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Sick building syndrome (SBS) among office workers in a Malaysian university — Associations with atopy, fractional exhaled nitric oxide (FeNO) and the office environment

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HIGHLIGHTS

- Atopy and elevated FeNO show strong association with SBS symptoms.
- Combined atopy and elevated FeNO levels strongly associated with SBS symptoms.
- Transient symptoms were associated with room temperature and relative air humidity.
- Der f1 levels in dust associated to SBS and transient symptoms
- Der f1 levels in dust associated to SBS symptoms of workers who are allergic to *D. farinae*

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ABSTRACT

There are few studies on sick building syndrome (SBS) including clinical measurements for atopy and fractional exhaled nitric oxide (FeNO). Our aim was to study associations between SBS symptoms, selected personal factors, office characteristics and indoor office exposures among office workers from a university in Malaysia. Health data were collected by a questionnaire (n = 695), skin prick test (SPT) (n = 463) and FeNO test (n = 460). Office settled dust was vacuumed and analyzed for endotoxin, (1,3)-β-glucan and house dust mites (HDM) allergens group 1 namely *Dermatophagoides pteronyssinus* (Der p 1) and *Dermatophagoides farinae* (Der f 1). Office indoor temperature, relative air humidity (RH), carbon monoxide (CO) and carbon dioxide (CO_2) were measured by a direct reading instrument. Associations were studied by two-levels multiple logistic regression with mutual adjustment and stratified analysis. The prevalence of weekly dermal, mucosal and general symptoms was 11.9%, 16.0% and 23.0% respectively. A combination of SPT positivity (allergy to HDM or cat) and high FeNO level (≥25 ppb) was associated with dermal ($p = 0.002$), mucosal ($p < 0.001$) and general symptoms ($p = 0.05$). Der f1 level in dust was associated with dermal ($p < 0.001$), mucosal ($p < 0.001$) and general ($p = 0.02$) symptoms. Among those with allergy to *D. farinae*, associations were found between Der f 1 levels in dust and dermal ($p = 0.003$), mucosal ($p = 0.001$) and general symptoms ($p = 0.007$). Office-related symptoms were associated with Der f 1 levels in dust ($p = 0.02$), low relative air humidity ($p = 0.04$) and high office temperature ($p = 0.05$). In conclusion, a combination of allergy to cat or HDM and high FeNO is a risk factor for SBS symptoms. Der f 1 allergen in dust can be a risk factor for SBS in the office environment, particularly among those sensitized to Der f 1 allergen.

1. Introduction

Indoor air quality is an important issue since people in industrialized countries spend most of their time in indoor environments. The World Health Organization (WHO) defined the concept of sick building

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syndrome (SBS) in 1983 as certain medical symptoms experienced by occupants in buildings with indoor environment problems (World Health Organization, 1983). SBS was initially studied among office workers, and include symptoms from eyes, upper airways, facial skin, headache and tiredness. SBS is a group phenomenon and not a syndrome as normally defined in medicine and individual diagnostic is difficult (Norbäck, 2009).

SBS studies have been carried out in different indoor environment but mostly among office workers (Apter et al., 1994). A number of risk factors for SBS have been identified (Andersson, 1998; Apter et al., 1994; Norbäck, 2009), including personal factors, psychosocial work environment and indoor environment factors. Female gender (Brasche et al., 2001; Stenberg and Wall, 1995), allergy (Björnsson et al., 1998; Sahlberg et al., 2012), personality traits (Runeson et al., 2004) and lower sense of coherence (Runeson et al., 2003) were reported to be associated with SBS. Moreover, unbalanced psychosocial work environment (Marmot et al., 2006; Runeson et al., 2006) and occupational stress (Azuma et al., 2014; Bakke et al., 2007) have been shown to be related to SBS symptoms. Indoor environmental factors associated with SBS include room temperature (Bakke et al., 2008), relative air humidity (Wolkoff, 2008), building dampness (Mendell et al., 2011; Park et al., 2008), ventilation flow (Seppänen and Fisk, 2004; Sundell et al., 2011), microbial exposure such as molds and bacteria (WHO, 2009), microbial volatile organic compounds (MVOC) (Araki et al., 2010; Sahlberg et al., 2013) and volatile organic compounds (VOC) (Takigawa et al., 2012).

SBS symptoms can be related to building dampness and indoor mold growth (World Health Organization, 2009). In damp buildings, mold and bacteria compounds are found in settled dust. Endotoxin is a compound found in the outer cell membrane of gram-negative bacteria (Gehring et al., 2008), while (1,3)-β-glucan is found in the cell-walls of mold (Iossifova et al., 2007). Endotoxin and (1,3)-β-glucan has pro-inflammatory effects. However, few studies have been carried out to study associations between these environmental microbial compounds and SBS symptoms among office workers. Previously, endotoxin exposure has been related to SBS in office buildings (Teeuw et al., 1994), high number of reported symptoms (Reynolds et al., 2001), upper respiratory symptoms and headache in office workers (Park et al., 2006). A study in water-damaged offices found that endotoxin exposure was positively associated with nasal inflammatory markers (eosinophilic cationic protein and interleukin-8) among office workers (Akpinar-Elci et al., 2013). An office study in Taiwan showed an association between (1,3)-β-glucan and fatigue in office workers (Wan and Li, 1999). Park et al. (2006) reported an interaction effect between endotoxin and fungal exposure among office workers from a water-damaged office building in United State (Park et al., 2006). House dust mites (HDM) contain allergens and HDM allergy is common globally (Milián and Díaz, 2004). HDM allergens are mainly studied in homes but can also be found in the office environment. Menzies and coworkers reported that respiratory symptoms in workers were associated with HDM levels in office dust (Menzies et al., 1998). However, Brunetto et al. (2009) did not find any association between nasal and skin symptoms in employees and HDM levels in office dust possible due to a low number of dust samples with HDM allergens (Brunetto et al., 2009).

Tropical countries have warm and humid climate which provide favorable conditions for microbial growth. Some studies on SBS among office workers have been carried out in tropical countries, such as in Turkey (Gül et al., 2007), Brazil (Costa and Brickus, 2000; Graudenz et al., 2002, 2005; Rios et al., 2009), Mauritius (Bholah and Subratty, 2002), Taiwan (Wan and Li, 1999) and Singapore (Ooi et al., 1998; Ooi and Goh, 1997). However, only a few office studies on SBS among office workers have been published from Malaysia. Zamani et al. (2013) reported that one old office building had higher prevalence of SBS than a new office building. Prevalence of SBS was associated with carbon dioxide (CO_2), total VOC (TVOC), particulate matter 10 (PM10), particulate matter 2.5 (PM2.5) and ultrafine particles (UFP) levels in the offices (Zamani et al., 2013). Fadilah and Juliana (2012) found a higher prevalence of nasal symptoms in workers from new office buildings (Fadilah and Juliana, 2012). Another office study found no association between prevalence of *Penicillium* specific IgE among office workers and prevalence of eyes or nasal symptoms (Goh et al., 2007). None of these office studies from Malaysia have included clinical data or biomarkers except the study from Goh and coworkers.

SBS is important to study since it can lead to poor productivity and absenteeism among workers (Singh, 2005). However, there is lack of office studies on associations between SBS symptoms and levels of microorganisms and allergens in tropical countries, especially in Malaysia. Moreover, we found that no study investigated associations between SBS symptoms and fractional exhaled nitric oxide (FeNO), a biomarker of T-helper 2 driven lower airway inflammation. Thus, the overall aim was to study SBS symptoms among office workers in a university in Malaysia and investigate associations between the office environment and selected personal factors, including FeNO and atopy, and these symptoms. The first aim was to study associations between SBS symptoms and age, gender, allergy (skin prick test positivity to HDM or cat), current smoking and fraction of exhaled nitric oxide (FeNO). The second aim was to study the associations between SBS symptoms and selected office characteristics and measured indoor exposures.

2. Materials and methods

2.1. Study population

The study population consisted of office workers in a major academic institution, Malaysia. The registrar office of the academic institution was contacted to get a list of all offices and number of employees in each office. Totally, there were 61 offices in the academic institution. The inclusion criterion for selection of offices was that they should be administrative offices equipped with air-conditioning mechanical ventilation system and have at least 15 office workers. Initially, 50 offices fulfilled the inclusion criteria, however, 4 offices were excluded because the workers had mainly work tasks different from ordinary office work. Letters were sent to the top management level of the 46 offices for permission and 40 out of 46 offices gave verbal or written consent.

Totally, 2192 office workers were employed in these 40 offices. All administrative office workers were invited to participate through email, announcement and face-to-face invitation. Totally 701 out of 2192 office workers agreed to participate (32.0%). Six office workers were excluded because of pregnancy leaving 695 to be included. Among these 695 respondents, 465 agreed to participate in skin prick test. However, two were excluded due to recent severe asthma leaving 463 respondents. Among these 463 respondents, 460 of them participated in both skin prick test (SPT) and fraction of exhaled nitric oxide (FeNO) test. Researchers distributed a self-administered questionnaire to the respondents which was collected on the same day or the following days. The questionnaires were answered by the respondents within two weeks from the environmental measurements. After collecting the questionnaire, the researchers went through it and face-to-face interviewed the respondents to clarify uncertainties in the answers or missing data.

The study was approved by the Ethics Committee for Research Involving Human Subjects at Universiti Putra Malaysia (UPM) before the field data collection. All participants gave informed consent. They gave written consent after being informed on the objective of the study and procedures.

2.2. Questionnaire

The respondents were given a self-administrative questionnaire to collect data about demographic information, home environment, office characteristics and SBS symptoms. The questions were adapted from Indoor Air Quality and Work Symptoms Survey, NIOSH (National Institute