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Cardiopulmonary Benefits of Reducing Indoor Particles of Outdoor Origin

A Randomized, Double-Blind Crossover Trial of Air Purifiers

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ABSTRACT

BACKGROUND Indoor exposure to fine particulate matter ($PM_{2.5}$) from outdoor sources is a major health concern, especially in highly polluted developing countries such as China. Few studies have evaluated the effectiveness of indoor air purification on the improvement of cardiopulmonary health in these areas.

OBJECTIVES This study sought to evaluate whether a short-term indoor air purifier intervention improves cardiopulmonary health.

METHODS We conducted a randomized, double-blind crossover trial among 35 healthy college students in Shanghai, China, in 2014. These students lived in dormitories that were randomized into 2 groups and alternated the use of true or sham air purifiers for 48 h with a 2-week washout interval. We measured 14 circulating biomarkers of inflammation, coagulation, and vasoconstriction; lung function; blood pressure (BP); and fractional exhaled nitric. We applied linear mixed-effect models to evaluate the effect of the intervention on health outcome variables.

RESULTS On average, air purification resulted in a 57% reduction in $PM_{2.5}$ concentration, from 96.2 to 41.3 $\mu g/m^3$, within hours of operation. Air purification was significantly associated with decreases in geometric means of several circulating inflammatory and thrombogenic biomarkers, including 17.5% in monocyte chemoattractant protein-1, 68.1% in interleukin-1β, 32.8% in myeloperoxidase, and 64.9% in soluble CD40 ligand. Furthermore, systolic BP, diastolic BP, and fractional exhaled nitrous oxide were significantly decreased by 2.7%, 4.8%, and 17.0% in geometric mean, respectively. The impacts on lung function and vasoconstriction biomarkers were beneficial but not statistically significant.

CONCLUSIONS This intervention study demonstrated clear cardiopulmonary benefits of indoor air purification among young, healthy adults in a Chinese city with severe ambient particulate air pollution. (Intervention Study on the Health Impact of Air Filters in Chinese Adults; NCT02239744) (J Am Coll Cardiol 2015;65:2279–87) © 2015 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

BP = blood pressure

CI = confidence interval

CRP = C-reactive protein

FeNO = fractional exhaled nitric oxide

MCP-1 = monocyte chemoattractant protein-1

$PM_{2.5}$ = particulate matter with an aerodynamic diameter <2.5 μm

sCD40L = soluble CD40 ligand

TNF-α = tumor necrosis factor-α

Numerous studies have demonstrated that ambient fine particulate (particulate matter with an aerodynamic diameter <2.5 μm, $PM_{2.5}$) air pollution is significantly associated with increased cardiopulmonary morbidity and mortality (1,2). Furthermore, $PM_{2.5}$ may exacerbate cardiopulmonary symptoms, sometimes even within hours of exposure, and may result in serious adverse outcomes, such as chronic obstructive pulmonary disease (3), myocardial infarction (4), heart failure (5), fatal arrhythmias (6), sudden cardiac arrest (7), and stroke (8). The underlying biological mechanisms for these associations

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are not yet well understood, although there are hypotheses that implicate inflammation, impaired lung function, oxidative stress, increased arterial blood pressure (BP), endothelial dysfunction, blood coagulation, arterial vasoconstriction, and altered cardiac autonomic function (1).

China has one of the highest levels of ambient $PM_{2.5}$ in the world. It was estimated that ambient $PM_{2.5}$ contributed to more than 1.2 million deaths and a loss of 24 million healthy years in China and ranked fourth among all contributions to the health burden (9). Outdoor $PM_{2.5}$ can penetrate indoors. In China, urban residents on average spend 87% of their time indoors, and this percentage may be even higher for vulnerable subgroups, such as young children and the elderly population (10). Therefore, it is critically important to identify ways to effectively reduce indoor exposure to $PM_{2.5}$ of outdoor origin. Unlike the outdoor environment, a substantial reduction of $PM_{2.5}$ can be achieved in the indoor environment simply by using air filters, cleaners, or purifiers. Indeed, several previous studies suggest potential benefits of indoor use of air filters on cardiopulmonary health (11–14). However, these studies were conducted in less polluted countries, and empirical evidence from China is lacking.

Therefore, we conducted a randomized, double-blind crossover study to examine whether short-term use of air purifiers improves cardiopulmonary health among healthy young adults in Shanghai, the largest city in China. We chose circulating biomarkers and lung function as the primary endpoints because they have been consistently associated with air pollution in observational studies (15–17). The secondary endpoints included BP and indicators of respiratory inflammation.

METHODS

STUDY PARTICIPANTS AND DESIGN. We recruited 35 healthy college students on the basis of sample size calculations for the primary endpoints using noninferiority tests in the software PASS version 11 (NCSS, LLC, Kaysville, Utah) (18,19). We set the significance level (alpha) at 0.05 with 80% power and estimated the noninferior margins and standard deviations of primary endpoints on the basis of data from 2 quasi-experimental air pollution studies among healthy college students in China (17,20). Our study participants were from 10 dormitory rooms (each approximately 20 m^2) in 2 adjacent buildings, with 3 or 4 participants per room. All participants and their roommates were nonsmokers. Their rooms were thoroughly cleaned before the intervention to ensure that there were no observable indoor sources of air pollution. All subjects declared that they had no clinically diagnosed chronic cardiopulmonary diseases.

The study was conducted during several weekends of 2014 at the Fenglin campus of Fudan University, located in the central urban area of Shanghai. This intervention was designed as a randomized, double-blind crossover study. To be specific, the 10 rooms were randomized into 2 groups of 5 rooms each. One group used an air purifier placed in the center of the room for 48 h, which corresponded to 2 weekends, followed by a 2-week washout period, and then used a sham air purifier under the same conditions for another 48 h. The other group simply reversed the order in which the real and sham air purifiers were used. All rooms used the same qualified air purifiers (model FAP04, 3M Filtrete, Shanghai, China), with the only difference being removal of the filter gauze in the sham purifiers. The air pollution autosensing feature of the air purifiers was disabled in both groups. All participants and research staff were blinded to the group assignment. We requested all participants to stay in their dormitory room with the windows and doors closed throughout each 48-h intervention period. We delivered food and drinks to each room during the intervention period. All interventions started at 8 AM to avoid issues related to diurnal variation. We evaluated health endpoints and drew blood immediately after the completion of each 48-h intervention.

The Institutional Review Board of the School of Public Health, Fudan University approved the study protocol, and all participants provided written informed consent before enrollment. This study was registered (Clinical Trials identifier NCT02239744).

EXPOSURE ASSESSMENT. We measured indoor and outdoor $PM_{2.5}$ concentrations in real time using the