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Sick building symptoms among hospital workers associated with indoor air quality and personal factors

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Abstract

This study assesses the interior air quality and infective factors in a hospital in Turkey to provide data about air quality to protect hospital workers. This study measured indoor air quality in eight different locations in a hospital, including particulate matter ($PM_{2.5}$ and PM_1), carbon dioxide, carbon monoxide, temperature, humidity and microbiological matter. The highest $PM_{2.5}$ and PM_1 concentrations were in emergency service, and the highest CO_2 was measured in the paediatric clinic. The poor interior air quality results are the most important cross-sectional data. For all participants, the prevalence of eye, upper respiratory tract, lower respiratory tract, skin and non-specific sick building syndrome symptoms were 23.0%, 40.7%, 22.5%, 36.3% and 63.7%, respectively. When sick building syndrome symptoms and environmental factors were investigated, skin symptoms increased 1.82 times in areas with stagnant air flow ($p = 0.046$; OR = 1.823; 95% CI: 1.010–3.290). Non-specific symptoms increased 2.17 times in locations with dry indoor air ($p = 0.039$; OR = 2.176; 95% CI: 1.041–4.549). Hospital workers are exposed to conditions that may increase the risk of a variety of sick building syndrome symptoms. Although the air quality measurements were not above the recommended limits in the hospital, long-term exposures should be considered for those experiencing sick building syndrome-related symptoms.

Keywords

Indoor air quality, Sick building syndrome, Work environment, Hospital, Occupational stress

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Introduction

In developing countries, intense workload, work stress and the majority of time spent in enclosed environments have become important public health problems in terms of worker health.[1,2] One of the causes of worker absenteeism and unproductive working is known as 'sick building syndrome' (SBS). SBS is a term defined by the World Health Organization (WHO) with symptoms such as eye, nose and throat irritation, dry mucous membranes and dry skin, rash, mental tiredness, headache, frequent upper respiratory tract infection and cough, loss of voice, wheezing, itching and non-specific hypersensitivity, nausea and

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dizziness.[3–5] Much epidemiological or experimental research has been published related to these symptoms in recent years. A variety of factors such as age of a building, type of ventilation system, room temperature, static electricity, particulate matter (PM) and microbial load have been shown to be associated with SBS symptoms.[3]

Workers, patients and carers staying in indoor environments of hospitals for long durations may be affected by the levels of air quality pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), PM in the air.[6] Many studies have shown that exposure to CO, CO_2 and PM and damp indoor environments would increase the risk of SBS.[7–9] A study by Apte et al.[10] measured the difference between the indoor and outdoor CO_2 concentrations and reported that the odds ratio (OR) of respiratory symptoms may increase by 1.1–1.5 per 100 ppm increase in the indoor CO_2 concentration. Seppänen et al.[11] reported that indoor CO_2 concentration and SBS symptoms had an effect on headache, fatigue, eye symptoms, nasal symptoms, respiratory symptoms and total SBS score. CO_2 concentrations exceeding 1000 ppm have been reportedly associated with increased incidence of SBS in a number of studies.[9,11,12]

Hospitals have crowded populations that are continuously in motion which increases the PM levels. Occupants walking indoors can affect the level of PM in the air.[10] Some studies have identified an association between PM and upper respiratory tract symptoms.[13] Another study stated that high PM_{10} concentration increased all SBS symptoms.[14] A study of schools, with crowded populations similar to hospitals, identified positive correlations between PM_{10} and CO_2 with the high incidence and high prevalence of SBS.[15] According to literature, increases in CO and PM levels are reported to be associated with non-specific syndromes.[16,17] Studies of headache in SBS symptoms have been reported in studies on indoor CO concentration.[16] As a result, we considered necessary to evaluate the features of non-biological pollutants in hospitals.

Indoor air quality (IAQ) assessment markers include CO_2 concentration,[18] PM, bacteria,[19] fungi and viruses, in addition to temperature and relative humidity (RH). Temperature and humidity in hospitals provide productive environments for the formation of bioaerosols. Recirculating air ventilation systems in hospitals cause spread of bioaerosols. Li et al.[20] in a review suggested that ventilation was significantly associated with the levels of microbiologic pollutants. Immediately after reducing mould and bacteria within buildings, there was a reduction shown in SBS symptoms.[21] Another study correlated the fungal concentrations in air with upper respiratory tract symptoms.[22] The composition, concentration and distribution of aerosols are affected by factors such as size and location of the treatment room, duration of treatment, mode of treatment, patient characteristics and seasonality.[23,24]

Medications, medical treatment and cleaning chemicals may affect the IAQ of hospitals. As hospitals are crowded and include infectious carriers, the measurement of biological and non-biological pollutants at the same time is necessary. The investigation of the distribution of IAQ in different working areas of the hospital is important to determine the sources of contaminants. Few published studies encompass different working areas in hospitals and measure biological and non-biological pollutants.

IAQ is a basic factor affecting the health, welfare and productivity of workers. IAQ is affected by the concentrations of microorganisms like bacteria, fungi and viruses. The IAQ in hospitals is influenced by air conditions, design and operation of the ventilation system, humidity input, microbial load of the external environment and the number of patients and visitors.[25] Considering that workers are exposed to the same air all day long in working environments, IAQ requires attention.[26] Our aim in this study was to analyse the microbes, CO and CO_2, PM concentrations and temperature and humidity in air in a variety of hospital departments to investigate the correlation between SBS symptoms of workers and IAQ.

Materials and methods

Study population

Kirşehir is a province located in the Central Anatolia region of Turkey. Kırşehir is located at latitude 39°41'–39°48' north and longitude 33°25'–34°43' east. The general population of the city was 229,975 in 2017.[27] There is an education and research hospital in the central county of Kırşehir province. The hospital has a 338-bed capacity and 24 wards and was built in 2011. There are 250 people, health officers and secretaries, working in the building. There is no source of industrial air pollution close to the hospital.

Study design

This study is a cross-sectional type of epidemiological research. Sampling processes and data collection were completed in March–April 2018 (spring season). There were 250 health officers and secretaries working in the hospital. Those with colds, flu or other diseases during the study were not included. The survey form was completed by 204 (81.6%) people due to people newly beginning work, those who did not want to participate or who were on leave at the time of the study. Participants had worked in the hospital from 3 to 10

years. All participants were in the hospital building for five days from 8 to 10 h per day. All participants were verbally informed about the aim of the study, and written consents were obtained. Before beginning the study, written permission was obtained from the hospital management and from Ahi Evran University Non-Medication Clinical Research Ethics Committee (Decision No: 2018–06/53).

Research data were collected by two researchers given preliminary training. All participants answered the questions. The survey form created by researchers collected data about socio-demographic characteristics, lifestyle, work-related factors and SBS. After the survey forms were collected by researchers, indoor air measurements were performed at selected locations.

Survey form

The survey form was created by researchers after a literature search. A total of 45 questions were included. The first section of the survey included characteristics like age, marital status, educational level and body mass. Additionally, participants were asked questions about working conditions, number of years of work and other risk factors. Items about SBS inquired about ergonomics, eye redness, throat irritation, cough, blocked nose, eczema and tendency to colds.

Air quality monitoring

Sampling was completed in March–April 2018. IAQ parameters were measured at eight locations during the busiest hours in the hospital of 10:00–12:00 and 13:00–15:00. Air quality measurements included PM ($PM_{2.5}$ and PM_1), CO_2, CO, microbes, temperature (°C), RH (%). Air sampling devices were located as close as possible to the centre of the sampling area. All measurements simulated the respiratory region of a seated health worker by being placed at 1–1.5 m above the floor. Air quality measurements were performed in the emergency service waiting room, paediatric diseases clinic, internal medicine clinic, blood sampling area, microbiology laboratory, biochemistry laboratory, intensive care unit and surgery areas.

A digital psychrometer device recording temperature, humidity, CO_2 and CO concentrations each minute was used (TSI, IAQ-CALC Model 7545, TSI Inc., USA). PM levels were measured with a portable dust monitor measuring the number of PM of 2.5 μm and 1 μm sizes every 6 s (TSI DustTrak II Model 8532, TSI Inc., USA). Microbial air measurements were performed using an air sampler at 6 m^3/h (100 L/min) flow speed (MAS 100, Merck, Darmstadt, Germany). During the sampling period, indoor air was conditioned but not heated. The sampling time was approximately 1 h average.

Microbial measurements

Microbial air measurements were performed using an air sampler with 6 m^3/h (100 L/min) flow rate (MAS 100, Merck). Microbial measurements were performed during the busiest hours in the hospital between 10:00–12:00 and 13:00–15:00. To determine indoor air microorganism levels, a 90-mm diameter petri dish of 5% sheep's blood agar and eosin methylene blue (EMB) agar (RDS, Turkey) was used for bacteria. To produce fungi from isolates, malt extract agar (MEA) with chloramphenicol (0.05%) (Oxoid, UK) was used. Blood agar and EMB agar plates were incubated at 37°C for 48 h, and the MEA plates were incubated at 25°C for seven days. Identification of proliferating bacterial colonies at species level was performed with conventional methods like gram staining, catalase, coagulase, oxidase, etc. with a Vitek 2 system (bioMérieux, Marcyl'Etoile, France). For identification of filamentous fungal colonies, preparations prepared with lactophenol cotton blue were investigated.

To calculate colony numbers, the number of colony-forming units (CFUs) per petri dish was corrected using the MAS-100 positive hole correction table provided by the supplier. The air bioburden values were expressed in CFUs per cubic meter (CFU/m^3), and the limit of quantification was 1 CFU/m^3.

Assessment of data

For all participants, independent variables (socio-demographic characteristics, working features and SBS) and indoor air parameters had their frequency distributions calculated. At the same time, mean values and standard deviations were calculated. In statistical analyses, associations between SBS symptoms and selected covariates, including participants' socio-demographic status, medical history and indoor air pollutants were tested using Pearson's χ^2 test and Fisher's exact test.

Data analysis initially measured the prevalence of specific SBS symptoms reported for five groups of complaints, including eyes, upper respiratory system, lower respiratory system, skin and non-specific sick building symptoms. Distributions of these symptoms were presented according to potential risk factors, including personal, psychosocial and environmental factors.

Correlations (Spearman's test) between the variables for multi-co-linearity were investigated by creating a correlation matrix and then scanning for highly correlated variables ($\geq$0.7). To prevent multi-co-linearity, highly correlated variables were not included in the

Table 1. Distribution of demographic characteristics and sick building syndrome among hospital workers.

Variables	n	%	Symptoms	n	%
Personal factors			Eye	47	23.0
Age (40>)	82	60.3			
Female	85	62.5	Upper respiratory, any	83	40.7
Current smoker	84	41.2	Throat redness	44	21.6
Physical activity	64	31.4	Throat dryness	57	27.9
Regular sleep	136	66.7	Voice loss	52	25.5
Psychosocial factors			Blocked nose	51	25.0
Working time>5 day/week	28	13.7	Nose bleeds	35	17.2
Desk working>5 h/day	97	47.5			
Allergy history	49	24.0	Lower respiratory	46	22.5
Workload (high)	163	79.9			
Work motivation (low)	86	42.2	Skin, any	74	36.3
Environmental factors			Itchy hands	55	27.0
Exposure to chemicals	135	66.2	Red hand	50	24.5
Low indoor air flow	113	55.4	Itchy face	41	20.1
Indoor dryness	105	51.5	Red face	40	19.6
No daylight	95	46.6	Eczema	45	22.1
Indoor air quality	Median	(Q_1–Q_3)			
Temperature	26.00 (25.51–26.38)		Non-specific, any	130	63.7
Humidity	21.24 (21.10–22.79)		Continuous cold	48	23.5
PM_1	10.53 (10.53–14.40)		Continuous tiredness	100	49.0
$PM_{2.5}$	22.79 (22.79–25.00)		Difficulty concentrating	95	46.6
CO_2	550.54 (550.54–611.79)		Headache	74	36.3
Total bacteria	99.00 (81.00–158.00)				
Total fungi	15.00 (15.00–22.00)				

multiple logistic regression model. Univariate associations between SBS and potential risk factors were examined, and factors with $p < 0.2$ were selected for multiple logistic regression analysis.

Initially, personal factors and work stresses were tested with multiple logistic regression analysis to determine the potential risk factors related to SBS (Model 1). Secondly, environmental factors were tested using multiple logistic regression analysis to determine the potential risk factors related to SBS (Model 2). Thirdly to determine the correlation between IAQ parameters and SBS, multiple logistic regression analysis was used. Goodness of fit was measured with the χ^2 test and Hosmer and Lemeshow tests.[28] We used $p < 0.05$ to indicate statistical significance. ORs and 95% confidence intervals (CIs) were determined for univariate and multivariate associations of prevalence. All data analyses were performed using IBM SPSS version 23 for Windows.

Results

Socio-demographic characteristics

Of the 204 people participating in the research, 60.8% were under the age of 40 years and 63.2% were female, of which 50.5% of participants had never smoked and 8.3% had stopped smoking; 52.5% of participants worked at a desk for 5 h or more per day and 79.9% stated they had high workloads; 66.2% of participants were exposed to chemical substances. Personal factors, psychosocial factors and environmental factors for participants are shown in Table 1.

Air quality monitoring

The mean indoor temperature and RH for the hospital departments were 26.0°C and 21.24%, respectively. The hourly mean indoor CO_2 concentration was 550.5 ppm (550.54–611.79). Hourly mean $PM_{2.5}$ and PM_1 concentrations were 22.79 (22.79–25.00) $\mu g/m^3$ and 10.53 (10.53–14.40) $\mu g/m^3$, respectively. When CO_2 levels were examined, the paediatric clinic had highest results, while the emergency service had highest results for $PM_{2.5}$ and PM_1. None of the $PM_{2.5}$ measurements were above the EPA standard 24-h concentration[29] limit of 35 $\mu g/m^3$. The indoor air measurements for departments in the hospital are shown in Table 2.

Microbial measurements

When the microorganism proliferation densities of samples taken from the hospital were examined, the

densest bacterial and fungal proliferations occurred in the paediatric clinic and emergency service. Median total bacteria were measured as 99.00 CFU/m^3 (81.00–158.00). Median total fungi were identified as 15.00 CFU/m^3 (15.00–22.00) (Table 2). The most commonly isolated bacteria in air samples taken from a variety of clinics in the hospital were *Micrococcus luteus* (40%), *Staphylococcus haemolyticus* (19%), *Diphteroid* basil (17%), *Kocuriar hizophila (10%)*, *Staphylococcus hominis* (10%), *Basillus* spp. (3%) and others (1%). The most commonly isolated fungal colonies were identified as *Penicillum* spp. (56%) and *Aspergillus* spp. (18%). When total bacteria and fungi were compared with SBS, there were significant correlations identified between lower respiratory tract symptoms, upper respiratory tract symptoms and skin symptoms. With the increase in total bacterial and fungal densities, the incidence of symptoms increased (total bacteria $p = 0.020$, $p = 0.013$, $p = 0.031$; total fungal $p = 0.015$, $p = 0.002$, $p = 0.030$, respectively). There was a negative correlation identified between total fungi and temperature ($r = -0.177$, $p = 0.011$). For total fungi, the most prevalent was identified as *Penicillum* spp. (56%). The optimum proliferation temperatures for *Penicillum* spp. is 20–25°C.[30] Environmental measurements showed that the mean temperature was 24–27°C. The ambient temperature is particularly close to the temperature suitable for the growth of *Penicillium*.

SBS

For all participants, the prevalence of eye, upper respiratory tract, lower respiratory tract, skin and non-specific SBS symptoms were 23.0%, 40.7%, 22.5%, 36.3% and 63.7% (Table 1). The distribution of SBS symptoms of eye, upper respiratory tract, lower respiratory tract, skin and non-specific symptoms with personal, psychosocial and environmental factors is shown in Table 3. When personal factors are examined, women appeared to have more skin symptoms ($p < 0.001$) and more non-specific symptoms ($p = 0.04$). Non-specific symptoms appear to be higher among those aged 40 years and younger ($p = 0.037$) and those with allergies ($p = 0.003$). Skin symptoms were observed less among those with regular sleep ($p = 0.049$). When environmental factors were examined, workers in areas reporting stagnant air appeared to have more upper respiratory tract ($p = 0.044$), lower respiratory tract ($p = 0.018$), skin ($p = 0.044$) and non-specific symptoms ($p = 0.008$). Those working in areas without daylight were identified to have more non-specific symptoms ($p = 0.014$) (Table 3).

Table 2. Air quality measurement results according to departments.

Variables	Internal medicine clinic	Paediatric clinic	Microbiology lab	Biochemistry lab	Blood sample	Emergency waiting room (Day)	Emergency waiting room (Night)	Intensive care	Surgery room
Temp (°C)	25.30 ± 0.32	26.0 ± 0.03	26.38 ± 0.04	26.45 ± 0.06	24.30 ± 0.80	24.89 ± 0.23	26.13 ± 0.14	26.51 ± 0.13	27.11 ± 0.22
Humidity (%)	19.76 ± 1.85	24.3 ± 0.22	23.85 ± 0.21	22.79 ± 0.28	21.24 ± 0.55	20.75 ± 0.65	21.44 ± 0.37	11.17 ± 0.44	20.58 ± 0.56
CO_2 (ppm)	764.27 ± 94.63	1012 ± 99.79	589.74 ± 31.36	556.60 ± 22.03	550.54 ± 50.99	611.79 ± 54.82	525.95 ± 42.76	425.01 ± 25.43	422.09 ± 19.12
$PM_{2.5}$ (μg/m^{-3})	12.29 ± 0.94	25.49 ± 3.96	25.00 ± 0.92	15.7 ± 0.70	22.79 ± 1.59	26.83 ± 2.83	28.41 ± 1.65	6.42 ± 1.18	14.40 ± 1.61
PM_1 (μg/m^{-3})	6.70 ± 1.20	10.5 ± 0.72	18.10 ± 0.68	11.66 ± 0.67	10.53 ± 0.87	13.68 ± 1.09	19.43 ± 1.01	3.67 ± 0.80	2.48 ± 1.49
Bacteria (CFU/mm^3)	101	195	81	158	67	188	305	99	1
Fungi (CFU/mm^3)	22	35	15	20	15	45	42	10	0

Table 3. Correlation between sick building syndrome symptoms with personal, psychosocial and environmental factors (n = 204).

Variables Total, n (%)	Eye 47 (23.0)	Upper respiratory 83 (40.7)	Lower respiratory 46 (22.5)	Skin 74 (36.3)	Non-specific 130 (63.7)
Personal factors					
Gender					
Male	13 (17.3)	24 (32.0)	13 (17.3)	15 (20.0)	41 (54.7)
Female	34 (26.4)	59 (45.7)	33 (25.6)	59 (45.7)	89 (69.0)
p	>0.05	>0.05	>0.05	<0.001	0.04
Age					
<40	28 (22.6)	53 (42.7)	29 (23.4)	48 (38.7)	86 (69.4)
>40	19 (23.8)	30 (37.5)	17 (21.3)	26 (32.5)	44 (55.0)
p	>0.05	>0.05	>0.05	>0.05	0.037
Smoking habit					
Yes	21 (25.0)	41 (48.8)	25 (29.8)	33 (39.3)	54 (64.3)
No/quite	26 (21.7)	42 (35.0)	21 (17.5)	41 (34.2)	76 (63.3)
p	>0.05	0.048	0.039	>0.05	>0.05
Allergy					
Yes	36 (23.2)	58 (37.4)	33 (21.3)	51 (32.9)	40 (81.6)
No	11 (22.4)	25 (51.0)	13 (26.5)	23 (46.9)	90 (58.1)
p	>0.05	>0.05	>0.05	>0.05	0.003
Physical activity					
Yes	12 (18.8)	24 (37.5)	15 (23.4)	19 (29.7)	40 (62.5)
No	35 (25.0)	59 (42.1)	31 (22.1)	55 (39.3)	90 (64.3)
p	>0.05	>0.05	>0.05	>0.05	>0.05
Regular sleep					
Yes	27 (19.9)	53 (39.0).	26 (19.1)	43 (31.6)	81 (59.6)
No	20 (29.4)	30 (44.1)	20 (29.4)	31 (45.6)	49 (72.1)
p	>0.05	>0.05	>0.05	0.049	>0.05
Psychosocial factors					
Working time					
>5 day/week	39 (22.2)	70 (39.8)	39 (22.2)	62 (35.2)	112 (63.6)
< 5day/week	8 (28.6)	13 (46.4)	7 (25.0)	12 (42.9)	18 (64.3)
p	>0.05	>0.05	>0.05	>0.05	>0.05
Desk work					
>5 h/day	28 (25.2)	40 (36.0)	24 (21.6)	35 (31.5)	78 (70.3)
<5 h/day	19 (20.4)	43 (46.2)	22 (23.7)	39 (41.9)	52 (55.9)
p	>0.05	>0.05	>0.05	>0.05	0.034
Workload (high)					
Yes	38 (23.3)	37 (22.7)	64 (39.3)	58 (35.6)	108 (66.3)
No	9 (22.0)	9 (22.0)	19 (46.3)	16 (39.0)	22 (53.7)
p	>0.05	>0.05	>0.05	>0.05	>0.05
Work motivation (low)					
Yes	23 (19.5)	47 (39.8)	25 (21.2)	45 (38.1)	74 (62.7)
No	24 (27.9)	36 (41.9)	21 (24.4)	29 (33.7)	56 (65.1)
p	>0.05	>0.05	>0.05	>0.05	>0.05
Environmental factors					
Exposure to chemicals					
Yes	29 (21.5)	57 (42.2)	30 (22.2)	51 (37.8)	86 (63.7)
No	18 (26.1)	26 (37.7)	16 (23.2)	23 (33.3)	44 (63.8)
p	>0.05	>0.05	>0.05	>0.05	>0.05
S4xLow indoor air flow					
Yes	31 (27.4)	53 (46.9)	33 (29.2)	48 (42.5)	81 (71.7)
No	16 (17.6)	30 (33.0)	13 (14.3)	26 (28.6)	49 (53.8)
p	>0.05	0.044	0.018	0.040	0.008

(continued)

Table 3. Continued.

Variables Total, n (%)	Eye 47 (23.0)	Upper respiratory 83 (40.7)	Lower respiratory 46 (22.5)	Skin 74 (36.3)	Non-specific 130 (63.7)
Indoor dryness					
Yes	26 (24.8)	51 (48.6)	29 (27.6)	42 (40.0)	78 (74.3)
No	21 (21.2)	32 (32.3)	17 (17.2)	32 (32.3)	52 (52.5)
p	>0.05	0.018	>0.05	>0.05	<0.001
No daylight					
Yes	24 (25.3)	44 (46.3)	25 (26.3)	39 (41.1)	69 (72.6)
No	23 (21.1)	39 (35.8)	21 (19.3)	35 (32.1)	61 (56.0)
p	>0.05	>0.05	>0.05	>0.05	0.014

Table 4. Associations between sick building symptoms and the Personal factors.

Personal factors	Upper respiratory	Lower respiratory	Skin	Non-specific
Gender				
Male	1	1	1	1
Female	1.893 (1.032–3.471)	1.627 (0.776–3.410)	3.160 (1.616–6.180)	1.546 (0.835–2.863)
p	0.039	0.197	0.001	0.166
Smoking habit				
Yes	1867 (1.047–3.330)	1.968 (0.998–3.883)		
No/quit	1	1		
p	0.034	0.051		
Regular sleep				
Yes		1	1	1
No		1.485 (0.739–2.984)	1.541 (0.828–2.866)	1.516 (0.793–2.901)
p		0.267	0.172	0.208

Regression analysis

When SBS symptoms and personal factors were investigated, being a woman would increase the upper respiratory tract symptoms by 1.89 times ($p = 0.039$; OR = 1.893; 95% CI: 1.032–3.471). The smoking habit would increase these symptoms by 1.87 times ($p = 0.034$; OR = 1.867; 95% CI: 1.047–3.330). Being a woman would increase skin symptoms by 3.16 times ($p = 0.001$; OR = 3.160; 95% CI: 1.616–6.180) (Table 4).

Skin symptoms increased 1.82 times in areas reporting stagnant air flow ($p = 0.046$; OR = 1.823; 95% CI: 1.010–3.290). Non-specific symptoms increased 2.17 times in areas reporting dry indoor air ($p = 0.039$; OR = 2.176; 95% CI: 1.041–4.549). Not seeing daylight increased these symptoms by 2.07 times ($p = 0.018$; OR = 2.078; 95% CI: 1.135–3.805) (Table 5).

Correlations were shown between SBS symptoms and PM_1 and CO_2 measurements in the hospital. Eye symptoms increased 4.45 times when CO_2 exceeded 750 ppm ($p = 0.002$; OR = 4.451; 95% CI: 1.753–11.303). Upper respiratory tract symptoms increased 2.24 times when CO_2 exceeded 750 ppm ($p = 0.036$; OR = 2.546; 95% CI: 1.015–1.219). Each unit of PM_1 increased upper respiratory tract symptoms by 1.11 times ($p = 0.023$; OR = 1.112; 95% CI: 1.015–1.219). Skin symptoms increased 4.57 times when CO_2 exceeded 750 ppm ($p = 0.001$; OR = 4.571; 95% CI: 1.862–11.219). Each unit of PM_1 increased skin symptoms by 1.12 times ($p = 0.019$; OR = 1.120; 95% CI: 1.019–1.232).

Discussion

In this study, the effects of personal and environmental factors for hospital workers and of IAQ on SBS were researched. It appeared that hospital workers mainly had complaints related to non-specific, upper respiratory tract and skin symptoms. Variables related to non-specific, skin and upper respiratory tract symptoms included gender, age, smoking habit, allergies, working at a desk, low air flow, dry indoor air and lack of daylight. Additionally, CO_2 and PM_1 levels were observed to be variables associated with eye, skin and upper respiratory symptoms.

In the study by Lee et al.,[31] the airborne contamination limit was <500 CFU/mm^3. According to this,

Table 5. Associations between sick building symptoms and the environmental factors.

Environmental factors	Eye	Upper respiratory	Lower respiratory	Skin	Non-specific
Low indoor air flow					
Yes	2.017 (0.861–4.725)	1.294 (0.629–2.664)	2,273 (0.940–5.494)	1.823 (1.010–3.290)	
No	1	1	1	1	
p	0.106	0.484	0.068	0.046	
Indoor dryness					
Yes	0.799 (0.350–1.823)	1,677 (0.820–3.429)	1,126 (0.484–2.616)		2.176 (1.041–4.549
No	1	1	1		1
p	0.593	0.157	0.783		0.039
No daylight					
Yes	1.242 (0.643–2.398)	1.515 (0.857–2.681)	1.451 (0.742–2.837)		2.078 (1.135–3.805)
No	1	1	1		1
p	0.519	0.153	0.276		0.018

bacterial and fungal concentrations were identified to be moderately high in indoor air.[31] It appeared that higher bacterial and fungal concentrations were associated with SBS.

The most common SBS complaints in this study were identified as 'feeling continuously tired' (49.0%), 'difficulty concentrating' (46.6%) and 'headache' (36.3%). A previous study of 4329 office workers described the most common SBS symptoms as 'tired or strained eyes' (22%), 'dry, itchy or irritated eyes' (19%) and 'pain or tenseness in back and shoulders'.[32] A study of nurses working in hospitals found the most common symptoms of SBS were 'headache' (83.3%), 'tiredness' (89.6%) and 'heavy head' (77%).[33] The results show that SBS continues with the time people spend in the building and is a significant health problem for workers in indoor environments.

When personal factors were investigated, gender and smoking appeared to be associated with SBS. The incidence of skin and upper respiratory tract symptoms was higher among women compared to men. A study by Azuma et al.[34] showed that all SBS symptoms were higher for females. This effect of gender is in accordance with previous studies in the literature.[35–37] Smoking has been found to increase the incidence of upper respiratory tract symptoms. A study of 387 office workers stated that it was associated with upper respiratory tract symptoms. Environmental tobacco smoke was reported to be a risk for SBS symptoms in several studies.[1,38,39]

Work-related psychosocial factors, such as working days per week, workload and work motivation, were not identified to be associated with SBS symptoms. Marmot et al.[40] stated that high work demands and low support produced higher building condition linked symptoms than environmental conditions. This study did not find a correlation between high workload and work motivation with SBS.

People reporting dry air had higher probability of non-specific symptoms compared to those working in other areas. Working in areas with low airflow was identified to be associated with skin symptoms. Another study of office workers reached similar conclusions.[1] Workers in areas without daylight appeared to have higher incidence of non-specific symptoms. More research with larger samples should be performed to investigate the risk of airflow in enclosed environments.[41]

When the density of microorganism proliferation in the hospital was examined, the densest bacterial and fungal proliferation was observed in the paediatric clinic and the emergency service (day/night). The high number of patients and carers in these areas may have caused these high results. The most commonly isolated bacteria in air samples from the hospital were *M. luteus* (40%) and *S. haemolyticus* (19%). The most commonly isolated fungal colonies were identified as *Penicillum* spp. (56%) and *Aspergillus* spp. (18%). Previous research in a dental hospital identified *M. luteus* (31%) and *S. haemolyticus* (3%) and found total bacteria were highest in the paediatric section.[19] The results of bioaerosol measurements in different areas of the hospital identified moderate bacterial and fungal concentrations in indoor air. Other studies have reported similar results.[19,42] Concentrations of bacteria and fungi appeared to cause lower/upper respiratory tract symptoms and skin symptoms. Many bacteria and fungi are reported to cause allergies, rhinorrhoea (runny nose), nasal congestion and sore throat and irritation of nose and eyes.[43,44] Total bacteria and fungi may be due to the fixed temperature, humidity and ventilation system. Care should be taken especially for patients with suppressed immune systems.

Research shows that CO_2 and CO levels are important indicators for poor IAQ. This study only considers CO_2 and CO as IAQ parameters. Seppänen et al.[11]

reported that indoor CO_2 concentration and SBS symptoms had an effect on headache, fatigue, eye symptoms, nasal symptoms, respiratory symptoms and total SBS score.[11] CO_2 increased the symptoms of SBS by 70%.[11,12] Identification of headache in SBS symptoms has been reported in studies on indoor CO concentration.[10] However, volatile organic compounds (VOCs) and their relationships with SBS have been shown in studies conducted in homes and workplaces. Increased prevalence of SBS related to VOCs and some chemicals is indicated in studies.[1,12,45,46] Although VOCs and formaldehyde are considered to be important pollutants for SBS, in this study, these were not monitored.

SBS symptoms were significantly correlated with IAQ. Indoor measurements in the hospital found CO_2 (1012 ± 99.79 ppm) was highest in the paediatric clinic, with $PM_{2.5}$ (28.41 ± 1.65 $\mu g/m^3$) and PM^1 (19.43 ± 1.01 $\mu g/m^3$) was highest in the emergency service. The high number of patients and carers in the paediatric clinic and the crowded and active environment in the emergency service are considered to have caused these elevated results. Improved ventilation systems will lower the level of CO_2. Indoor CO_2 level was identified as a risk factor for eye, upper respiratory tract and skin symptoms. A study of schools by Norbäck et al.[47] identified that CO_2 was a risk factor for eye, respiratory tract and non-specific symptoms. Another study stated that there was no correlation between CO_2 and SBS.[1] A study with ventilation better than current ventilation standards did not show a significant correlation between CO_2 concentration and symptoms.[19] CO_2 is an indicator of ventilation adequacy in relation to occupant density. In indoor environments where the ventilation system is insufficient, CO_2 levels are high. In some of the studies, a relationship has been found between CO_2 and eye symptoms.[11] It was considered that the employees experienced eye and skin symptoms due to inadequate ventilation.[11]

PM_1 is a fine dust particle measurement. Each unit of PM_1 increased skin symptoms by 1.12 times ($p = 0.019$; $OR = 1.120$; 95% CI: 1.019–1.232). Experimental studies have shown that there was a relationship between eye irritation and exposure to PM_1, and that these symptoms were reduced with floor cleaning.[48] However, the measurements with the optical instrument used in the current study only provide information on particle concentrations, and no information on the particle composition. Particle composition analysis may be an important factor for skin symptoms. Each air quality parameter affects different SBS symptoms, and therefore a broad range of air quality parameters may need to be examined.

Limitations

There are some limitations to this study. It uses a cross-sectional study design, which limits any causal inferences and may be subject to a recall bias. This study was based on a self-reported questionnaire survey. Several environmental factors reported by respondents are subjective, and inaccuracies may have resulted in bias. This is also true of the subjective, self-reported health outcome assessments used in the study. Additionally, SBS may form with long durations spent indoors. The duration and type of indoor conditions that participants spend time in apart from work were unknown. The prevalence of SBS identified in the study may be affected by time spent in indoor environments apart from the hospital. In other studies, VOC measurements were performed but were unavailable in this study. Future studies are planned.

Conclusion

This paper has found that workers in the study hospital were exposed to conditions that may increase the risk of a variety of SBS symptoms. The observation of SBS symptoms among hospital workers was identified to be linked to PM_1, CO_2, being female, smoking, low airflow, dry air and lack of daylight. Indoor air pollution of hospitals may be related to building environment factors such as construction materials, ventilation systems and ventilation rates and to human factors such as crowding in limited areas. This study found high bacterial counts of up to 305 CFU/m^3 in the emergency service at night. This is considered to be related to high patient and carer numbers. Long-term observation can be performed to monitor the effects of IAQ on SBS in physicians, other health personnel and patients. Additionally, as some personal factors such as sex, age, smoking habits were correlated with the prevalence of the syndrome, epidemiological research about these factors and SBS should be carefully completed.

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Authors' contribution

All authors contributed equally to the preparation of this article.

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