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Effect of Portable Air Filtration Systems on Personal Exposure to Fine Particulate Matter and Blood Pressure Among Residents in a Low-Income Senior Facility

A Randomized Clinical Trial

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IMPORTANCE Fine particulate matter (smaller than 2.5 μm) ($PM_{2.5}$) air pollution is a major global risk factor for cardiovascular (CV) morbidity and mortality. Few studies have tested the benefits of portable air filtration systems in urban settings in the United States.

OBJECTIVE To investigate the effectiveness of air filtration at reducing personal exposures to $PM_{2.5}$ and mitigating related CV health effects among older adults in a typical US urban location.

DESIGN, SETTING, AND PARTICIPANTS This randomized, double-blind crossover intervention study was conducted from October 21, 2014, through November 4, 2016, in a low-income senior residential building in Detroit, Michigan. Forty nonsmoking older adults were enrolled, with daily CV health outcome and $PM_{2.5}$ exposure measurements.

INTERVENTIONS Participants were exposed to the following three 3-day scenarios separated by 1-week washout periods: unfiltered air (sham filtration), low-efficiency (LE) high-efficiency particulate arrestance (HEPA)–type filtered air, and high-efficiency (HE) true-HEPA filtered air using filtration systems in their bedroom and living room.

MAIN OUTCOMES AND MEASURES The primary outcome was brachial blood pressure (BP). Secondary outcomes included aortic hemodynamics, pulse-wave velocity, and heart rate variability. Exposures to $PM_{2.5}$ were measured in the participants' residences and by personal monitoring.

RESULTS The 40 participants had a mean (SD) age of 67 (8) years (62% men). Personal $PM_{2.5}$ exposures were significantly reduced by air filtration from a mean (SD) of 15.5 (10.9) $\mu g/m^3$ with sham filtration to 10.9 (7.4) $\mu g/m^3$ with LE fitration and 7.4 (3.3) $\mu g/m^3$ with HE filtration. Compared with sham filtration, any filtration for 3 days decreased brachial systolic and diastolic BP by 3.2 mm Hg (95% CI, −6.1 to −0.2 mm Hg) and 1.5 mm Hg (95% CI, −3.3 to 0.2 mm Hg), respectively. A continuous decrease occurred in systolic and diastolic BP during the 3-day period of LE filtration, with a mean of 3.4 mm Hg (95% CI, −6.8 to −0.1 mm Hg) and 2.2 mm Hg (95% CI, −4.2 to −0.3 mm Hg), respectively. For HE filtration, systolic and diastolic BP decreased by 2.9 mm Hg (95% CI, −6.2 to 0.5 mm Hg) and 0.8 mm Hg (95% CI, −2.8 to 1.2 mm Hg), respectively. Most secondary outcomes were not significantly improved.

CONCLUSIONS AND RELEVANCE Results of this study showed that short-term use of portable air filtration systems reduced personal $PM_{2.5}$ exposures and systolic BP among older adults living in a typical US urban location. The use of these relatively inexpensive systems is potentially cardioprotective against $PM_{2.5}$ exposures and warrants further research.

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The World Health Organization attributes more than 4 million deaths per year to ambient fine (<2.5 μm in diameter) particulate matter ($PM_{2.5}$).[1] Short-term exposures (eg, days) increase risks for numerous cardiovascular (CV) events, including myocardial infarction, stroke, and heart failure.[2] Longer-term exposures (eg, years) amplify this risk and potentiate development of chronic cardiometabolic conditions (eg, type 2 diabetes, hypertension).[2]

The extremely high air pollution levels across Asia are a major public health threat.[1] However, mounting evidence indicates that even low levels of $PM_{2.5}$ exposure within World Health Organization air quality guidelines of less than 10 μg/m^3 pose significant health risks.[1,3] Despite improvements in air quality during prior decades, the range of $PM_{2.5}$ concentrations across the United States remains associated with excess mortality.[3] As such, Brook et al[4] and Giles et al[5] have advocated more testing of preventive strategies that individuals can use to protect their health.

With the US population spending nearly 90% of their time indoors—70% of this in their own residence[6,7]—portable residential air filtration units may be a practical tool for reducing $PM_{2.5}$ exposures. A growing body of studies shows that high-efficiency particulate arrestance (HEPA) filtration can reduce indoor $PM_{2.5}$ concentrations and may deliver health benefits. Although some trials demonstrated improvements in surrogate CV outcomes, including vascular function and blood pressure (BP),[8-11] overall evidence remains mixed.[12-14] Few studies have been performed in the United States with pollution levels more representative of urban environments faced by millions of at-risk individuals. In addition, a paucity of data exists among the elderly, the fastest growing vulnerable population, who are particularly susceptible to adverse health effects of $PM_{2.5}$ exposure.[15-19]

In this context, we tested the capacity of 2 inexpensive, commercially available air filtration systems to reduce $PM_{2.5}$ exposures among elderly adults in a low-income senior residence in a typical urban US environment (Detroit, Michigan). We hypothesized that air filtration would reduce personal $PM_{2.5}$ exposure, which differs from indoor levels due to several factors, including daily activities,[20] thereby yielding improvements in CV health. Change in BP was selected as the primary end point because high BP is the leading cause of global morbidity and mortality[1,21] and because $PM_{2.5}$ exposure has been shown to increase BP in our study location[22-24] and across global environments.[25,26]

Key Points

Question Can portable air filtration systems reduce personal exposures to fine particulate matter air pollution and blood pressure levels among elderly adults living in a typical US urban location?

Findings In this randomized, double-blind crossover intervention study, short-term use of portable air filtration systems reduced personal exposures to fine particulate matter and systolic blood pressure in senior citizens living in a low-income residence.

Meaning The use of portable air filtration systems is potentially cardioprotective against exposures to fine particulate matter and warrants further research.

Methods

Study Population

The Reducing Air Pollution in Detroit Intervention Study (RAPIDS) enrolled 40 nonsmoking adults not receiving supplementary oxygen and living in a government-subsidized, low-income residential building for senior citizens in Midtown Detroit; participants received an in-residence air filtration intervention. The building is near a major state highway (approximately 100 m, with 21 900 vehicles/d),[27] major interstate highways (approximately 800 m, with 133 000 vehicles/d),[27] and several large industrial facilities. Individual residences used the same floor plan (approximately 46.8 m^2) and hydronic baseboard heating. Participants were not restricted from going outdoors or opening windows during the interventions. The study protocol is found in Supplement 1. The study was approved by the institutional review board of the University of Michigan, and participants signed a written informed consent document during screening visits.

Intervention Study Design

RAPIDS was a randomized, double-blind, 3-way crossover intervention study conducted from October 21, 2014, through November 4, 2016 (excluding December 1 through April 30). Interventions included 3 blinded scenarios in computer-generated random order: unfiltered ambient air exposure (sham filtration), low-efficiency (LE) HEPA-type filtration, and high-efficiency (HE) true-HEPA filtration of ambient air using air purifier systems in the bedroom and main living space of each residence. The LE filter removes 99% of particles at 2.0 μm in size, whereas the HE filter removes 99.97% of particles at 0.3 μm in size. Each scenario lasted 3 days, separated by 1-week washout periods.

On Monday during each study week, an unblinded team member placed randomized portable air filter systems (HAP424-U; Holmes), with a clean air delivery rate of 3.29 m^3/min for smoke, in each participant's residence. Participants, health technicians, and the data analysists (S.D.A. and J.D.) were blinded to intervention ordering. Participants wore personal air monitors starting at 8:00 AM and carried them for 72 hours. Each participant underwent CV outcome testing in a fasting condition (>8 hours) at the same time between 8:00 and 10:00 AM on 3 consecutive days starting 24 hours after filter system placement (Tuesday through Thursday). Daily PM filter samples were collected in each participant's residence throughout each 3-day filtration period, during which time no filtration, LE recirculating filtration (HAPF30D-U2 HEPA-type filter; Holmes), or HE recirculating filtration (HAPF300D-U2 true-HEPA filter; Holmes) was used. For the sham condition, the air filtration systems (ie, HAP424-U) were operated without any filter element.

Cardiovascular Outcome Measurements

The primary outcome was brachial BP. Although this outcome included systolic BP (SBP) and diastolic BP (DBP), we specifically powered the trial based on a change in SBP because in prior studies in Detroit[22,23] that had been completed at the time of designing this study, ambient $PM_{2.5}$ had shown stronger and more consistent association with SBP compared with DBP. A repeated-measures design with 40 participants provided 90% power to detect a 1.4-mm Hg difference in SBP between active filtration interventions (HE and LE together) vs sham filtration. Secondary outcomes included noninvasive aortic hemodynamics, pulse-wave velocity (PWV), and heart rate variability (HRV). First, participants rested while seated for 5 minutes, and then CV outcome measurements were performed each morning in the following order: BP (approximately 5 minutes), PWV (approximately 10 minutes), and HRV (approximately 6 minutes). The measurement protocol is detailed in Supplement 1 and briefly reviewed below.

Brachial BP

Five-minute resting seated BP, a well-established causal factor for CV events,[21] was measured according to guidelines[28] using an automatic validated device (BpTRU; http://www.medsource-sw.com/blood-pressure/item-bpm-100/). The mean of the last 5 of 6 automated BP measurements (taken at 60-second intervals) was recorded.

Central Aortic Hemodynamics and PWV

A detection system (SphygmoCor System; http://atcormedical.com) was used to measure aortic augmentation pressure and augmentation indices (alone and controlled to a heart rate of 75 beats/min), metrics of aortic arterial pressure-wave reflection, and aortic systolic and pulse pressure. Carotid-femoral PWV was also determined by applanation tonometry using this system.[29]

Cardiac Autonomic Function

Participants rested supine for 6 minutes of continuous electrocardiographic monitoring (Evo Holter system; Spacelabs Healthcare). Time domain (SD of normal-to-normal R-R intervals) and frequency domain (high and low frequencies) HRV metrics were analyzed using echocardiographic analysis software (Pathfinder system; https://www.spacelabshealthcare.com:443/).

Exposure Assessment

Indoor Air Sampling

Indoor $PM_{2.5}$ samples were collected in the living room at the furthest point from the air filtration unit. Twenty-four-hour indoor $PM_{2.5}$ samples were collected daily on polytetrafluoroethylene (PTFE [Teflon; Pall Laboratory]) filters using cyclone sample inlets at a flow rate of 16.7 L/min.

Personal Air Sampling

Each participant wore a battery-powered personal particulate monitor (pDR-1500; Thermo Scientific) that collected particles on 37-mm PTFE filters for subsequent gravimetric analysis. The monitor also continuously recorded $PM_{2.5}$ concentration, relative humidity, and temperature. Participants were instructed to place monitors on a nearby nightstand or equivalent while sleeping.

Outdoor Air Sampling

We collected 24-hour ambient $PM_{2.5}$ samples daily on PTFE filters using a dichotomous sequential air sampler (Partisol-Plus Model 2025, Rupprecht and Patashnick, Inc). All samples were processed and analyzed in class 100 ultraclean rooms at the Michigan State University Exposure Science Laboratory and the University of Michigan Air Quality Laboratory.

Statistical Analysis

Summary statistics were calculated as the overall mean (SD) of the mean value for each participant under each intervention scenario. We tested whether LE and HE filtration resulted in CV outcomes statistically better than sham filtration using mixed models of the following formula:

$$CV_{it} = b_o + [(\beta_{11} \times LE_{it}) + (\beta_{12} \times HE_{it})] + (\beta_2 \times CONFOUNDER_{it}) + \varepsilon_{it}$$

where CV_{it} is the continuous CV health outcome in individual i at time t; b_o is the overall intercept; β_{11} and β_{12} are the overall effects of LE vs unfiltered air and HE vs unfiltered air, respectively; $CONFOUNDER_{it}$ is a vector of time-varying covariates that may confound associations of interest (eg, intervention sequence, calendar time, month of intervention, temperature, or day of intervention); and β_2 is the associated effect of these confounders. As a balanced design in which every participant contributes information to every intervention, time-invariant characteristics such as sex, race, and age cannot confound the associations of interest. Within the error term of this model (ε_{it}), we accounted for the repeated nature of the samples from each participant and allowed for increased correlation among observations from the same participant that are closer in time.

In sensitivity analyses, we explored the inclusion of additional adjustment for outdoor $PM_{2.5}$ exposure, examined different covariance structures, and tested whether intervention effects varied during the 3 days of sampling or by personal characteristics (ie, obesity, defined as body mass index [calculated as weight in kilograms divided by height in meters squared] ≥30, and sex) using interaction terms in our models. We also tested the effects of any filtration vs no filtration. We used SAS software (version 9.3; SAS Institute Inc) to implement these models; $P < .05$ indicates significance.

Results

Forty participants (25 men [62%] and 15 women [38%]; mean [SD] age, 67 [8] years) were enrolled based on our a priori power analyses for the primary outcome. Participants were predominantly African American (38 [95%]) (**Table 1**), and nearly one-half had class I obesity (19 [48%]). Mean brachial SBP and DBP during sham scenarios were 133.2 (17.1) and 82.1 (10.6) mm Hg, respectively. Nearly all participants contributed 3 BP measurements per intervention scenario, totaling 359 of 360 expected measurements (**Table 2** and **Figure 1**). Less complete information was available on the secondary outcomes, leaving 34 participants and 208 measurements for secondary analyses.

The mean outdoor $PM_{2.5}$ concentration during our study was 9.3 (3.2) μg/m^3, with similar levels across different interventions. Mean indoor and personal $PM_{2.5}$ concentrations without LE or HE air filtration were 17.5 (13.0) μg/m^3 and 15.5 (10.9) μg/m^3, respectively. Mean personal $PM_{2.5}$ exposure reductions by LE and HE filtration (compared with sham filtration) were 31% and 53% ($P < .05$), respectively (Melissa M. Maestas, PhD, R.D.B, R.A.Z., et al; unpublished data; December 2017) (Table 2).

Table 1. Participant Characteristics

Variable	Data[a]
Age, mean (SD), y	67 (8)
Sex, No. (%)	
Male	25 (62)
Female	15 (38)
Race, No. (%)	
White	2 (5)
African American	38 (95)
BMI, mean (SD)	32.7 (7.0)
BP, mean (SD), mm Hg[b]	
Systolic	133.2 (17.1)
Diastolic	82.1 (10.6)
Medications used, No./total No. (%)[c]	
High blood pressure	19/24 (79)
Diabetes	6/24 (25)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); BP, blood pressure.

[a] Unless otherwise indicated, data include 40 participants.

[b] Obtained in sham filtration scenario.

[c] Includes the 24 participants with available data by self-reporting.

Compared with the sham scenario, using any air filtration for 3 days decreased brachial SBP by 3.2 mm Hg (95% CI, −6.1 to −0.2 mm Hg) and brachial DBP by 1.5 mm Hg (95% CI, −3.3 to 0.2 mm Hg) (**Figure 2**A). Figure 2B illustrates the temporal variation of brachial SBP and DBP during the interventions and shows that LE filtration reduced mean SBP by 3.4 mm Hg (95% CI, −6.8 to −0.1 mm Hg) and mean DBP by 2.2 mm Hg (95% CI, −4.2 to −0.3 mm Hg). High-efficiency filtration decreased mean SBP by 2.9 mm Hg (95% CI, −6.2 to 0.5 mm Hg) and mean DBP by 0.8 mm Hg (95% CI, −2.8 to 1.2 mm Hg), respectively. These reductions did not differ significantly between HE and LE air filtration ($P = .75$ for SBP and $P = .14$ for DBP).

In post hoc exploratory analyses, we evaluated for potential effect modifiers of the BP responses. The 19 individuals with obesity experienced significantly greater decreases in SBP (−7.5 mm Hg; 95% CI, −12.0 to −3.1 mm Hg) and DBP (−2.9 mm Hg; 95% CI, −5.6 to −0.2 mm Hg) with filtration compared with the 21 nonobese participants (SBP, −0.4 mm Hg [95% CI, −3.7 to 4.5 mm Hg]; DBP, −0.6 mm Hg [95% CI, −3.1 to 2.0 mm Hg]) ($P < .001$ for interaction for brachial SBP; $P = .01$ for interaction for brachial DBP) (Figure 2C). Except for PWV, HE and LE filtration also improved all secondary outcomes more for obese participants than for nonobese participants, although these differences only met statistical significance for aortic

Table 2. Cardiovascular Outcome and Exposure Assessment Results Under 3 Scenarios

			Type of Filtration, Mean (SD)[a]			
Characteristic	No. of Participants	No. of Measurements	Sham	LE	HE	Any
Brachial SBP, mm Hg	40	359	133.2 (17.1)	129.5 (17.0)	130.7 (15.8)	130.1 (16.3)
Brachial DBP, mm Hg	40	359	82.1 (10.6)	80.2 (11.2)	81.9 (10.5)	81.1 (10.8)
HRV metrics						
SDNN, ms	40	356	44.5 (23.5)	47.3 (35.6)	46.6 (30.4)	47.0 (32.9)
LF:HF ratio	40	348	1.8 (1.2)	1.6 (2.0)	1.8 (2.0)	1.7 (2.0)
Aortic augmentation pressure, mm Hg	40	354	11.4 (5.8)	10.7 (5.5)	10.4 (4.8)	10.5 (5.2)
AIx@75, %	40	350	24.1 (8.7)	23.6 (9.6)	23.7 (9.3)	23.6 (9.4)
Aortic pulse pressure, mm Hg	40	355	40.0 (11.6)	38.1 (10.4)	38.1 (10.2)	38.1 (10.2)
PWV, m/s	34	275	10.9 (3.2)	11.3 (3.5)	10.8 (3.5)	11.1 (3.5)
Air temperature, °C	40	350	28.1 (2.6)	28.4 (2.4)	28.0 (2.5)	28.2 (2.5)
Relative humidity, %	40	349	40.4 (10.3)	40.6 (9.5)	40.2 (9.7)	40.4 (9.5)
$PM_{2.5}$ concentration, μg/m^3						
Indoor[b]	40	359	17.5 (13.0)	8.4 (3.9)	7.1 (3.5)	7.7 (3.8)
Personal[c]	40	309	15.5 (10.9)	10.9 (7.4)	7.4 (3.3)	9.1 (5.9)
Outdoor[d]	40	337	9.1 (2.8)	9.0 (3.3)	9.6 (3.5)	9.3 (3.4)

Abbreviations: AIx@75, augmentation index controlled to a heart rate of 75 beats/min; DBP, diastolic blood pressure; HE, high-efficiency; HF, high frequency; HRV, heart rate variability; LE, low-efficiency; LF, low frequency; $PM_{2.5,}$ fine (<2.5 μm) particulate matter; PWV, pulse-wave velocity; SBP, systolic blood pressure; SDNN, SD of normal-to-normal R-R intervals.

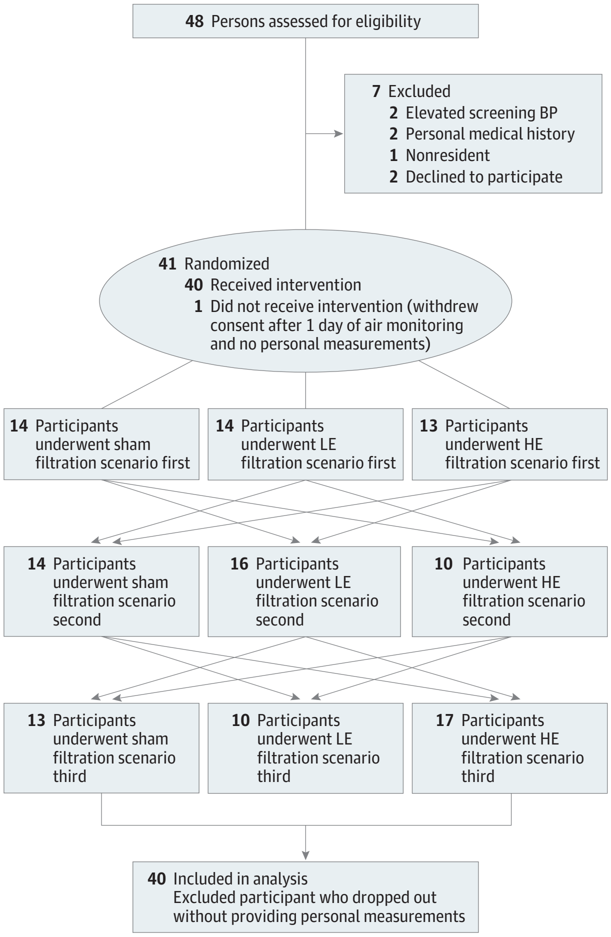
[a] Mean (SD) values were estimated using the mean value for each participant within each scenario.

[b] Median values are 13.1 μg/m^3 for sham, 7.8 μg/m^3 for LE, ad 6.0 μg/m^3 for HE filtration.

[c] Median values are 12.1 μg/m^3 for sham, 8.1 μg/m^3 for LE, and 7.6 μg/m^3 for HE filtration.

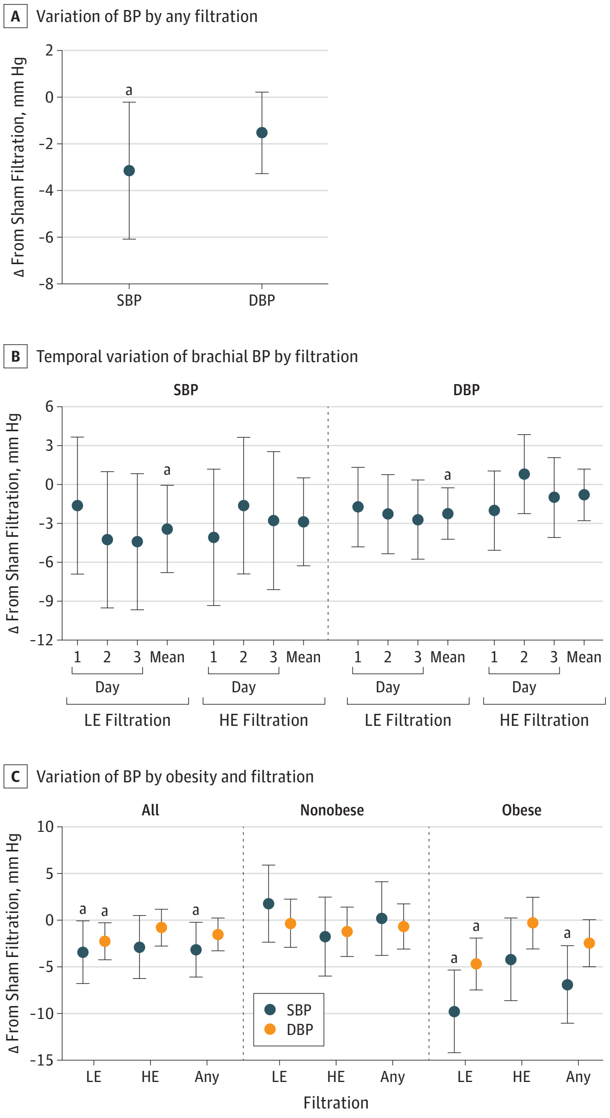
[d] Median values are 9.0 μg/m^3 for sham, 8.7 μg/m^3 for LE, and 9.7 μg/m^3 for HE filtration.

Figure 1. CONSORT Diagram



BP indicates blood pressure.

Figure 2. Changes in Brachial Blood Pressure (BP) Levels



A, BP levels represent overall changes during all days of any filtration type compared with the 3-day sham filtration. B, BP levels represent individual daily and 3-day mean changes during each separate filtration type compared with the corresponding sham filtration day. C, BP levels represent overall changes during all days of any filtration type compared with the 3-day sham filtration among all, 19 obese (body mass index [calculated as weight in kilograms divided by height in meters squared]≥30), and 21 nonobese participants. Error bars indicate 95% CIs; Δ, difference. DBP indicates diastolic BP; HE, high-efficiency; LE, low-efficiency; and SBP, systolic BP.

[a] *P* < .05, test of fixed effects from the adjusted mixed model.

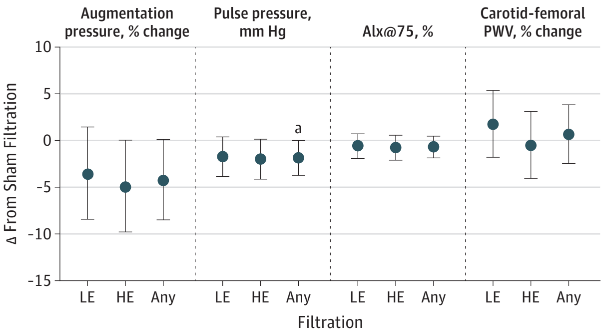
pulse pressure (decrease by 4.6 mm Hg; 95% CI, −7.3 to −1.8 mm Hg). The intervention effects did not consistently differ by other factors, including sex and day of intervention.

Among secondary CV study outcomes, central aortic, aortic augmentation pressure, pulse pressure, and augmentation index controlled to a heart rate of 75 beats/min tended to decrease during the filtration interventions. For instance, compared with no filtration, any filtration reduced pulse pressure by 1.9 mm Hg (95% CI, −3.7 to −0.01 mm Hg), but remaining secondary outcomes were not statistically different from no association (**Figure 3**). No significant consistent differences between interventions were observed for PWV and cardiac HRV variables (eTable in Supplement 2).

Discussion

Fine particulate matter air pollution is the fifth leading risk factor for global morbidity and mortality.[1] Even low levels across the United States pose significant public health risks[3]; however, no proven personal strategy exists to protect at-risk individuals.[4] We demonstrate herein that 2 relatively inexpensive (<US $70), commercially available portable air filtration systems can significantly decrease SBP and 24-hour mean personal $PM_{2.5}$ exposure in elderly adults in a typical urban US location (Detroit). There was also a concomitant reduction in DBP; however, this change did not reach statistical significance. We further demonstrate that health benefits may appear more rapidly than previously known,[12,16] with BP reductions manifesting within 3 days. Notably, 24-hour mean reductions in personal $PM_{2.5}$ exposures occurred despite air

Figure 3. Change in Secondary Outcomes (Aortic Hemodynamics) by Filtration Type During Each 3-Day Intervention



Results represent individual daily and 3-day mean changes during each separate filtration intervention type compared with the sham filtration. Augmentation and pulse pressures are measured for the aorta. Error bars indicate 95% CI; Δ, difference. AIx@75 indicates augmentation index standardized to a heart rate of 75 beats/min; HE, high-efficiency; LE, low-efficiency; and PWV, pulse-wave velocity.

[a] $P < .05$, test of fixed effects from the adjusted mixed model.

filtration systems being fixed to indoor in-residence locations. The effectiveness of this intervention on personal exposures is important because in real-world scenarios, people spend a variable portion of time outside of their residence.

Previous Air Filter Studies

Several prior studies tested air filter interventions in mostly younger adults living in exceptionally polluted regions (Asia) or locations heavily affected by wood smoke.[9,11,13,30] Improvements in BP and metrics of vascular function have been reported.[9,11] A recent study among students in Shanghai[31] demonstrated reductions in circulating stress hormone levels (eg, catecholamines, corticosteroids) and other markers of adverse systemic responses by metabolomic profiling. Conversely, we conducted our trial among an elderly population at greater risk of health effects of $PM_{2.5}$ exposure and in a typical US city facing more widely relevant $PM_{2.5}$ levels (ie, compliant with National Ambient Air Quality Standards) from urban sources. The few other HEPA-intervention studies conducted in less-polluted environments[12-14] reported mixed changes in health end points. Although a study of elderly adults in Denmark reported improved microvascular function,[8] BP levels were not affected, and experimental limitations prevented replication of their results in a follow-up trial.[12] Blood pressure was also only a secondary outcome and not repetitively determined for 3 days using a fully automated device as in our trial, which likely contributed to our ability to detect significant reductions. Last, a recent in-home air filtration study of 21 middle-aged adults living near a Massachusetts roadway[14] reported negative findings. The smaller sample size, younger age, lack of air filters placed in participants' bedrooms (important for the success of 24-hour mean exposure reduction),[12] and single measurement of follow-up BP may have contributed to their null findings. Nevertheless, together with our new findings, the overall body of evidence highlights the need for further large-scale investigations to fully understand the potential health benefits of air filtration systems.

Biological Mechanisms

Short-term increases in ambient $PM_{2.5}$ concentrations promote elevated arterial BP in areas with poor or good air quality.[22-26] Autonomic imbalance favoring sympathetic activation and vascular dysfunction have been implicated.[2,24,25] Our study could not elucidate the precise mechanism because HRV metrics and arterial function variables were not consistently improved with filtration. This finding may be owing to inadequate power to evaluate secondary end points or research technique shortcomings or because other pathways may be responsible. Nonetheless, our results support a trend toward improved central aortic hemodynamics and arterial compliance with parallel decreases in brachial BP. In follow-up analyses, we will evaluate via metabolomic profiling whether stress hormones (eg, activation of the hypothalamic-pituitary-adrenal axis) or other hemodynamically active mediators were mechanistically involved.[31] We will also investigate whether microvascular tone, assessed by retinal arterial photography, played a mediating role.

Clinical Implications

For this study, BP was only monitored during a 3-day period of air filtration. However, the observed 3.2-mm Hg reduction in SBP could possibly be sustained for more prolonged interventions. Even such modestly lower BP levels, if maintained for the long term (eg, months to years), could result in an approximate 16% decrease in composite CV events based on epidemiologic calculations.[21] Given the size of the population affected by $PM_{2.5}$ exposure,[1] widespread use of economical exposure-reduction solutions could potentially deliver substantial improvements in global public health.[4] We recognize this possibility is only speculation, and we aim to launch a follow-up study specifically to evaluate the efficacy and health benefits of longer-term interventions. Our results also showed that participants with obesity may exhibit greater decreases in BP from air filtration. This finding is consistent with that of a recent review in which 11 of 14 panel studies showed stronger associations between $PM_{2.5}$ exposure and acute changes in physiological measures of CV health among obese participants, including BP.[32] Because the prevalence of obesity has more than doubled since 1980, improved understanding of the interactions among air pollution, obesity, CV health, and intervention tools will be required to tackle this important public health issue.

A recent study of the Medicare population[3] demonstrated that the adverse effects of $PM_{2.5}$ exposure are more pronounced among self-identified racial minorities and people with low income. Seniors in urban low-income housing are particularly vulnerable to air pollution, and an economical and easily implemented intervention is needed to reduce their PM exposure. This group is understudied; in 2015, almost 4.2 million seniors lived below the poverty level and another 2.4 million were classified as near poor.[19] To our knowledge, this study is the first to focus on low-income housing facilities in an urban US environment and on personal $PM_{2.5}$ exposures.

Limitations

Although the slightly more expensive HE system was more effective in reducing personal exposures, this intervention did not clearly yield superior CV health outcomes, likely because the study was a priori powered to detect a difference in SBP while using any air filtration (HE and LE pooled together) vs sham filtration. This power may have therefore been inadequate to detect statistically significant changes in secondary CV outcomes. As such, the differences shown in Figure 3 represent secondary (hypothesis-generating) end points only, and a larger follow-up trial is needed to determine whether the small (statistically insignificant) differential BP response unexpectedly favoring LE over HE filtration was a result of chance alone, as we suspect.

Although this study showed that interventions as short as 24 hours can reduce BP, previous studies[10] suggest that a longer intervention (eg, 9 days) might have demonstrated more robust changes and detectable improvements in our secondary CV outcomes. A preliminary study in Taiwan[31] conducted for 1 year suggests that this may indeed be the case. Longer-term studies of months to years in duration are ultimately required to determine whether health benefits of air filtration persist and could thereby potentially translate into reductions in overt CV events (eg, myocardial infarctions).

The study size and design were inadequate for assessing effect modification by multiple factors. Our objective was to model a real-world scenario as much as possible; thus, we did not exclude participants based on the presence of many comorbidities, including hypertension or use of specific antihypertensive medications. The heterogeneous nature of the participants may have also led to variability in responses owing to differences in underlying disease states and medications. Furthermore, although the participants were nonsmokers and the residential building was a nonsmoking building, we did not assess effects of secondhand smoke. In future analyses, we plan to assess PM$_{2.5}$ components and their sources (eg, smoking) related to changes in CV outcomes.

Whether such in-home interventions would be less effective among more free-living adults, such as those who spend more time outside their residence, also remains unknown. Considering these limitations, larger trials are required to determine optimal populations to target and the comparative effectiveness among various strategies (eg, face masks) for intervention.

Finally, the primary study end point was brachial BP. Although SBP significantly decreased, the reduction in DBP after any filtration did not reach statistical significance, most likely because we specifically powered the study based on changes in SBP and it may have therefore been underpowered to detect a decrease in DBP. Our prior studies in Detroit had suggested that ambient PM$_{2.5}$ may have a more consistent association with SBP compared with DBP.[22,23] However, recent studies have found that ambient PM$_{2.5}$ can increase SBP and DBP.[24] In this study, DBP was also significantly decreased by LE filtration. These findings suggest that future trials with appropriate power are warranted to determine whether air filtration indeed lowers DBP and not just SBP. Regardless, the fact that SBP alone was reduced in this study is still of clinical relevance because SBP is well established as a stronger and more important determinant of CV risk in elderly people than DBP.[33]

Conclusions

In this trial, use of indoor portable air filtration for 3 days led to significant reductions in SBP in elderly adults. Our findings suggest that this relatively inexpensive and practical approach may be an effective tool for reducing PM$_{2.5}$-related health effects. Future studies are required to better understand how to optimally deploy this personal-level intervention in real-world settings, how it performs among different populations (eg, patients with established cardiovascular diseases), and its efficacy over longer time frames (eg, >9 days).

ARTICLE INFORMATION

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Concept and design: Morishita, Adar, Bard, Spino, Brook.
Acquisition, analysis, or interpretation of data: All authors.
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