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Personal Interventions for Reducing Exposure and Risk for Outdoor Air Pollution: An Official American Thoracic Society Workshop Report

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Personal Interventions for Reducing Exposure and Risk for Outdoor Air Pollution

An Official American Thoracic Society Workshop Report

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Abstract

Poor air quality affects the health and wellbeing of large populations around the globe. Although source controls are the most effective approaches for improving air quality and reducing health risks, individuals can also take actions to reduce their personal exposure by staying indoors, reducing physical activity, altering modes of transportation, filtering indoor air, and using respirators and other types of face masks. A synthesis of available evidence on the efficacy, effectiveness, and potential adverse effects or unintended consequences of personal interventions for air pollution is needed by clinicians to assist patients and the public in making informed decisions about use of these interventions. To address this need, the American Thoracic Society convened a workshop in May of 2018 to bring together a multidisciplinary group of international experts to review the current state of knowledge about personal interventions for air pollution and important considerations when helping patients and the general public to make decisions about how best to protect themselves. From these discussions, recommendations were made regarding when, where, how, and for whom to consider personal interventions. In addition to the efficacy and safety of the various interventions, the committee considered evidence regarding the identification of patients at greatest risk, the reliability of air quality indices, the communication challenges, and the ethical and equity considerations that arise when discussing personal interventions to reduce exposure and risk from outdoor air pollution.

Keywords: air pollution; exposure; personal intervention; air filtration; respirators

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Summary of Workshop Conclusions and Recommendations

1. Emission reduction is the most important action needed to reduce health burdens caused by outdoor air pollution. Workshop participants uniformly agreed that personal interventions are secondary to the need to reduce pollution emissions at the source. The use of personal interventions to reduce individual exposures to outdoor air pollution is not a substitute for policies, regulations, and economic forces that are needed to drive reductions in pollution emissions. Pollution reduction strategies are much more cost-effective and socially equitable than widespread use of personal interventions. However, the workshop participants recognized the need to supplement these efforts with exposure reduction strategies where and when air pollution concentrations are expected to exceed health-based standards, with particular attention to individuals who may be susceptible to adverse effects from even relatively low concentrations of air pollution.
2. There are several types of personal interventions available to reduce exposure to outdoor air pollution. When ambient air pollution concentrations are elevated, several measures are available to individuals to reduce their exposure and risk of adverse health effects. These personal interventions include staying indoors, limiting physical activity during times with elevated pollution concentrations and near air pollution sources, cleaning indoor air with central system filters or portable room air purifiers, and using personal protective devices such as respirators. More empirical, outcome-based evidence is needed to better help individuals and clinicians make informed decisions about the use of these interventions on the basis of relative efficacy, effectiveness, safety, and cost.
3. The information on air quality currently available for making decisions about personal interventions has limitations and should be evaluated. Most developed regions of the world provide air pollution information to the public through use of an air quality index; however, these indices are often not specifically designed on the basis of health risks but rather reflect regulatory or recommended limits of individual pollutants. Regardless of how they are constructed, air quality indices need to be rigorously evaluated. In some cases, index values are not predictive of population-level health risks because of monitored pollution values not being representative of individual exposures. However, when positive associations are observed among individual pollutant concentrations and population-level health outcomes, but index values are not associated with population-level health outcomes, then the development of alternative formulations of air quality indices is recommended for improved risk communication.
4. People should continue to exercise but may seek ways to modify activity to reduce exposure to peak air pollutant exposures. Given the clear health benefits of regular physical activity, clinicians may consider suggesting ways to reduce exposure to outdoor air pollution by modifying the times and locations of outdoor exercise but only insomuch that these modifications do not jeopardize efforts to participate in regular exercise. There is a clear need for more and better research on the trade-offs of exercise and avoiding outdoor air pollution; this is particularly critical for medical conditions that have been shown to have better long-term outcomes as a result of regular exercise.
5. Respirators can reduce exposure to particulate matter (PM) air pollution when used properly but have significant limitations when used for protection against ambient air pollution. Commonly available respirators (e.g., N95 respirators in the United States, FFP2 respirators in Europe) can reduce exposure to PM by widely varying degrees depending on the type of respirator and how it is used. However, unless specifically designed for the purpose, respirators do not reduce exposure to gaseous pollutants. Although healthy people are able to wear properly fitted respirators without undue adverse health impacts, this may not be the case for individuals with respiratory or cardiovascular conditions who are most susceptible to the adverse effects of air pollution exposures.
6. Portable indoor air cleaners (or whole-house systems) can be effective at reducing indoor pollutant concentrations. Room air purifiers and whole-house filters can reduce concentrations of outdoor air pollution in indoor environments. Studies have

shown reductions in PM by about 20–80% under a range of conditions. A few experimental studies have found improvements in cardiorespiratory biomarkers after trials of air filtration in homes, but results have been inconsistent, and clinical outcomes have not been rigorously evaluated. Future clinical studies of the potential efficacy and effectiveness of home filtration are needed to evaluate clinical health outcomes.

7. There are significant equity considerations that may prevent patients from using personal interventions. Important barriers include affordability and the challenge of communicating complex behavioral interventions in the context of the priorities, circumstances, and values of individual patients. Environmental justice and equity issues should be considered when making recommendations for personal interventions. The evaluation of the accessibility of information, the potential availability of financial resources, and the potential mechanisms by which individuals can be supported to afford these interventions need to be considered in parallel with development of any guidelines regarding their use.

Introduction

Short-term and long-term exposures to elevated concentrations of outdoor air pollution increase the risk of adverse health outcomes in individuals around the world. The best option to mitigate adverse health impacts from outdoor air pollution, from both an economic and an equity perspective, is to reduce ambient concentrations through emission control strategies. However, these policy and regulatory efforts are largely outside of the influence of individuals currently being impacted by elevated ambient pollution. Until outdoor concentrations of air pollution fall below levels at which adverse health impacts occur, it would be beneficial for some individuals to take proactive measures to reduce their exposures to adequately protect their health and quality of life. These benefits are likely to be greatest among individuals who have heightened susceptibility to the adverse effects of air pollution.

Armed with knowledge of where and when air pollution concentrations are elevated, individuals have several options for changing their behavior in ways that may reduce exposure with varying degrees of effectiveness. The committee reviewed the evidence regarding individual susceptibility, the usefulness of air quality indicators, and the efficacy and effectiveness of personal-level interventions, as well as the potential harms or unintended consequences of these interventions. *Who* should take *what* actions *where*, *when*, and *how* were the main questions addressed by the committee. These questions were addressed from the perspective of healthcare providers who are engaged in helping patients make decisions about personal interventions. The committee also considered communication challenges, equity concerns, and practical aspects that are likely to be important determinants of the effectiveness of proposed interventions. Given the wide differences between rich and poor countries in air pollution sources and conditions, as well as resources, the scope of the committee's analysis was largely limited to outdoor air pollution in industrialized urban areas, although some of the underlying principles may be more broadly generalizable.

Methods

Workshop participants presented prepared talks as part of seven sessions: *1*) defining susceptibility and identifying susceptible individuals; *2*) air quality indices and other sources of air quality information; *3*) indoor and outdoor environments, physical activity, and modes of transportation; *4*) effectiveness of respirators as personal protective devices; *5*) air cleaners and ventilation as indoor environmental interventions; *6*) equity and justice considerations of personal interventions; and *7*) communicating about risks and interventions to patients and clinicians. Participants were invited on the basis of expertise in these topic areas. For each topic, two or three experts were asked to review the relevant literature. After speaker comments, there was additional time provided for in-depth group discussion to clarify key aspects of each topic and to elucidate principles most relevant to the overall goals of the workshop.

A major goal of the workshop was to identify the available scientific evidence for the efficacy and/or effectiveness of personal interventions to reduce exposures and health risks from outdoor air pollution. Critical areas with insufficient scientific evidence were identified together with recommendations for specific research that is needed in the near term to better inform our understanding of personal interventions, particularly as it relates to patient care (see Table 1). When scientific evidence was available, key information was summarized with recommendations provided for how this information can be best

Table 1. Managing exposures to harmful concentrations of outdoor air pollution can occur through a combination of public policy and individual decision-making

Preintervention
“Reduce pollution emissions at the source.”
“Air quality indices need to be rigorously evaluated and improved when needed.”
“Air pollution monitoring networks need to be improved with higher spatial and temporal resolution.”
“Environmental justice and equity issues should be considered when making recommendations for personal interventions.”
Personal interventions
“Staying indoors”
“Cleaning indoor air with central system filters or portable room air purifiers”
“Choosing among alternative modes of transportation or modifying controllable conditions”
“Modifying the times and locations of outdoor exercise but only insomuch that these modifications don't jeopardize efforts to participate in regular exercise”
“Limiting [strenuous] physical activity during times with elevated pollution concentrations and near air pollution sources”
“Properly using respirators to reduce exposure to high concentrations of particulate matter air pollution”

Quotations are taken directly from recommendations developed from the workshop.

communicated to the public and to clinicians. However, no specific clinical practice guidelines were discussed in the workshop or included in this report. The following is a summary of some of the most pressing questions relevant to patient care that were addressed during the workshop.

Which Individuals Are More Susceptible to Air Pollution and More Likely to Benefit from the Use of Personal Interventions?

Individuals who are more susceptible to air pollution may experience adverse health effects similar to those of less susceptible individuals but do so with greater frequency and/or at lower levels of exposure. Individuals who are more susceptible may also experience more severe, or even different, health outcomes as compared with less susceptible individuals at the same levels of air pollution exposure. Examples of the latter include exacerbations of preexisting diseases, such as asthma and chronic obstructive pulmonary disease (COPD). When assessing which patient subpopulations may have increased susceptibility to air pollution, it is recommended that the absolute increase in risk attributable to air pollution is considered, in addition to the comparison of relative risks that are typically reported in observational epidemiology studies. Absolute risk facilitates evaluation of the comparative importance of different risks and the risk reductions that may be expected from alternative interventions.

Patients with chronic diseases or conditions may be at increased risk of adverse health outcomes from elevated air pollution. These patients may be more likely to benefit from personal interventions. Specific diseases or medical conditions that confer increased risk of adverse health outcomes include asthma in children and adults (acute asthma exacerbation, decreased lung function, poor asthma control) (1); COPD (increased COPD exacerbations, prolonged illness after exacerbation due to infection, decreased lung function, increased mortality risk) (2); cystic fibrosis (acute exacerbations, earlier acquisition of *Pseudomonas* and methicillin-resistant *Staphylococcus aureus*) (3); idiopathic pulmonary fibrosis (acute exacerbations, decreased lung function, increased mortality risk) (4); receiving a lung transplant (acute and chronic rejection, increased mortality risk) (5, 6); and coronary artery disease (myocardial infarction, congestive heart failure, increased mortality risk) (7). Other at-risk groups include pregnant women and fetuses, young children, and older age groups.

Additional work is needed to provide clinicians with clearer guidance regarding who should be informed about potential health risks and personal interventions to reduce exposures to outdoor air pollution. Ultimately, tools for risk stratification that include air pollution would assist providers and patients in making evidence-based decisions about interventions. Prioritization of susceptible groups for this research may include consideration of the risk attributable to air pollution, the relative importance of air pollution compared with other risk factors, and the likely effectiveness of personal interventions to reduce exposures. For additional review of evidence regarding susceptibility to air pollution as it relates to personal interventions, *see* Appendix A in the online supplement.

What Information about Outdoor Air Pollution Is Available to Assist Patients and Clinicians in Making Day-to-Day Decisions regarding Personal Interventions?

Most countries that monitor outdoor air pollution have some form of an air quality index to uniformly communicate daily concentrations of pollutants and associated health risks to the public, although indices vary from country to country. Most commonly, the index value corresponds to the individual pollutant with the highest concentration relative to regulatory limits or other specified cut points. This approach is effective at alerting the public to extreme pollution episodes but has structural limitations in differentiating health risks associated with exposure to multiple pollutants, particularly on days with good to moderate levels of pollution when susceptible individuals would benefit the most from accurate information. In response to these limitations, some countries and cities have already transitioned or are currently considering adopting health-based, multipollutant indices (e.g., Canada, Hong Kong, Europe, Mexico City, etc.) (8).

Regardless of how air quality indices are formulated, it is essential that they are rigorously evaluated to ensure that index values are representative of population-level health risks (9). It is important that the ability of air pollution indices to reflect health risks is distinguished from the also important work of evaluating risk communication efforts to promote awareness and effective use of the index (10).

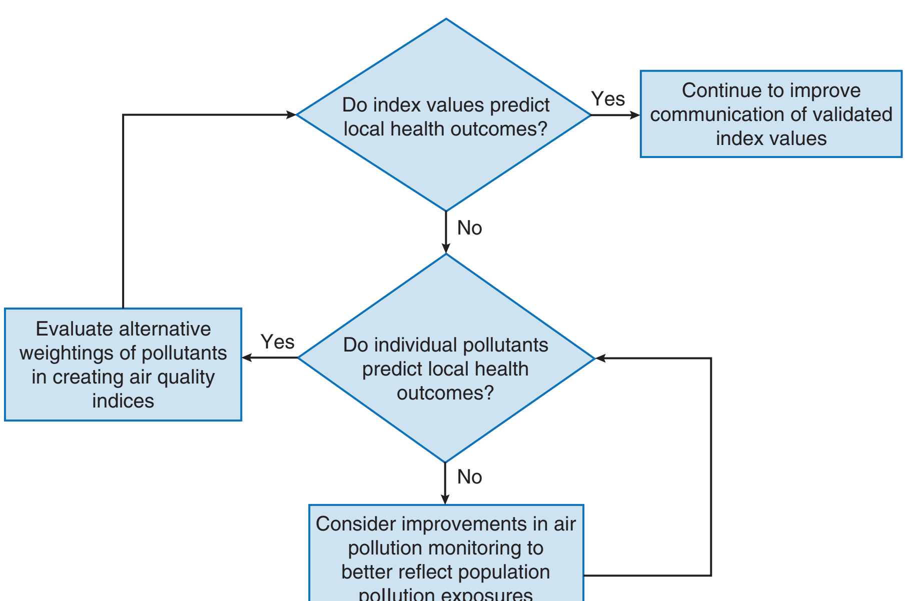

Figure 1. A process for evaluating and improving the ability of existing air quality indices to represent population-level health risks of outdoor air pollution.

A three-step research process can be used to evaluate the ability of existing air quality indices to represent population-level health risks of outdoor air pollution (Figure 1). First, an assessment of the association of index values with population-level health risks can be made using location-specific health data. Second, associations of the individual air pollutants and population-level health outcomes can be assessed to determine whether pollution concentrations underlying the index (e.g., from central site monitors or forecasted estimates) are sufficiently reflective of pollution exposures. Third, if positive associations with population-level health risks are observed for individual pollutants, but not index values, then alternative indices could be considered and evaluated (11). If there are no observed positive associations with individual pollutants and health outcomes, it may be necessary to consider improvements to air pollution monitoring, which may include adding or changing the location of central site monitors or deployment of supplemental monitoring strategies, including low-cost sensor networks, remote sensing data, or combined approaches (12, 13).

Does the Use of Indoor Air Cleaners Protect against Adverse Health Impacts?

Residential air cleaners vary greatly in terms of operation, cost, energy usage, and maintenance requirements. A recent report by the U.S. Environmental Protection Agency (EPA) (2018) recommended using portable air cleaners with high-efficiency particulate air filters to reduce fine particles (PM with an aerodynamic diameter <2.5 μm) in homes (14). Higher-efficiency air filters in central forced air systems can also be effective, but this is only the case if the system has sufficient run time, as most systems operate intermittently as needed to heat or cool (15). A study evaluating air filtration in homes of children with asthma found that using central forced air system air filters to remove particles may be generally less effective than using portable air cleaners, which removed about 50% of fine particles PM2.5 (16).

Air cleaners that advertise the use of "plasma" or "ions" can generate harmful concentrations of ozone. Other alternative filtration technologies, such as negative ion generators, have been associated with adverse health effects (17). The California Air Resources Board mandates testing of air cleaners to make sure that ozone production does not reach hazardous amounts. However, there is currently no national regulation requiring this certification. For removing gas-phase air pollutants, the EPA (2018) report concluded that activated carbon filters are the only technology shown to be effective without producing potentially harmful byproducts (14).

The effectiveness of air cleaners in removing indoor PM of outdoor origin will depend on a number of factors. A study of standalone air cleaners placed in the bedrooms of children with asthma over multiple seasons found a drop in usage among participants (18). The study by Bennett and colleagues (2018) also observed greater particle reductions in homes of children with asthma that continued to use filtration throughout the study and that kept windows closed (16). This and other studies (e.g., Hacker and Sparrow, 2005 [19]) suggested the most effective way to use filtration is in the bedroom with the door closed. With windows closed, it is desirable to maintain adequate ventilation in homes, as adverse effects of real-world carbon dioxide concentrations have been reported (20).

There are relatively few studies of changes in health outcomes resulting from interventions to reduce indoor pollutant concentrations (21). Several small studies have measured changes in biomarkers believed to represent pathophysiological pathways that can lead to clinical outcomes. Assessing the relevance of biomarker changes to reduction in health risk is complex, and the reader is referred to the discussion in "A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework" (22) Even though pollution concentrations are consistently observed to be reduced through the use of portable air cleaners, the observed associations between reductions in PM and improvement in health-related biomarkers are less uniform.

The effect of using PM filtration in homes on primarily cardiovascular health outcomes and associated biomarkers in subjects without allergies or asthma had been summarized by the EPA (2018) (14). The 11 studies included portable air cleaners ($N = 8$) and other air filter configurations ($N = 3$), such as those used as part of the central forced air systems. Although 10 out of 11 studies evaluated reported at least one significant biomarker change, examining a given biomarker across many studies showed substantially less agreement, despite what appeared to be comparable large changes in pollutants; significantly positive associations were shown for CRP (C-reactive protein) in three out of eight studies, microvascular function in three out of five studies, IL-6 (interleukin-6) in zero out of five studies, and blood pressure in four out of seven studies (14). The committee summarized studies of home use of air purifiers to modify short-term cardiorespiratory outcomes, which can be found in Appendix B in the online supplement. It is unclear whether further biomarker studies will clarify the efficacy of air purifiers to mitigate adverse health effects, and it is strongly recommended that clinical trials investigating impacts on clinical endpoints be pursued (23).

Does Staying Indoors on Days When Ambient Air Pollution Concentrations Are Elevated Reduce Exposure and Risk of Adverse Health Effects?

People spend their time in a variety of microenvironments on a daily basis, including home, workplace, school, and transportation microenvironments, and also spend time outdoors while working, in transit, or participating in recreation. In addition to ambient air pollutants, the air that people breathe in these microenvironments is subject to air contamination by internal or nearby sources. In high-income countries, most people typically spend nearly 90% of their time in indoor environments, with approximately half the remaining time spent inside vehicles (24). Although concentrations of ambient air pollutants are generally lower indoors than outdoors, the ratio of indoor to outdoor air pollutant concentrations varies widely, and people generally receive most of their total exposure to ambient air pollution while indoors. The health impacts of short-term, higher-concentration exposures to air pollutants, which often occur in transportation environments, are poorly understood (25).

Indoor air quality is influenced by indoor and outdoor pollutant sources and complex chemical and physical processes. Air exchange between the indoor and outdoor environments (general ventilation) is a key factor in determining indoor air pollutant concentrations. Generally, *increasing* ventilation can mitigate concentrations of air pollutants arising from *indoor* sources, whereas *decreasing* air exchange can mitigate indoor concentrations of air pollutants arising from *outdoor* sources (26). The presence of mechanical ventilation with filtration of intake air may complicate these relationships between air pollutant concentrations and air exchange. Thus, when outdoor concentrations of pollutants such as PM and ozone are elevated, it is likely that staying indoors will reduce exposure, especially if windows and doors and other openings to the outside air are closed (19). A major caveat is that staying indoors and limiting ventilation will likely increase exposure to air pollutants from indoor sources, such as environmental tobacco smoke, cooking fumes, resuspended dust, cleaning products, and other indoor air pollutant sources, if present.

Studies have shown that concentrations of PM and other air pollutants are lower indoors than outdoors because of infiltration efficiencies that vary widely, with reductions ranging from greater than 60% for buildings with mechanical ventilation to less than 20% in buildings with natural ventilation (i.e., open windows) (27, 28). For ozone, the other major air pollutant of concern in rich countries, concentrations are generally substantially lower (30–70% reduction) indoors than outdoors, which is primarily because of removal of ozone from indoor air by reactions that occur in the air and on surfaces (29).

In transportation microenvironments, people are often in proximity to sources of air pollutants such as vehicle tailpipe emissions, products of vehicle and road wear, and resuspended particles. Distinct transportation microenvironments include the cabins of passenger vehicles, buses, trains, and airplanes, and being outdoors while motorcycling, bicycling, and walking on and alongside roadways. Studies have shown that the relative intensity of exposure to traffic-source air pollutants may vary widely with different modes of transportation, depending on many factors (25, 30, 31). To reduce exposure to air pollution, people may have options to choose among alternative modes of transportation or to modify controllable conditions. For example, keeping windows closed and setting a vehicle's climate control system to recirculate mode can substantially reduce occupant exposure to air pollutants arising from other vehicles on the roadway (32). Whether vehicle occupants have more or less exposure to traffic pollutants than pedestrians or cyclists depends on additional factors such as the distance from the roadway and the wind speed and direction (33).

How Effective Is Limiting Physical Exertion at Times and in Places Where Air Pollution Is Higher?

The inhaled dose of air pollutants is determined by the pulmonary ventilation rate as well as the air pollutant concentration. Therefore, shifting outdoor physical exertion away from times and locations where air pollutant concentrations are highest would reduce the inhaled dose of air pollution (34). However, the committee could not identify any studies providing high-quality evidence that health outcomes are improved by advising patients or the general public to not engage in physical activity when air quality is poor. In fact, the evidence suggests that the long-term cardiovascular and respiratory benefits of physical activity may remain even after accounting for the effects of exposure to higher levels of traffic-related air pollution (35, 36). Similarly, the short-term pulmonary benefits of physical exertion among healthy adults are greater when exposures to traffic-related pollutants are lower but are not completely reversed in highly polluted environments (37, 38).

Given the proven health benefits of physical activity, a careful assessment of potential benefits and harms of advice to individual patients regarding where and when to reduce activity is needed. Depending on the circumstances, it may be prudent to focus advice on temporarily reducing the degree of exertion and/or modifying the location of physical activity, such as indoors instead of outdoors or away from pollution sources. Choosing a walking or cycling route away from traffic can reduce exposure, as pollutant concentrations decrease rapidly with increasing distance downwind of major roadways, typically falling to background concentrations within about 400 m (39). Similarly, altering the time of increased physical activity, such as avoiding later-day ozone by exercising in the morning during the summer, may optimize the benefits of physical activity while minimizing exposure to ambient air pollutants.

Can Respirators, or Other Types of Face Masks, Protect Individuals from Air Pollution?

Depending on how they are designed and used, air filtering devices worn on the face and covering the nose and mouth may provide widely varying protection from inhalation of air pollution. It is important to distinguish between tight-fitting, government-certified respirators (such as "N95s"), which can provide a reduction in exposure well over 90%, and dust masks or improvised, loose-fitting face masks, which generally provide much less protection from exposure to particle air pollution (40). Unless they contain special sorbent material, respirators and face masks generally do not provide protection against gases and vapors. Unlike the use of respirators in occupational settings or to control the spread of infectious disease (i.e., coronavirus disease [COVID-19]), the use of respirators by the public for reducing exposure to ambient air pollution is less common, and no consensus exists on how effective respirators might be for this purpose.

The efficacy and effectiveness of respirators or other face masks for reducing exposure to air contaminants depends on the efficiency of the filtering material at removing air pollutants and the tightness of the face seal. A filtering facepiece respirator commonly used occupationally in healthcare settings in the United States is the N95 respirator, which has filtering material that removes at least 95% of particles tested and is certified by the National Institute for Occupational Safety and Health. In Europe, the FFP2 is very similar to the N95. The actual effectiveness of respirators is usually limited by the leakiness of the face seal. During inhalation, contaminated air will take the path of least resistance and enter the facepiece through any leaks in the face seal. Facial hair can break the face seal, some individuals cannot obtain a good fit because of an incompatible size and shape of the face and respirator, and these types of respirators have not been certified for use by children. The training and fit-testing that is usually mandatory before using a respirator for respiratory protection in the workplace is not commonly available to the general public. A poorly fitted respirator may provide little more than a false sense of protection, which may lead to decisions or behaviors that increase exposure.

The use of tight-fitting respirators to reduce exposure to air pollution is not without potential adverse effects. Respirators increase the work of breathing and create a dead space under the face piece, contributing to discomfort (41). Although a few studies have indicated that respirators may prevent increases in blood pressure associated with short-term exposure to urban PM (*see* Appendix C in the online supplement), other studies have suggested that respirator use itself may cause acute increases in blood pressure (42). Because of the potential adverse respiratory and cardiovascular effects of respirator use, the U.S. Occupational Safety and Health Administration requires medical clearance for occupational respirator use. Even among workers who may be relatively healthy, the evidence basis for medical clearance for use of respirators is limited (43), and there are currently no guidelines for assessing the ability of members of the general public to use respirators in preventing exposures to outdoor air pollution.

Although a few studies have found that the use of respirators is well tolerated by healthy people, including pregnant women (44, 45), individuals with respiratory and cardiovascular disease who may benefit most from reductions in exposure to ambient air pollution are also likely to be those most at risk for adverse health effects from wearing respirators. Caution in the use of respirators is especially advised for individuals who may be susceptible to the mild increases in cardiovascular and respiratory stress caused by the use of respirators, although the potential trade-offs in using respirators to reduce exposure to outdoor air pollution should be considered separately from the use of face masks for reducing the spread of infectious diseases.

Several studies have examined physiological and biomarker effects of wearing N95 respirators or similar respirators in high-pollution areas for short periods of 1–2 hours. A few of these studies have found a lowering of blood pressure and improvements in biomarkers in unblinded comparisons of responses to ambient PM exposure with and without the respirator (46, 47). Studies of the net benefits for health outcomes of respirator use, including in susceptible groups and over longer periods of time, are needed before respirators can be recommended for use to control exposure to air pollution among members of the general public during times of regular pollution exposures.

What Important Equity, Social Justice, and Communication Issues Need to be Considered in Discussing Personal Interventions with Patients?

Equity and social justice issues play an important role in determining both exposures to outdoor air pollutants as well as shaping the successful use of feasible interventions. In fact, these issues are critical factors in determining vulnerability to the adverse health effects of air pollution. In most settings, low-income communities are more likely to experience higher exposures to ambient pollutants (48). These differential exposures to ambient pollutants across race and class lines are shaped by asymmetry in decision-making, class-based residential segregation, and other factors that operate at the individual and societal levels (49). Time activity, building design, and many other factors also contribute to differences in overall personal exposure to air pollutants (50).

Unfortunately, populations with the largest potential need to adopt protective actions to reduce exposure levels and health impacts from outdoor air pollution may also be the least able to take advantage of these interventions because of lack of access to information and financial resources. Recognizing and addressing these potential limitations, particularly when there are significant costs associated with the intervention (e.g., air purifiers, personal respirators, etc.), will be essential to any successful effort to promote the use of personal interventions.

In general, the evidence basis on how socioeconomic and demographic factors may shape the likelihood of successful personal interventions is limited (51, 52). In one example, data from the 2007–2008 National Health and Nutrition Examination Survey were used to study the prevalence of individual-level action to reduce personal exposure to air pollution among the U.S. adult population if informed that outdoor air quality was "bad." Although their results showed that individual action was infrequent among the overall population, they also showed that college graduates were at a significantly higher odds of changing behaviors (odds ratio, 1.54; 95% confidence interval, 1.14–2.09) than those with less than a high school education (53). It is unclear if this result was due to a lack of information or a lack of opportunity to modify behaviors, but it does illustrate some of the challenges in promoting potentially effective personal interventions.

For people to successfully engage in protective behaviors, they need to know what to do and when to do it. Success also depends on having the necessary skills, equipment, and other resources. Perhaps equally important in adopting protective actions is the belief that their efforts will be effective in reducing their risk (54–64). In communicating with patients, it is important to recognize that beliefs regarding the effectiveness of personal interventions can be strongly influenced by information that is conveyed through advertisements, product information, and reviews for masks, filters, air monitors, and other products, which are widely available on the internet and from other sources. This information may be inaccurate or misleading and may compete with information provided by clinicians and public health authorities.

Conclusions

Persistently poor, and in some cases worsening, air quality in many locations around the world has underscored the need for better understanding and application of the actions that individuals can take now to reduce their exposure and risk of adverse health effects. As reviewed in this report, the appropriate actions may be tailored to individual susceptibility, availability, reliability of air quality data and communications, equity and ethical considerations, and personal circumstances, as well as the efficacy and effectiveness of a given intervention. Although more knowledge about the relationships between personal interventions and clinical health outcomes is needed, available evidence can be used to assist clinicians and patients in making prudent decisions regarding personal actions to reduce exposure and risk from unhealthy concentrations of ambient air pollution. ■

This official workshop report was prepared by an *ad hoc* subcommittee of the ATS Assembly on Environmental, Occupational, and Public Health.

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References

1 Zheng XY, Ding H, Jiang LN, Chen SW, Zheng JP, Qiu M, *et al*. Association between air pollutants and asthma emergency room visits and hospital admissions in time series studies: a systematic review and meta-analysis. *PLoS One* 2015;10:e0138146.
2 Li J, Sun S, Tang R, Qiu H, Huang Q, Mason TG, *et al*. Major air pollutants and risk of COPD exacerbations: a systematic review and meta-analysis. *Int J Chron Obstruct Pulmon Dis* 2016;11:3079–3091.
3 Goss CH, Newsom SA, Schildcrout JS, Sheppard L, Kaufman JD. Effect of ambient air pollution on pulmonary exacerbations and lung function in cystic fibrosis. *Am J Respir Crit Care Med* 2004;169:816–821.
4 Sesé L, Nunes H, Cottin V, Sanyal S, Didier M, Carton Z, *et al*. Role of atmospheric pollution on the natural history of idiopathic pulmonary fibrosis. *Thorax* 2018;73:145–150.
5 Nawrot TS, Vos R, Jacobs L, Verleden SE, Wauters S, Mertens V, *et al*. The impact of traffic air pollution on bronchiolitis obliterans syndrome and mortality after lung transplantation. *Thorax* 2011;66:748–754.
6 Benmerad M, Slama R, Botturi K, Claustre J, Roux A, Sage E, *et al*.; SysCLAD Consortium. Chronic effects of air pollution on lung function after lung transplantation in the Systems Prediction of Chronic Lung Allograft Dysfunction (SysCLAD) study. *Eur Respir J* 2017;49:1600206.
7 Buteau S, Goldberg MS, Burnett RT, Gasparrini A, Valois MF, Brophy JM, *et al*. Associations between ambient air pollution and daily mortality in a cohort of congestive heart failure: Case-crossover and nested case-control analyses using a distributed lag nonlinear model. *Environ Int* 2018; 113:313–324.
8 Plaia A, Ruggieri M. Air quality indices: a review. *Rev Environ Sci Biotechnol* 2011;10:165–179.
9 Perlmutt LD, Cromar KR. Comparing associations of respiratory risk for the EPA Air Quality Index and health-based air quality indices. *Atmos Environ* 2019;202:1–7.
10 Borbet TC, Gladson LA, Cromar KR. Assessing air quality index awareness and use in Mexico City. *BMC Public Health* 2018;18:538.
11 Yao J, Stieb DM, Taylor E, Henderson SB. Assessment of the Air Quality Health Index (AQHI) and four alternate AQHI-Plus amendments for wildfire seasons in British Columbia. *Can J Public Health* 2020;111:96–106.
12 Cromar KR, Duncan BN, Bartonova A, Benedict K, Brauer M, Habre R, *et al*. Air pollution monitoring for health research and patient care: an official American Thoracic Society workshop report. *Ann Am Thorac Soc* 2019; 16:1207–1214.
13 Carvlin GN, Lugo H, Olmedo L, Bejarano E, Wilkie A, Meltzer D, *et al*. Development and field validation of a community-engaged particulate matter air quality monitoring network in Imperial, California, USA. *J Air Waste Manag Assoc* 2017;67:1342–1352.
14 U.S. Environmental Protection Agency. Residential air cleaners: a technical summary, 3rd ed. Washington, DC: U.S. Government Printing Office; 2018. EPA Publication No. 402-F-09-002.
15 Alavy M, Siegel JA. IAQ and energy implications of high efficiency filters in residential buildings: a review (RP-1649). *Sci Technol Built Environ* 2019; 25:261–271.
16 Bennett DH, Kenyon N, Tancredi D, Schenker M, Fisk WJ, Moran R, *et al*. Benefits of high efficiency filtration to children with asthma. Sacramento, California: California Air Resources Board; 2018.
17 Liu W, Huang J, Lin Y, Cai C, Zhao Y, Teng Y, *et al*. Negative ions offset cardiorespiratory benefits of $PM_{2.5}$ reduction from residential use of negative ion air purifiers. *Indoor Air* 2021;31:220–228.
18 Batterman S, Du L, Mentz G, Mukherjee B, Parker E, Godwin C, *et al*. Particulate matter concentrations in residences: an intervention study evaluating stand-alone filters and air conditioners. *Indoor Air* 2012;22: 235–252.
19 Hacker DW, Sparrow EM. Use of air-cleaning devices to create airborne particle-free spaces intended to alleviate allergic rhinitis and asthma during sleep. *Indoor Air* 2005;15:420–431.
20 Azuma K, Kagi N, Yanagi U, Osawa H. Effects of low-level inhalation exposure to carbon dioxide in indoor environments: a short review on human health and psychomotor performance. *Environ Int* 2018;121:51–56.
21 Lanphear BP, Hornung RW, Khoury J, Yolton K, Lierl M, Kalkbrenner A. Effects of HEPA air cleaners on unscheduled asthma visits and asthma symptoms for children exposed to secondhand tobacco smoke. *Pediatrics* 2011;127:93–101.
22 Thurston GD, Kipen H, Annesi-Maesano I, Balmes J, Brook RD, Cromar K, *et al*. A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework. *Eur Respir J* 2017; 49:1600419.
23 Brook RD, Newby DE, Rajagopalan S. Air pollution and cardiometabolic disease: an update and call for clinical trials. *Am J Hypertens* 2017;31:1–10.
24 Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, *et al*. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *J Expo Anal Environ Epidemiol* 2001;11:231–252.

25 Cepeda M, Schoufour J, Freak-Poli R, Koolhaas CM, Dhana K, Bramer WM, *et al*. Levels of ambient air pollution according to mode of transport: a systematic review. *Lancet Public Health* 2017;2:e23–e34.
26 Fisk WJ. How home ventilation rates affect health: a literature review. *Indoor Air* 2018;28:473–487.
27 Allen RW, Adar SD, Avol E, Cohen M, Curl CL, Larson T, *et al*. Modeling the residential infiltration of outdoor $PM_{2.5}$ in the Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). *Environ Health Perspect* 2012;120:824–830.
28 Tang M, Thompson D, Chang D-Q, Chen S-C, Pui DYH. Filtration efficiency and loading characteristics of $PM_{2.5}$ through commercial electret filter media. *Separ Purif Tech* 2018;195:101–109.
29 Weschler CJ. Ozone in indoor environments: concentration and chemistry. *Indoor Air* 2000;10:269–288.
30 de Nazelle A, Bode O, Orjuela JP. Comparison of air pollution exposures in active vs. passive travel modes in European cities: a quantitative review. *Environ Int* 2017;99:151–160.
31 Jiao W, Frey HC. Comparison of fine particulate matter and carbon monoxide exposure concentrations for selected transportation modes. *Transp Res Rec* 2014;2428:54–62.
32 Fruin SA, Hudda N, Sioutas C, Delfino RJ. Predictive model for vehicle air exchange rates based on a large, representative sample. *Environ Sci Technol* 2011;45:3569–3575.
33 Fu X, Xiang S, Liu Y, Liu J, Yu J, Mauzerall DL, *et al*. High-resolution simulation of local traffic-related NO_x dispersion and distribution in a complex urban terrain. *Environ Pollut* 2020;263:114390.
34 Nyhan M, McNabola A, Misstear B. Comparison of particulate matter dose and acute heart rate variability response in cyclists, pedestrians, bus and train passengers. *Sci Total Environ* 2014;468-469:821–831.
35 Kubesch NJ, Therming Jørgensen J, Hoffmann B, Loft S, Nieuwenhuijsen MJ, Raaschou-Nielsen O, *et al*. Effects of leisure-time and transport-related physical activities on the risk of incident and recurrent myocardial infarction and interaction with traffic-related air pollution: a cohort study. *J Am Heart Assoc* 2018;7:e009554.
36 Andersen ZJ, de Nazelle A, Mendez MA, Garcia-Aymerich J, Hertel O, Tjønneland A, *et al*. A study of the combined effects of physical activity and air pollution on mortality in elderly urban residents: the Danish Diet, Cancer, and Health cohort. *Environ Health Perspect* 2015;123:557–563.
37 Kubesch N, de Nazelle A, Guerra S, Westerdahl D, Martinez D, Bouso L, *et al*. Arterial blood pressure responses to short-term exposure to low and high traffic-related air pollution with and without moderate physical activity. *Eur J Prev Cardiol* 2015;22:548–557.
38 Laeremans M, Dons E, Avila-Palencia I, Carrasco-Turigas G, Orjuela-Mendoza JP, Anaya-Boig E, *et al*. Black carbon reduces the beneficial effect of physical activity on lung function. *Med Sci Sports Exerc* 2018;50:1875–1881.
39 Beckerman B, Jerrett M, Brook JR, Verma DK, Arain MA, Finkelstein MM. Correlation of nitrogen dioxide with other traffic pollutants near a major expressway. *Atmos Environ* 2008;42:275–290.
40 Rengasamy S, Eimer B, Shaffer RE. Simple respiratory protection: evaluation of the filtration performance of cloth masks and common fabric materials against 20-1000 nm size particles. *Ann Occup Hyg* 2010;54:789–798.
41 Johnson AT. Respirator masks protect health but impact performance: a review. *J Biol Eng* 2016;10:4.
42 Jones JG. The physiological cost of wearing a disposable respirator. *Am Ind Hyg Assoc J* 1991;52:219–225.
43 Belafsky S, Vlach J, McCurdy SA. Cardiopulmonary fitness and respirator clearance: an update. *J Occup Environ Hyg* 2013;10:277–285.
44 Roberge RJ, Kim J-H, Palmiero A, Powell JB. Effect of pregnancy upon facial anthropometrics and respirator fit testing. *J Occup Environ Hyg* 2015;12:761–766.
45 Roberge RJ, Kim J-H, Powell JB. N95 respirator use during advanced pregnancy. *Am J Infect Control* 2014;42:1097–1100.
46 Langrish JP, Li X, Wang S, Lee MMY, Barnes GD, Miller MR, *et al*. Reducing personal exposure to particulate air pollution improves cardiovascular health in patients with coronary heart disease. *Environ Health Perspect* 2012;120:367–372.
47 Langrish JP, Mills NL, Chan JK, Leseman DL, Aitken RJ, Fokkens PH, *et al*. Beneficial cardiovascular effects of reducing exposure to particulate air pollution with a simple facemask. *Part Fibre Toxicol* 2009;6:8.
48 Hajat A, Hsia C, O'Neill MS. Socioeconomic disparities and air pollution exposure: a global review. *Curr Environ Health Rep* 2015;2:440–450.
49 Cushing L, Morello-Frosch R, Wander M, Pastor M. The haves, the have-nots, and the health of everyone: the relationship between social inequality and environmental quality. *Annu Rev Public Health* 2015;36:193–209.
50 Adamkiewicz G, Zota AR, Fabian MP, Chahine T, Julien R, Spengler JD, *et al*. Moving environmental justice indoors: understanding structural influences on residential exposure patterns in low-income communities. *Am J Public Health* 2011;101:S238–S245.
51 Benmarhnia T, Rey L, Cartier Y, Clary CM, Deguen S, Brousselle A. Addressing equity in interventions to reduce air pollution in urban areas: a systematic review. *Int J Public Health* 2014;59:933–944.
52 Chakraborty J, Collins TW, Grineski SE. Environmental justice research: contemporary issues and emerging topics. *Int J Environ Res Public Health* 2016;13:1072.
53 Lissåker CTK, Talbott EO, Kan H, Xu X. Status and determinants of individual actions to reduce health impacts of air pollution in US adults. *Arch Environ Occup Health* 2016;71:43–48.
54 Green LW. Editorial. *Health Educ Monogr* 1974;2:324–325.
55 Becker MH. The health belief model and sick role behavior. *Health Educ Monogr* 1974;2:409–419.