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# Long-term indoor air conditioner filtration and cardiovascular health: A randomized crossover intervention study

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ABSTRACT

The association of short-term air pollution filtration with cardiovascular health has been documented. However, the effect of long-term indoor air conditioner filtration on the association between air pollution and cardiovascular health is still unclear. We recruited 200 homemakers from Taipei and randomly assigned 100 of them to air filtration or control intervention; six home visits were conducted per year from 2013 to 2014. The participants under air filtration intervention during 2013 were reassigned to control intervention in 2014. The air pollution measurements consisted of particulate matter less than or equal to 2.5 μm in diameter ($PM_{2.5}$) and total volatile organic compounds (VOCs); blood pressure was monitored for each participant during each visit. The following morning, blood samples were collected after air pollution monitoring. The blood samples were used to analyze biological markers, including high sensitivity-C-reactive protein (hs-CRP), 8-hydroxy-2′-deoxyguanosine (8-OHdG) and fibrinogen. Household information, including cleaning, cooking, and air conditioning, was collected by a questionnaire. Mixed-effects models were used to investigate the associations among air pollution measurements, blood pressure and biological markers. The results showed that increased levels of $PM_{2.5}$ and total VOCs were associated with increased hs-CRP, 8-OHdG and blood pressure. The health variables were higher among participants in the control intervention phase than among those in the air filtration intervention phase. We concluded that air pollution exposure was associated with systemic inflammation, oxidative stress and elevated blood pressure. The long-term filtration of air pollution with an air conditioner filter was associated with cardiovascular health of adults.

## 1. Introduction

The association between air pollution exposure and cardiovascular effects has been well documented in previous epidemiological studies (Chuang et al., 2011; Kaufman et al., 2012; Lipfert, 2016). The World Health Organization (WHO) has announced that approximately 7 million deaths worldwide in 2012 were linked to air pollution exposure (WHO, 2014). It has been reported that indoor air pollution has equal or greater effects on cardiovascular health compared with ambient air pollution because people spend more time indoors (Klepeis et al., 2001), exposing themselves to indoor air pollutants. These pollutants comprise particulate matter (PM) and volatile organic compounds (VOCs) and are mostly derived from cooking, cleaning and incense burning (Huang et al., 2014) as well as from the outdoors (Polidori

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et al., 2007). The association between indoor air pollution and cardiovascular effects has also been reported in previous studies (Bräuner et al., 2008; Huang et al., 2014; Jung et al., 2016; Lin et al., 2013).

Previous studies have reported that particle filtration reduced adverse health effects in subjects with allergies or asthma (Sublett, 2011; Wood, 2002). The potential benefits of particle filtration on the association between reducing indoor exposure to particles from outdoor air and reductions in morbidity and mortality has been suggested in a previous review (Fisk, 2013). Recently, several studies have investigated the relationship between short-term indoor air filtration and human health. Allen et al. (2011) conducted a randomized crossover intervention study of 45 healthy adults in a wood smoke-impacted community who were exposed to consecutive 7-day periods of filtered and non-filtered air by portable air filters in Canada. The results showed that air filtration was associated with improved endothelial function and decreased inflammatory biomarkers. Padró-Martínez et al. (2015) conducted a randomized crossover intervention study of 20 healthy adults in public housing near a highway who were exposed to consecutive 21-day periods of filtered and non-filtered air by window-mounted air filtration units in the USA. They found no significant association of air filtration with improved cardiovascular health. However, the association between long-term indoor air filtration and cardiovascular health using personal exposure and health data is still unclear. Therefore, we designed this study to evaluate this scientific question and assess whether long-term improvements in indoor air quality by air conditioner filtration are beneficial for cardiovascular health.

## 2. Methods

### 2.1. Participants and randomized crossover design

We recruited 422 healthy homemakers (housewives and husbands) aged 30 to 65 years who were living in the Taipei metropolitan area through an advertisement. The selection criteria of the study participants were as follows: no history of smoking and no related cardiovascular diseases, such as arrhythmia, hypertension, diabetes mellitus and coronary artery disease. Two hundred homemakers (47%) met the selection criteria and were willing to participate after the study design had been explained.

The study design (Fig. 1) included 12 home visits that occurred at two-month intervals from January 1, 2013 to December 31, 2014. The air pollution and blood pressure were monitored for each participant during each visit. The following morning, a blood sample was collected for biological marker analysis. Half of the 200 participants were randomly assigned to air filtration intervention from January 1, 2013 to December 31, 2013, during which six home visits were conducted. Then, they were reassigned to control intervention from January 1, 2014 to December 31, 2014, during which another six home visits were conducted. The remaining 100 participants were assigned to control intervention in 2013, during which six home visits were conducted, and were then reassigned to air filtration intervention in 2014, during which another six home visits were conducted. Each of the 200 participants experienced both the air filtration and control interventions as well as 12 home visits from January 1, 2013 to December 31, 2014. During the air filtration intervention, the participants were instructed to close their windows, the research staff added a true air conditioner filter (Filtrete™ A/C Filter, 3M, MN, USA) to their air conditioner, and the participants left their air conditioner on all day during the study period (approximately one year). The Micro-Particle Performance Rating, Minimum Efficiency Reporting Value Rating and the efficiency of this filter were 1000, 11 and 80%, respectively. For the control intervention phase, the participants were also instructed to close their windows, but research staff added a false air conditioner filter (gauze, pore size $> 10$ μm) to their air conditioner, and the participants left the air conditioner on until the end of the control intervention. All of the participants' air conditioners were window-mounted air conditioners. Each participant had approximately three window-mounted air conditioners in his/her home, which were installed in the living room plus dining room, master bedroom and guest bedroom. The sizes were approximately 135 $m^3$, 60 $m^3$ and 51 $m^3$ for living room plus dining room, master bedroom and guest bedroom, respectively.

The air conditioner filter or gauze was cut to fit the air conditioners in each participant's home for both the air filtration and control intervention phases. The research staff checked the air conditioner every week and replaced the air conditioner filter and gauze if necessary (broken, fallen, etc.). Each participant's age, sex, body mass index (BMI), home characteristics and time-activity patterns were recorded by a questionnaire that was completed during each home visit. The research staff recovered and checked the questionnaire every week and contacted the participant by phone if necessary (missing data). The research staff who were responsible for data analysis and all participants were blinded to the intervention assignment.

This study was approved by the local ethics committee and

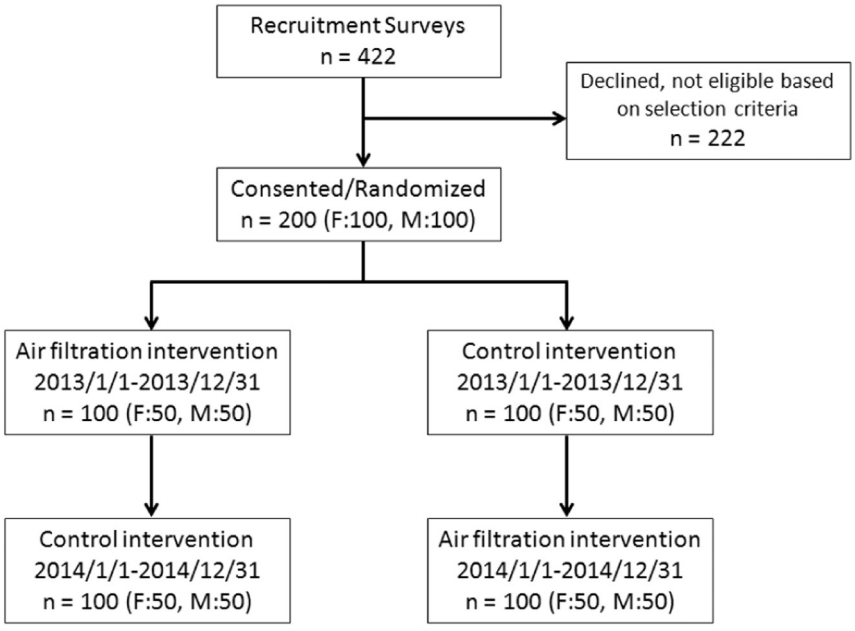


**Fig. 1.** Study flow chart.