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Association between indoor air pollutant exposure and blood pressure and heart rate in subjects according to body mass index

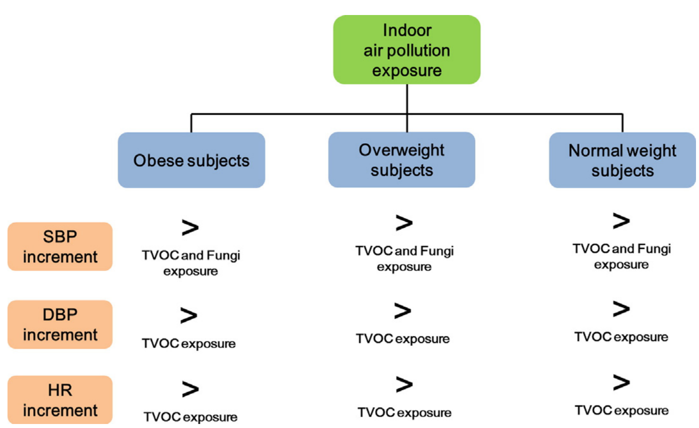
Chien-Cheng Jung, Huey-Jen Su *, Hsiu-Hao Liang

Dept. of Environmental and Occupational Health, College of Medicine, National Cheng Kung University, Tainan City, Taiwan

HIGHLIGHTS

- Obese populations have high SBP values when they exposure to high TVOC and fungi.
- There are higher DBP and HR levels with increasing BMI and exposure to TVOC level.
- Obese population have higher heart diseases risk when they exposure to poorer IAQ.

GRAPHICAL ABSTRACT



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ABSTRACT

This study investigates the effects of high body mass index (BMI) of subjects on individual who exhibited high cardiovascular disease indexes with blood pressure (BP) and heart rate (HR) when exposed to high levels of indoor air pollutants. We collected 115 office workers, and measured their systolic blood pressure (SBP), diastolic blood pressure (DBP) and HR at the end of the workday. The subjects were divided into three groups according to BMI: 18–24 (normal weight), 24–27 (overweight) and >27 (obese). This study also measured the levels of carbon dioxide (CO_2), total volatile organic compounds (TVOC), particulate matter with an aerodynamic diameter less than 2.5 μm ($PM_{2.5}$), as well as the bacteria and fungi in the subjects' work-places. The pollutant effects were divided by median. Two-way analysis of variance (ANOVA) was used to analyze the health effects of indoor air pollution exposure according to BMI. Our study showed that higher levels of SBP, DBP and HR occurred in subjects who were overweight or obese as compared to those with normal weight. Moreover, there was higher level of SBP in subjects who were overweight or obese when they were exposed to higher levels of TVOC and fungi ($p < 0.05$). We also found higher value for DBP and HR with increasing BMI to be associated with exposure to higher TVOC levels. This study suggests that individuals with higher BMI have higher cardiovascular disease risk when they are exposed to poor indoor air quality (IAQ), and specifically in terms of TVOC.

* Corresponding author at: Department of Environmental and Occupational Health, Out-Patient Building, College of Medicine, National Cheng Kung University, 138 Sheng-Li Road, Tainan City 70403, Taiwan.
E-mail address: hjsu@mail.ncku.edu.tw (H.-J. Su).

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1. Introduction

A WHO reports (WHO, 2008) has indicated that the prevalence of obesity in 2008 was already nearly twice that in 1980, and there about 1.9 billion adults (18 years and older) identified as being overweight in 2014. These figures imply that obesity is clearly an important consideration when evaluating public health concerns. Previous studies have shown that populations with obesity have higher values of inflammatory mediators, blood pressure (BP) and heart rate (HR) than to non-obese populations (Bhan et al., 2010; Cao et al., 2012; Ke et al., 2009; Lumeng and Saltiel, 2011; Vazquez-Vela et al., 2008). Inflammatory mediators can involve the pathogenesis of cardiovascular diseases (Ikeoka et al., 2010; Lumeng and Saltiel, 2011; Van Gaal et al., 2006; Wang et al., 2007). BP and HR are markers of autonomic activity (Bootsma et al., 1994; Grassi, 1998). Many studies have indicated that patients with cardiovascular diseases have higher BP and HR than the healthy population (Kolloch et al., 2008; Palatini et al., 2002), and these studies have further suggested that BP and HR can be viewed as markers of cardiovascular diseases (Kannel, 1996; Vasan et al., 2001). Therefore, populations with obesity have a higher risk of cardiovascular diseases than those with normal weight (Li et al., 2006; Reinehr et al., 2006).

Many studies have demonstrated that air pollutants, such as particulate matter (PM), TVOC and ozone (O_3), can increase the mortality or hospital admission for cardiovascular diseases (Azevedo et al., 2011; Bell et al., 2009; Pope et al., 2004; Xu et al., 2010). Some studies have also found that exposure to pollen can increase the mortality due to of cardiovascular diseases (Brunekreef et al., 2000; Diaz et al., 2007). PM or O_3 exposure has also been associated with variability in BP and HR (Baumgartner et al., 2011; Hoffmann et al., 2012; Lin et al., 2011; Lin et al., 2009; Wu et al., 2010). Therefore, air pollution is an important risk factor for cardiovascular diseases.

Recently, many studies have further demonstrated that populations with obesity exhibit higher risk of cardiovascular diseases when they are exposed to air pollutants compared to populations with normal weight (Chen et al., 2007; Huang et al., 2012; Miller et al., 2007; Puett et al., 2009; Weichenthal et al., 2014). However, even though most people spend a large proportion of their time indoors, much of the environmental data used for reference is taken from outdoor air quality monitoring stations. Moreover, the compositions, sources and levels of indoor and outdoor pollutants are different from those indoors. Some studies have found the levels of TVOCs in indoor air to be higher than those in outdoor air, and the sources of TVOCs have been shown to be different for indoor and outdoor air (Edwards et al., 2001; Pegas et al., 2012). Pegas and his co-researchers also found that the levels of methanol, acetone, dichloromethane and toluene were higher in indoor than in outdoor air (Pegas et al., 2012). Other studies have found that the PM levels and compositions were different in indoor and outdoor air. Oeder's study indicated that there were higher levels of organic matter and silicon (Si) metal in indoor air as compared to outdoor air, but the level of sulfur (S) was shown to be lower in indoor air (Pegas et al., 2012). Some studies have also found that the levels of organic and elemental carbon were higher in indoor air as compared to outdoor air (Oeder et al., 2012). Pegas and his co-workers indicated that the concentrations of soluble chloride, sodium and calcium were higher in indoor air as compared to outdoor air (Pegas et al., 2012). Furthermore, many studies have demonstrated that organic carbon, elemental carbon and chloride exposure can increase the risk of cardiovascular diseases (Polidori et al., 2006; Son et al., 2012; Zanobetti et al., 2009). Thus, indoor air pollution data seems to be an appropriate to measure to accurately assess and compare the effects of air pollutant exposure on obese and non-obese populations.

In this study, we sampled indoor air pollutants in office spaces, and took the values of BP and HR from subjects on the same day. We also analyzed whether subjects who are overweight or obese have higher values for BP and HR when they are exposed to higher levels of indoor air pollutants than those exhibited in individuals of normal weight.

2. Material and methods

2.1. Study design and subject

A cross-sectional study was performed to investigate whether indoor air pollutant exposure resulted in higher BP and HR values in people according to body weight index (BMI). For the purposes of this study, 143 office workers (twenty-one office spaces) from four organizations in Kaohsiung and Tainan City were recruited from July, 2011 to December, 2012. Of these 28 subjects were further eliminated either because of the lack of their health indicators or because of missing information on their questionnaires. Thus, a total of 115 subjects were included in the final assessment. Air pollutants in these offices were measured during office hours (09:00–17:00). BP and HR were taken at the end of the workday. All participants were also asked to complete a self-reported questionnaire including questions regarding their personal information. This study was approved (ER-99–040) by Institutional Review Board of National Cheng Kung University Hospital, Tainan, Taiwan. All participants also signed and provided their consent form to be in the study group.

2.2. Indoor air quality measurement

CO_2, TVOCs, $PM_{2.5}$, fungi and bacteria were monitored simultaneously during office hours. CO_2 levels were examined using the Q-TRAK Indoor Air Quality Monitor (Model 7575, TSI Corporation, Shoreview, USA). A real-time RAE/PGM-730 instrument (Model ppbRAE 3000, ProRAE Corporation, San Jose, USA) was used to measure the levels of TVOCs. The level of $PM_{2.5}$ was determined using a DUST-TRAK Aerosol Monitor (Model 8520, TSI Corporation, Shoreview, USA). A Signal-stage Anderson bioaerosol sampler with a flow rate of 28.3 l/min was used to collect bacteria and fungi in the air every three hours, and the sampling time was one minute. Concentrations of bacteria and fungi were obtained using two culturing media and conditions: Dichloran Glycerol (DG-18) at 25 ± 1 °C for five days and Tryptic Soy Agar (TSA) at 30 ± 2 °C for two days.

2.3. Health indicators and personal information collection

SBP, DBP and HR were taken using a BP monitoring meter (Terumo, Japan). Queries for personal information included age, gender, level of education, monthly income, smoking behavior, alcohol consumption, exercise frequency and height. Body weight was taken using a body weight scale (OMRON, Japan). BMI was calculated by dividing body weight (kg) by height squared (m^2). BMI was divided into three groups: 18–24 (normal weight), 24–27 (overweight) and >27 (obese) according to Taiwan Minister of Health and Welfare recommendations.

2.4. Statistical analysis

Two-way ANOVA was used to test the differences in BP and HR in the different groups with the BMI and pollutant levels. A logistic regression model was used to calculate the odds ratio (OR). A Mixed-effect model was used to estimate the regression coefficient, and SAS 9.2 software (SAS Institute Inc., Cary, USA) was used to analyze data. The statistical significance was set at $p < 0.05$.

3. Results

3.1. Study population characteristics

This study randomly recruited 115 office workers from 21 offices in order to obtain their SBP, DBP and HR values and to investigate whether subjects who were overweight or obese have higher SBP, DBP and HR values when they are exposed to higher levels of indoor air pollutants. The distribution for the SBP, DBP and HR values for the subjects is