppl. 4), 32–39.

Apte, M.G., Fisk, W.J. and Daisey, J.M. (2000) Associations between indoor CO_2 concentrations and sick building syndrome symptoms in U.S. office buildings: an analysis of the 1994–1996 BASE study data, *Indoor Air*, **10**, 246–257.

Apter, A., Bracker, A., Hodgson, M., Sidman, J. and Leung, W.Y. (1994) Epidemiology of the sick building syndrome, *J. Allergy Clin. Immunol.*, **94**, 277–288.

Azuma, K., Ikeda, K., Osawa, H., Kagi, N., Yanagi, U. and Shimodaira, T. (2011) Questionnaire Survey on Indoor Air Quality and Maintenance of Sanitary Environment in Buildings. Proceedings of the 12th International Conference on Indoor Air Quality and Climate, Austin, USA, Paper 248, 6 p.

Azuma, K., Ikeda, K., Osawa, H., Kagi, N., Yanagi, U., Saito, H. and Kamakura, R. (2012) Actual Status of Environmental Sanitation and Building Maintenance in Japan, *Trans. Soc. Heat. Air Cond. Sanit. Eng. Jpn.*, **179**, 19–26 (in Japanese with English abstract).

Bai, R., Zhang, L., Liu, Y., Meng, L., Wang, L., Wu, Y., Li, W., Ge, C., Le Guyader, L. and Chen, C. (2010) Pulmonary responses to printer toner particles in mice after intratracheal instillation. *Toxicol. Lett.*, **199**, 288–300.

BMEC (2007) *Law for Maintenance of Sanitation in Buildings*, Tokyo, Building Management Education Center.

Brightman, H.S., Milton, D.K., Wypij, D., Burge, H.A. and Spengler, J.D. (2008) Evaluating building-related symptoms using the US EPA BASE study results, *Indoor Air*, **18**, 335–345.

Burge, P.S. (2004) Sick building syndrome, *Occup. Environ. Med.*, **61**, 185–190.

Chao, H.J., Schwartz, J., Milton, D.K. and Burge, H.A. (2003) The work environment and workers' health in four large office buildings, *Environ. Health Perspect.*, **111**, 1242–1248.

Dormann, C.F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J.G.R., Gruber, B., Lafourcade, B., Leitão, P.J., Münkemüller, T., McClean, C., Osborne, P.E., Reineking, B., Schröder, B., Skidmore, A.K., Zurell, D. and Lautenbach, S. (2013) Collinearity: a review of methods to deal with it and a simulation study evaluating their performance, *Ecography*, **36**, 27–46.

Erdmann, C.A. and Apte, M.G. (2004) Mucous membrane and lower respiratory building related symptoms in relation to indoor carbon dioxide concentrations in the 100-building BASE dataset, *Indoor Air*, **14**(Suppl. 8), 127–134.

Finnegan, M.J., Pickering, C.A.C. and Burge, P.S. (1984) The sick building syndrome: prevalence studies, *BMJ*, **289**, 1573–1575.

Fisk, W.J., Lei-Gomez, Q. and Mendell, M.J. (2007) Meta-analyses of the associations of respiratory health effects with dampness and mold in homes, *Indoor Air*, **17**, 284–296.

Fisk, W.J., Mirer, A.G. and Mendell, M.J. (2009) Quantitative relationship of sick building syndrome symptoms with ventilation rates, *Indoor Air*, **19**, 159–165.

Hansen, A.M., Meyer, H.W. and Gyntelberg, F. (2008) Building-related symptoms and stress indicators, *Indoor Air*, **18**, 440–446.

Hosmer, D.W., Hosmer, T., Cessie, S.L. and Lemeshow, S. (1997) A comparison of goodness-of-fit tests for the logistic regression model, *Stat. Med.*, **16**, 965–980.

Jaakkola, J.J.K., Heinonen, O.P. and Seppänen, O. (1989) Sick building syndrome, sensation of dryness and thermal comfort in relation to room temperature in an office building: need for individual control of temperature, *Environ. Int.*, **15**, 163–168.

Kanazawa, A., Saito, I., Araki, A., Takeda, M., Ma, M., Saijo, Y. and Kishi, R. (2010) Association between indoor exposure to semi-volatile organic compounds and building-related symptoms among the occupants of residential dwellings, *Indoor Air*, **20**, 72–84.

Khatri, M., Bello, D., Gaines, P., Martin, J., Pal, A.K., Gore, R. and Woskie, S. (2013) Nanoparticles from photocopiers induce oxidative stress and upper respiratory tract inflammation in healthy volunteers, *Nanotoxicology*, **7**, 1014–1027.

Könczöl, M., Weiß, A., Gminski, R., Merfort, I. and Mersch-Sundermann, V. (2013) Oxidative stress and inflammatory response to printer toner particles in human epithelial A549 lung cells, *Toxicol. Lett.*, **216**, 171–180.

Marmot, A.F., Stafford, J.M., Stansfeld, S.A., Warwick, E. and Marmot, M.G. (2006) Building health: an epidemiological study of "sick building syndrome" in the Whitehall II study, *Occup. Environ. Med.*, **63**, 283–289.

Mendell, M.J., Lei-Gomez, Q., Mirer, A.G., Seppänen, O. and Brunner, G. (2008) Risk factors in heating, ventilating, and air-conditioning systems for occupant symptoms in US office buildings: the US EPA BASE study, *Indoor Air*, **8**, 301–316.

MHLW (2002) *Report of Committee on Maintenance of Sanitation in Buildings*, Tokyo, Ministry of Health, Labour and Welfare (in Japanese).

Mizoue, T., Reijula, K. and Andersson, K. (2000) Environmental tobacco smoke exposure and overtime work as risk factors for sick building syndrome in Japan, *Am. J. Epidemiol.*, **154**, 803–808.

Nafiu, O.O. and Onyewuche, V. (2014) Association of abdominal obesity in children with perioperative respiratory adverse events, *J. Perianesth Nurs.*, **29**, 84–93.

Nakazawa, H., Ikeda, H., Yamashita, T., Hara, I., Kumai, Y., Endo, G. and Endo, Y. (2005) A case of sick building syndrome in a Japanese office worker, *Ind. Health*, **43**, 341–345.

Niven, R., Fletcher, A., Pickering, C., Faragher, E., Potter, I., Booth, W., Jones, T. and Potter, P. (2000) Building sickness syndrome in healthy and unhealthy buildings: an epidemiological and environmental assessment with cluster analysis, *Occup. Environ. Med.*, **57**, 627–634.

Norbäck, D. and Nordström, K. (2008) Sick building syndrome in relation to air exchange rate, CO(2), room temperature and relative air humidity in university computer classrooms: an experimental study, *Int. Arch. Occup. Environ. Health*, **82**, 21–30.

Norbäck, D., Torgén, M. and Edling, C. (1990) Volatile organic compounds, respirable dust, and personal factors related to prevalence and incidence of sick building syndrome in primary schools, *Br. J. Ind. Med.*, **47**, 733–741.

Ogasawara, K., Nakamura, Y., Aleksic, B., Yoshida, K., Ando, K., Iwata, N., Kayukawa, Y. and Ozaki, N. (2011) Depression associated with alcohol intake and younger age in Japanese office workers: a case-control and a cohort study, *J. Affect. Disord.*, **128**, 33–40.

Ooi, P.L., Goh, K.T., Phoon, M.H., Foo, S.C. and Yap, H.M. (1998) Epidemiology of sick building syndrome and its associated risk factors in Singapore, *Occup. Environ. Med.*, **55**, 188–193.

Ozaki, K., Motohashi, Y., Kaneko, Y. and Fujita, K. (2012) Association between psychological distress and a sense of contribution to society in the workplace, *BMC Public Health*, **12**, 253.

Redlich, C.A., Sparer, J. and Cullen, M.R. (1997) Sick-building syndrome, *Lancet*, **349**, 1013–1016.

Reijula, K. and Sundman-Digert, C. (2004) Assessment of indoor air problems at work with a questionnaire, *Occup. Environ. Med.*, **61**, 33–38.

Runeson, R. and Norbäck, D. (2013) Sick building syndrome (SBS) and sick house syndrome (SHS) in relation to psychosocial stress at work in the Swedish workforce, *Int. Arch. Occup. Environ. Health*, **86**, 915–922.

Runeson, R., Norbäck, D., Klinteberg, B. and Edling, C. (2004) The influence of personality, measured by the Karolinska Scales of Personality (KSP), on symptoms among subjects in suspected sick buildings, *Indoor Air*, **14**, 394–404.

Runeson, R., Wahlstedt, K., Wieslander, G. and Norbäck, D. (2006) Personal and psychosocial factors and symptoms compatible with sick building syndrome in the Swedish workforce, *Indoor Air*, **16**, 445–453.

Ruotsalainen, R., Jaakkola, N. and Jaakkola, J.J. (1995) Dampness and molds in day-care centers as an occupational health problem, *Int. Arch. Occup. Environ. Health*, **66**, 369–374.

Santos, I.S., Griep, R.H., Alves, M.G., Goulart, A.C., Lotufo, P.A., Barreto, S.M., Chor, D. and Benseñor, I.M. (2014) Job stress is associated with migraine in current workers: the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), *Eur. J. Pain*, **18**, 1290–1297.

Shimomitsu, T., Ohno, H., Maruta, T. and Tanigawa, T. (2000) *Investigation Research Report Concerning Prevention of Disease Related to Work in 1997 the Ministry of Labor: III Stress Measurement Research Group Report*, Tokyo, Japan, Tokyo Medical University, 101–169, (in Japanese).

Teeuw, K.B., Vandenbroucke-Grauls, C.M. and Verhoef, J. (1994) Airborne gram-negative bacteria and endotoxin in sick building syndrome. A study in Dutch governmental office buildings, *Arch. Intern. Med.*, **154**, 2339–2345.

USEPA (2003) *A Standardized EPA Protocol for Characterizing Indoor air Quality in Large Office Buildings*, Washington, DC, Environmental Protection Agency.

Wada, K., Sairenchi, T., Haruyama, Y., Taneichi, H., Ishikawa, Y. and Muto, T. (2013) Relationship between the onset of depression and stress response measured by the brief job stress questionnaire among Japanese employees: a cohort study, *PLoS ONE*, **8**, e56319.

WHO (2009) *Guidelines for Indoor air Quality, Dampness and Mould*, Copenhagen, World Health Organization Regional Office for Europe.

Wolkoff, P. (2008) "Healthy" eye in office-like environments, *Environ. Int.*, **34**, 1204–1214.

Wolkoff, P. (2010) Ocular discomfort by environmental and personal risk factors altering the precorneal tear film, *Toxicol. Lett.*, **199**, 203–212.

Zhang, X., Sahlberg, B., Wieslander, G., Janson, C., Gislason, T. and Norbäck, D. (2012) Dampness and moulds in workplace buildings: associations with incidence and remission of sick building syndrome (SBS) and biomarkers of inflammation in a 10 year follow-up study, *Sci. Total Environ.*, **430**, 75–81.

Zweers, T., Preller, L., Brunekreef, B. and Boleij, J.S.M. (1992) Health and indoor climate complaints of 7043 office workers in 61 buildings in the Netherlands, *Indoor Air*, **2**, 127–136.