Personal strategies to minimise effects of air pollution on respiratory health: advice for providers, patients and the public

Christopher Carlsten MD[1], Sundeep Salvi PhD, Gary WK Wong MD, Kian Fan Chung MD

1. Corresponding author

Online supplement

SUPPLEMENTARY TABLE S1 Search strategy details.

The search was restricted to references published in English and in humans. In addition to PubMed, the following sources were searched for relevant references: The Global Burden of Disease Study, World Health Organization reports, Royal College of Physicians of London reports, The Lancet Commissions, and guidelines for use of devices designed to reduce levels of air pollution.

Search terms	**Database**	**Number of results**	**Number of relevant articles**
STRATEGIES TO MINIMISE EXPOSURE TO AIR POLLUTION			
Strategies to minimise personal exposure to ambient air pollution			
(air pollution OR particulate matter) AND (masks OR facemasks OR mask OR facemask OR respirator OR respirators OR "barrier methods" OR pollution domes OR pollution dome)	PubMed	120	36
(air pollution OR particulate matter) AND personal protective equipment	PubMed	98	18
(air pollution OR particulate matter) AND (risk reduction behavior OR “behavioral change” OR “behavioural change” OR “behavior change” OR “behaviour change” OR “exposure reduction” OR “exposure reducing”)	PubMed	124	14
"air quality health index" OR "air quality index" AND (exposure OR behavior)	PubMed	48	14
(air pollution OR particulate matter) AND (monitor OR monitors OR phone OR phones OR smartphone OR smartphones OR app) AND “personal exposure”	PubMed	43	13
("wearable sensor" OR "wearable sensors" OR "portable sensor" OR "portable sensors") AND (air pollution OR particulate matter)	PubMed	9	4
(air pollution [Title] OR particulate matter[Title] OR pollutants[Title]) AND (exercise OR physical activity) AND (exposure OR behavior OR behaviour)	PubMed	117	56

(air pollution OR particulate matter) AND (“traffic fumes” OR exhaust OR “traffic exposure” OR “traffic emissions”) AND personal exposure	PubMed	43	4
(air pollution OR particulate matter) AND (commute[Title/Abstract] OR commutes[Title/Abstract] OR commuting[Title/Abstract]) AND exposure	PubMed	77	49
(vehicle OR traffic OR car OR vehicles OR cars) AND idling AND (air pollution OR particulate matter)	PubMed	18	6
("traffic-related air pollution" OR "traffic related air pollution") AND (manage OR prevent* OR reduc* OR minimi* OR mitig* OR eliminat* OR interven* OR abrogat*) AND respiratory	PubMed	41	8
(wildfire OR wildfires OR "wild fire" OR "wild fires") AND (air pollution OR particulate matter) AND exposure	PubMed	60	9
(duststorm* OR dust storm* OR “dust storm” OR "dust storms") AND (air pollution OR particulate matter) AND exposure	PubMed	36	4
(air pollution OR particulate matter) AND (“personal exposure” or “individual exposure”) AND (manag*[Title] OR prevent*[Title] OR reduc*[Title] OR minimi*[Title] OR behav*[Title] OR mitigat*[Title])	PubMed	13	3
(air pollution OR particulate matter) AND exposure AND (guideline[Title] OR guidelines[Title] OR guidance[Title] OR advice[Title] OR recommendation[Title] OR recommendations[Title])	PubMed	31	2
Strategies to minimise personal exposure to household air pollution			
(Air pollution) AND (respiratory health) [Title/Abstract]	PubMed	160	60
(air pollut*) OR (particulate matter) OR (particle poll*) AND (air purifier) OR (air filter) OR (nasal filter) OR (air cleaner) OR (ventilation) [Title/Abstract]	PubMed	327	136
(air pollut*) OR (particulate matter) OR (particle poll*) AND (behaviour) OR (behavior) [Title/Abstract]	PubMed	354	17

(air pollut*) OR (particulate matter) OR (particle poll*) AND (monitor) OR (forecast) OR (index) AND (respiratory) [Title/Abstract]	PubMed	121	13
(air pollut*) OR (particulate matter) OR (particle poll*) AND (fire) OR (coal) OR (cookstove) OR (cook stove) OR (wood stove) OR (woodstove) OR (kerosene) OR (biomass) AND (household) OR (indoor) AND (manag*) OR (prevent*) OR (mitigat*) OR (abrogat*) OR (reduc*) OR (minimi*) OR (eliminat*) OR (interven*) [Title/Abstract]	PubMed	69	18
(air pollut*) OR (particulate matter) OR (particle poll*) AND (tobacco smoke) OR (cigarette smoke) AND (manag*) OR (prevent*) OR (mitigat*) OR (abrogat*) OR (reduc*) OR (minimi*) OR (eliminat*) OR (interven*) AND (respiratory) [Title/Abstract]	PubMed	148	8
(air pollut*) OR (particulate matter) OR (particle poll*) AND (household) OR (indoor) AND (manag*) OR (prevent*) OR (mitigat*) OR (abrogat*) OR (reduc*) OR (minimi*) OR (eliminat*) OR (interven*) AND (respiratory) [Title/Abstract]	PubMed	149	20
(air pollut*) OR (particulate matter) OR (particle poll*) AND (recommendation) OR (guideline) OR (guidance) OR (best practice) OR (expert opinion) OR (consensus) OR (strategy) AND (manag*) OR (prevent*) OR (mitigat*) OR (abrogat*) OR (reduc*) OR (minimi*) OR (eliminat*) OR (interven*) AND (respiratory) [Title/Abstract]	PubMed	58	14
Strategies to protect those most at risk (e.g. children, older people, and people with chronic health problems/co-morbidities)			
(air pollution OR particulate matter) AND respiratory AND (manage OR prevent* OR reduc* OR minimi* OR mitig* OR eliminat* OR interven* OR abrogat*) AND (children[Title] OR elderly[Title] OR pregnancy[Title] OR “in utero”[Title] OR asthma[Title] OR allergic rhinitis[Title] OR chronic obstructive pulmonary disease[Title] OR genetic counseling[Title] OR infection[Title] OR inflammation[Title] OR “at risk”[Title] OR “susceptible”[Title]]	PubMed	341	57
Effect modifiers, treatments/interventions to minimise exposure/strengthen defence mechanisms			

(Air pollution[Title/abstract] OR particulate matter[Title/abstract]) AND respiratory AND (diet[Title/abstract] OR dietary[Title/abstract] OR antioxidant*[Title/abstract] OR vitamins[Title/abstract] OR supplements[Title/abstract])	PubMed	88	22
(Air pollution[Title/abstract] OR particulate matter[Title/abstract]) AND respiratory AND (leukotriene receptor antagonist[Title/abstract] OR antileukotrienes OR salmeterol[Title/abstract] OR albuterol[Title/abstract] OR long-acting bronchodilator[Title/abstract] OR corticosteroid*[Title/abstract] OR anti-inflammatory[Title/abstract] OR chemoprevention[Title/abstract] OR counselling[Title/abstract])	PubMed	36	9
Misconceptions about air pollution and respiratory health			
(Air pollution[Title/abstract] OR particulate matter[Title/abstract]) AND respiratory AND (diet[Title/abstract] OR dietary[Title/abstract] OR antioxidant*[Title/abstract] OR vitamins[Title/abstract] OR supplements[Title/abstract])	PubMed	6	1

*the asterisk at the end of a truncated word is used to search for all terms that begin with the word root.

SUPPLEMENTARY TABLE S2 Description of levels of evidence used in this review (adapted from the levels of evidence used in the GINA guidelines 2019 [1]).

Evidence level	Sources of evidence	Definition
A	RCTs and meta-analyses. Rich body of data.	Evidence is from endpoints of well-designed RCTs, meta-analyses or strong observational evidence that provide a consistent pattern of findings in the population for which the recommendation is made. Category A requires substantial numbers of studies involving substantial numbers of participants.
B	RCTs and meta-analyses. Limited body of data.	Evidence is from endpoints of intervention studies that include only a limited number of patients, post-hoc or subgroup analysis of RCTs, or meta-analysis of such RCTs. In general, Category B pertains when few randomised trials exist, they are small in size, they were undertaken in a population that differs from the target population of the recommendation, or the results are somewhat inconsistent.
C	Non-randomised trials. Observational studies.	Evidence is from outcomes of uncontrolled trials or non-randomised trials or from observational studies.
D	Panel consensus judgement.	This category is used only in cases where the provision of some guidance was deemed valuable but the clinical literature addressing the subject was insufficient to justify assignment of one of the other categories. The Panel Consensus is based on clinical experience or knowledge that does not meet the above listed criteria.

GINA: Global Initiative for Asthma; RCT: randomised controlled trial.

SUPPLEMENTARY TABLE S3 Summary of the key supporting evidence for each recommendation from studies that included at least one respiratory health outcome.

1. **Use facemasks under appropriate circumstances**

Reference	Design	Population, sample size	Key findings
Cherrie et al., 2018 [2]	Non-randomised, non-controlled	Healthy adults in China (n=10)	Four commercial masks were tested on volunteers exposed to diesel exhaust inside an experimental chamber. The facemasks did not provide adequate protection from particles primarily due to poor facial fit.
Guan et al., 2018 [3]	Randomised, controlled, double-blind, crossover	Healthy adults in China (n=15)	N95 facemasks provided some protection against airway inflammation following exposure to traffic-associated particle pollution, but neither systemic oxidative stress nor endothelial dysfunction improved significantly.
Yang et al., 2018 [4]	Randomised, non-controlled, crossover	Healthy adults in China (n=39)	Short-term wearing of N95-like particulate-filtering masks was associated with improved autonomic nervous function. Masks were tested for facial fit.
Shi et al., 2017 [5]	Randomised, non-controlled, crossover	Healthy adults in China (n=24)	Short-term wearing of N95 particulate-filtering masks was associated with improved autonomic nervous function and reduced blood pressure. Masks were tested for facial fit.
Shakya et al., 2016 [6]	Non-randomised, non-controlled	Healthy adults in Nepal (n=53)	N95 facemasks provided a modest but acute improvement in lung function (measured by spirometry) when were worn by traffic officers for just half of a workweek.

2. **Shift from motorised to active transport whenever possible**

Reference	Design	Population, sample size	Key findings
Cepeda et al., 2017 [7]	Systematic review	39 studies (intervention, observational and mixed design) comparing AP exposure according to transport mode	The benefits of physical activity when actively commuting versus using motorised transport outweighed the risks associated with the increased inhaled dose of air pollutants. Commuters using motorised transport were estimated to lose up to 1 year of life expectancy compared with cyclists.
Raza et al., 2018 [8]	Systematic review	18 studies (health impact	Shifts from motorised transport to active travel would reduce traffic volume and

		assessment) comparing AP exposure according to transport mode	related AP emissions thereby contributing small health benefits for the general population overall.
Mueller et al., 2015 [9]	Systematic review	30 studies (health impact assessment) comparing AP exposure according to transport mode	Net health benefits of active travel exceeded detrimental effects of AP exposure and traffic incidents. Older people were estimated to benefit more than younger people due to the increased protection physical activity offers against chronic degenerative disease incidence but may be more vulnerable to traffic incidents when walking and cycling.
Xia et al., 2015 [10]	Health impact assessment	Modelling of AP and comparative risk assessment in Adelaide, Australia, estimated population 1.4 million	Shifting 10% of vehicle kilometres travelled from passenger vehicles to cycling would prevent 321 deaths/year and 4,132 Disability-Adjusted Life Years/year, mainly through a reduction in total disease burden associated with lack of physical activity.
Tainio et al., 2016 [11]	Health impact assessment	Health impact model of AP and physical activity using all-cause mortality as the health outcome	Benefits from active travel generally outweighed health risks from AP. For 30 minutes of cycling every day, the background $PM_{2.5}$ concentration would need to be 95 μg m^{-3} to reach the point above which additional physical activity would not lead to higher health benefits. In the WHO Ambient Air Pollution Database <1% of cities have $PM_{2.5}$ annual concentrations above that level. For 30 minutes of cycling every day the background $PM_{2.5}$ concentration would need to be 160 μg m^{-3} to reach the point above which additional physical activity would cause adverse health effects. The average urban background $PM_{2.5}$ concentration in the WHO database was 22 μg m^{-3} and the point above which additional physical activity would cause adverse health effects would only be reached after 7 hours of cycling and 16 hours of walking per day. In a highly polluted city such as Delhi with background $PM_{2.5}$ concentrations of 153 μg m^{-3}, up to 30 minutes of cycling and 6 hours 15 minutes of walking per day

			would lead to a net reduction in all-cause mortality versus staying at home (i.e. background $PM_{2.5}$ concentration).
Andersen et al., 2015 [12]	Epidemiological study	Subjects (n=52,061; 50–65 years old) from the Danish Diet, Cancer and Health cohort living in Aarhus and Copenhagen, reported data on physical activity in 1993–1997 and were followed to 2010	Benefits from physical activity during cycling generally outweighed health risks from AP. There was a statistically significant inverse association between cycling and all-cause mortality (HR 0.83; 95% CI 0.78, 0.88), and cycling and respiratory mortality (HR 0.62; 95% CI 0.5, 0.77). Long-term benefits of physical activity on mortality were not moderated by exposure to high levels of NO_2 defined as ≥19.0 μg m^{-3} NO_2.
Gaffney et al., 2016 [13]	Cross-sectional population-based study	Adults in Shanghai, China (n=20,102)	Commuting by walking and by bus but not by car was associated with small but statistically significant reductions in pulmonary function (FEV_1 and FVC) compared with cycling ($p<0.01$).

3. **Choose travel routes that minimise near-road AP exposure**

Reference	Design	Population, sample size	Key findings
Jarjour et al., 2013 [14]	Non-randomised, non-controlled comparative study	Healthy adults in California, US (n=15)	Subjects were exposed to lower BC, UFP, and CO levels on a single commute (8.0–9.5 km) by bicycle on a low-traffic versus a high-traffic route ($p<0.06$). However, no significant differences in lung function (measured by spirometry) were observed.
Park HY et al., 2017 [15]	Non-randomised, non-controlled	Healthy adults in Brisbane, Australia (n=32)	Short-term increases in UFPM levels (used as proxy for near-road TRAP) were associated with decreased lung function when cycling (22.2 km) versus baseline. Lung function decrements (FVC and FEV_1) were greater in cyclists using high traffic versus low traffic routes ($p<0.005$); cyclists should plan their route to reduce exposures.
Sinharay et al., 2018 [16]	Randomised, crossover	Adults aged ≥60 years old with COPD (n=40), ischemic heart disease (n=39) and aged-matched healthy	Concentrations of BC, NO_2, $PM_{2.5}$, PM_{10}, and UFPs were greater on the high traffic versus the low traffic route ($p<0.001$). Participants with COPD reported higher scores for respiratory symptoms after walking down the high traffic versus low traffic route ($p<0.05$).

		volunteers (n=40) in London, UK	Improvements in lung function (FVC and FEV_1) were observed in healthy subjects and those with COPD after walking down the low traffic but not the high traffic route versus baseline. The findings suggest that older individuals and adults with chronic cardiorespiratory disorders should minimise walking on streets with high levels of pollution because this negates the cardiorespiratory benefits of exercise.

4. **Optimise driving style and vehicle settings**

Reference	Design	Population, sample size	Key findings
Yu et al., 2017 [17]	Non-randomised, non-controlled	Taxi drivers (n=17), mean age 47 years old, in Los Angeles, US	Driving with windows closed and using a high efficiency cabin air filter reduced $PM_{2.5}$ and UFP levels inside the vehicles by 37% and 47%, respectively ($p<0.05$) and reduced drivers urinary MDA concentrations by 17% (not significant) versus no intervention. Urinary MDA levels were used as a marker of systematic oxidative stress induced by in-vehicle PM exposure; however, there was a lack of clinical studies assessing health outcomes.

5. **Moderate outdoor physical activity when and where AP levels are high**

Reference	Design	Population, sample size	Key findings
Sinharay et al., 2018 [16]	randomised, crossover	Adults aged ≥60 years old with COPD (n=40), ischemic heart disease (n=39) and aged-matched healthy volunteers (n=40) in London, UK	Adults with COPD, who walked for 2 hours on a traffic-polluted road were found to have more cough ($p<0.1$), sputum ($p<0.05$), shortness of breath ($p<0.1$) and wheeze ($p<0.05$) versus walking in a traffic-free area. A reduction in lung function from baseline was associated with an increase in during-walk exposure to NO_2, UFP, and $PM_{2.5}$. The beneficial effects of physical activity on respiratory/pulmonary measures were attenuated in healthy adults and those with COPD when exposed to high versus low AP levels.
Lamichhane et al., 2018 [18]	Non-randomised,	Adults (n=1264), mean age 58 years	Although not significant, the negative effect of $PM_{2.5}$ on lung function (measured by spirometry) was greater

	non-controlled, cross sectional	old, with suspected COPD or asthma in South Korea	among those who did not exercise versus those that did.
Zhang et al., 2018 [19]	Prospective, longitudinal cohort	Adults (n=359,067), mean age 40 years old at start, in Taiwan	Regular exercise was associated with lower markers of systemic inflammation (indicated by white blood cell counts) than inactivity at all levels of $PM_{2.5}$ exposure (<21.7 μg m^{-3} to ≥28.1 μg m^{-3}) ($p<0.001$). High levels of physical activity had greater beneficial effects at all levels of $PM_{2.5}$ exposure versus moderate or low levels of physical activity ($p<0.001$).
Andersen et al., 2015 [12]	Epidemiological	Adults (n=52,061) aged 50–65 years old from the Danish Diet, Cancer, and Health cohort, living in Aarhus and Copenhagen	Inverse associations were observed between cycling and respiratory mortality ($p=0.09$) and this was stronger among subjects with NO_2 exposure <19.0 μg m^{-3} (HR=0.55; 95% CI: 0.42, 0.72) than those with high NO_2 exposure ≥19.0 μg m^{-3} (HR=0.77; 95% CI: 0.54, 1.11). Cycling in areas with high versus moderate/low levels of AP reduced, but did not reverse, the benefits of physical activity on respiratory mortality.
Fisher et al., 2016 [20]	Epidemiological	Adults (n=53,113) aged 50–65 years old from the Danish Diet, Cancer, and Health cohort, living in Aarhus and Copenhagen	The beneficial effects of doing sports, cycling, and gardening in reducing risk of new asthma and COPD hospitalisations were not moderated in subjects who lived in areas with high NO_2 levels ≥21.0 μg m^{-3} versus those in areas with low NO_2 levels <14.3 μg m^{-3}, despite positive associations between NO_2 and incident asthma/COPD hospitalisations. Increased exposure to NO_2 did not outweigh the beneficial effects of physical activity for reducing risk of hospitalisation for asthma and COPD.
Matt et al., 2016 [21]	Real-world, non-randomised, crossover	Healthy adults (n=30) in Barcelona, Spain	Individuals had a short-term increase in lung function (spirometry) for several hours after physical activity even in highly-polluted environments. However, high TRAP versus low TRAP exposure attenuated the immediate respiratory benefits of physical activity.
Kubesch et al., 2015 [22]	Real-world, non-	Healthy adults (n=28) in	Intermittent moderate physical activity (15-minute intervals of alternating rest

	randomised, crossover	Barcelona, Spain	and cycling on a stationary bicycle) increased pulmonary function at low and high TRAP levels versus rest ($p \leq 0.05$).
Laeremans, 2018 [23]	Real-world, non-randomised, crossover	Healthy adults (n=122) in three European cities	Physical activity increased lung function versus baseline (FEV_1: +15.63 mL; $p<0.05$), while exposure to BC was associated with a decrease in lung function (PEF: −0.10 mL; $p<0.05$). An interaction between physical activity and BC on lung function ($p<0.05$) suggested a potential protective effect of physical activity against the negative effects of AP on lung function.

6. **Monitor AP levels**

Reference	Design	Population, sample size	Key findings
Stergiopoulou et al., 2018 [24]	Epidemiological	Children (n=97) aged 10–11 years old in Athens, Greece	Higher O_3 concentrations indicated by the local O_3 AQI were associated with increased daily occurrence of respiratory symptoms cough and nasal congestion; however, the study did not investigate whether knowledge of the AQI was associated with reduced incidence of respiratory symptoms.

7. **Use clean fuels, ensure adequate household ventilation where possible, and adopt improved cookstoves where resources remain sufficient**

Reference	Design	Population, sample size	Key findings
Choi et al., 2015 [25]	Real-world, non-randomised, non-crossover	Adult females (n=547), aged 18–85 years and children (n=845) ages 0–17 years in households exclusively cooking with either kerosene or LPG in Bangalore, India	In women, cooking with kerosene was associated with cough (OR=1.88; $p<0.01$) and chest illness (OR=1.61; $p<0.05$), relative to cooking with LPG in the multivariate models. In children, living in a household cooking with kerosene was associated with bronchitis (OR=1.91; $p<0.05$) and phlegm (OR=2.20; $p<0.01$) after adjusting for other covariates.
Lamichhane et al., 2017 [26]	Survey	Children (n=16,157) aged <5 years in India	In rural households use of LPG was associated with 10.7% lower probability of ARI versus exclusive use of polluting fuels.

Lewis et al., 2017 [27]	Cross-sectional observational cohort	Households (n=105) in Odisha, India	Use of improved (electric or gas) cookstoves was associated with a 72% reduction in $PM_{2.5}$, a 78% reduction in Polycyclic aromatic hydrocarbons levels, and reductions in water-soluble organic carbon and nitrogen compared with traditional mud stoves ($p<0.01$). Improved cookstove use was associated with shorter hospital stays for ARI compared with traditional mud stoves ($p<0.10$).
Downward et al., 2018 [28]	Cross-sectional observational	Female bakery workers (n=35) aged 18–60 years in Addis Ababa, Ethiopia	Biomass cookstoves were associated with higher exposure to $PM_{2.5}$ and CO versus electric cookstoves ($p<0.05$), and greater odds of reporting stopping for breath when walking (OR: 6.9; 95% CI: 1.3, 52.8).
Yu et al., 2018 [29]	Prospective cohort	Adults (n=271,217), mean age 51 years in rural China	Adults who switched from solid fuels to clean fuels (electric or gas) for cooking or who used ventilation when cooking had a lower risk of all-cause mortality than persistent solid fuel users or those who reported no ventilation during cooking (HR: 0.87; 95% CI: 0.79, 0.95 and HR: 0.91; 95% CI: 0.85, 0.96), respectively. Adults with longer self-reported duration of solid fuel use for cooking and heating had higher risks of all-cause mortality ($p<0.001$) than those with shorter duration.
Mortimer et al., 2017 [30]	Open cluster RCT	Children (n=10,453), aged <5 years in rural Malawi	Cleaner burning biomass-fuelled cookstoves did not reduce the risk of pneumonia in young children versus open fire cooking over a 2-year period.
Noonan et al., 2017 [31]	RCT	Children with asthma (n=114), mean age 12·4 years in three US states	Use of improved-technology wood-burning appliances did not reduce indoor $PM_{2.5}$ levels or improve Paediatric Asthma Quality of Life Questionnaire scores relative to placebo in children with asthma who were chronically exposed to wood smoke; however, use of an air filtration device reduced indoor PM levels by 67% and improved the secondary measured dPFV by 11.8% versus baseline, an indirect measure of airway hyper-responsiveness.
Guarnieri et al., 2015 [32]	Longitudinal, randomised cohort	Women (n=265) in Guatemala	No association between lung function parameters in women measured by spirometry (PEF and FEV_1) following

			an early stove intervention with improved ventilation versus a delayed stove intervention; however, individuals had continued heavy smoke exposure despite reductions associated with the improved cookstoves.
Heinzerling et al., 2016 [33]	Longitudinal, randomised cohort	Children (n=880), aged 5–8 years in Guatemala	Decreases in PEF growth of 173 mL/min/year (95% CI: −341, −7; p=0.041) and FEV_1 of 44 mL/year (95% CI: −91, 4, p=0.07) were observed in children whose families did not receive a chimney stove until 18 months of life versus stove installation at birth in analyses adjusted for multiple covariates. No associations were observed between personal household AP exposure and lung function; individuals had continued heavy smoke exposure despite reductions associated with the improved cookstoves.
Quansah et al., 2017 [34]	Systematic review and meta-analysis	Systematic review (n=55 studies); meta-analysis of experimental studies (n=15 studies)	There was limited evidence that improving cookstoves in homes using solid fuel in low- and middle-income countries yielded any health benefits despite reducing personal exposures to PM and CO.
Thakur et al., 2018 [35]	Systematic review and meta-analysis	(Quasi-)experimental studies (n=29); longitudinal observational studies (n=29)	Improved cookstove efficiency or ventilation was associated with reduced respiratory symptoms (cough, phlegm, wheezing/breathing difficulty) and a reduction in COPD among women versus use of traditional cookstoves; no demonstrable child health impact was observed.
Das et al., 2018[36]	Survey	Children (n=694) aged <5 years in Gisenyi, Rwanda	Outdoor cooking areas were associated with fewer symptoms of respiratory infection ($p<0.05$), illness with cough ($p<0.1$) and difficulty breathing ($p<0.05$) in children compared with enclosed dwellings. Ventilation was associated with fewer symptoms of illness with cough ($p<0.01$) and difficulty breathing ($p<0.01$) versus no ventilation in the cooking area.
Accinelli et al., 2014 [37]	Prospective survey	Children (n=82) aged 2–14 years in Andahuaylas province in Peru	Sleep-related problems, sore throat and headache improved in children following a switch from traditional stoves to improved kitchen stoves ($p<0.05$). Improved stoves with external

			exhausts were found to reduce PM concentrations by 74%.
Castañeda et al., 2013 [38]	Prospective survey	Children (n=59) aged <15 years in Cangallo province in Peru	Implementation of stoves with external exhausts in homes reduced nasal congestion (33.9% versus 1.8%, p<0.0001), sore throat (38.2% versus 5·5%, p<0.0001), breathing through the mouth during the day (33.9% versus 1.8%, p<0.001) as well as sleep-related symptoms versus traditional wood-burning stoves.
Seow et al., 2014 [39]	Review of case-control and cohort studies	Adults in Xuanwei, China	The installation of a chimney in homes reduced lung cancer incidence and mortality, lowered COPD incidence and reduced incidence of pneumonia by 50%, for both men and women, and for users of both smoky and smokeless coal.
Kim et al., 2015 [40]	Prospective cohort	Women (n=71,320) in Shanghai, China	Coal use in poorly ventilated kitchens was associated with a 49% increased risk of lung cancer (HR: 1.49; 95% CI: 1.15, 1.95), and the strength of association increased with years of exposure. Women who had lived in a home with poor ventilation during childhood and adulthood had a 69% increased risk of lung cancer versus women never exposed to poor ventilation during their lives (HR: 1.69; 95% CI: 1.22, 2.35).
Jin et al., 2014 [41]	Population-based, case-control	Subjects with lung cancer (n=1,424) and healthy controls (n=4,543) in Jiangsu Province, China	Good ventilation of households was associated with lung cancer risk reduction versus poor ventilation (OR: 0.87; 95% CI: 0.75, 1.00) and use of coal for cooking was associated with an increased lung cancer risk versus not using coal (OR: 1.27; 95% CI: 1.10, 1.47).
Mu et al., 2013 [42]	Population-based, case-control	Adults with lung cancer (n=399) and healthy controls (n=466) in Taiyuan, China	Housing characteristics related to poor ventilation, including single-story, less window area, no separate kitchen, no ventilator and rarely having windows open, were associated with increased risk of lung cancer. Every 10 ug m^{-3} increase in PM_1 was associated with 45% increased risk of lung cancer (p<0.01).
Hu et al., 2014 [43]	Survey	Adults (n=163) in Xuanwei and Fuyuan, China	$PM_{2.5}$ levels were 34–80% lower among vented stoves compared with unvented stoves and firepits, which paralleled the

			observation of reduced risks of malignant and non-malignant lung diseases in the region.
Zhou Y et al., 2014 [44]	Nine-year prospective cohort	Adults (n=996) aged ≥40 years in Yunyan, Southern China	Replacing biomass with biogas for cooking and improving kitchen ventilation was associated with improved indoor air quality, a reduced decline of lung function and reduced spirometry-measured COPD incidence (OR: 0.28; 95% CI: 0.11, 0.73). The longer the duration of use of improved fuel and ventilation, the slower the decline in FEV_1 ($p<0.05$).
Liu F et al., 2014 [45]	Cross-section	Children (n=23,326) aged 6–13 years in Northeast China	The use in a household of any of the following ventilation devices: exhaust fan, chimney, or fume hood (typically above a cookstove) was associated with decreased odds of asthma as well as decreased prevalence of persistent cough ($p<0.01$) and persistent phlegm ($p<0.05$) versus no ventilation device use.
Langbien, 2017 [46]	Review of 41 surveys	Children aged <5 years in 30 developing countries from Asia, Africa and Latin America	Outdoor cooking was associated with a decrease in ARI occurrence of 9% for children aged 0–4 years and 13% for children aged 0–1 year versus indoor cooking ($p<0.01$).
Kile, 2014 [47]	Cross-sectional survey	Children (n=12,570) aged 2–16 years in the US	Children whose parents reported using ventilation when operating their gas stove had higher lung function and lower odds of asthma (OR: 0.64; 95% CI: 0.43, 0.97), wheeze, (OR: 0.60, 95% CI: 0.42, 0.86), and bronchitis (OR: 0·60, 95% CI: 0.37, 0.95) compared with households that did not have ventilation or where no ventilation was used.
Lajoie et al., 2015 [48]	RCT	Children with asthma (n=83) aged 2–16 years in Canada	Improved ventilation via a mechanical ventilation system reduced episodes of wheezing in children and reduced levels of formaldehyde versus no intervention.
Salvi et al., 2016 [49]	Cross-sectional survey	Households using MC (n=153) in India	Burning of MCs produced indoor levels of $PM_{2.5}$ (up to 1031 μg m^{-3}) and CO (up to 6.50 parts per million) that were higher than those reported during the burning of biomass fuels for cooking purposes. Levels were reduced by improving ventilation, ~50% when the window was opened and >90% when

			both the window and the door were opened. There was a higher prevalence of respiratory symptoms and self-reported respiratory and allergic diseases among those using MCs; however, the values did not reach statistical significance.

8. **Use portable air cleaners as an indoor environmental intervention**

Reference	Design	Population, sample size	Key findings
Chen R et al., 2015 [50]	RCT	Healthy adults (n=35) in Shanghai, China	Air filter use in dormitories for 48 hours reduced $PM_{2.5}$ concentration by 57% on average versus sham-filter. Fractional exhaled nitrous oxide was reduced by 17% versus sham filter but no significant improvement in lung function was observed.
Cui et al., 2018 [51]	Randomised, blind, crossover intervention	Healthy adults and children (n=70), aged 10–26 years in Shanghai, China	A single overnight residential air filtration using a portable air cleaner with a HEPA filter and activated carbon, reduced indoor $PM_{2.5}$ concentrations by 72% versus sham-filtration and improved airway mechanics but no significant improvements for spirometry indicators (FEV_1, FVC) were observed.
Shao et al., 2017 [52]	Randomised, blind, crossover intervention	Older adults with COPD (n=20), mean age 67 years, and without COPD (n=15), mean age 66 years in Beijing, China	Use of HEPA filters with activated carbon in living room and bedroom areas for 2 weeks reduced $PM_{2.5}$ by 60% and BC by 53% versus sham-filter but no significant changes were observed in the cardiorespiratory outcomes of the participants.
Karottki et al., 2013 [53]	Randomised, double-blind crossover intervention	Older adults (n=48), aged 51–81 years, in Greater Copenhagen, Denmark	Use of HEPA filters in living room and bedroom areas for 2 weeks reduced $PM_{2.5}$ by ~50% versus sham-filter. No differences were found in lung function measures or lung cell damage markers versus sham-filter.
Peng et al., 2015 [54]	Stratification of a randomised intervention trial	Children with asthma (n=75), aged 6-12 years in Baltimore, US	Among children for whom the air cleaner with HEPA filter reduced indoor PM concentrations by an average of 18.4 ug m^{-3}, the intervention resulted in an increase of 2 asthma symptom-free days versus no intervention.
Hackstadt, 2014 [55]	Stratification of a randomised	Children with asthma (n=75), aged 6–12 years	Among children for whom the air cleaner with HEPA filter reduced indoor PM concentrations, the intervention

	intervention trial	in Baltimore, US	resulted in an improvement in asthma symptoms versus no intervention.
Jia-Ying, 2018 [56]	Non-randomised, non-crossover	Adults and children with allergic rhinitis (n=32), aged 4–61 years in Guangzhou, China	HEPA filter air cleaners were placed in bedroom for 4 months. House dust mite allergen concentration was reduced in the indoor air ($p<0.05$) as well as PM_{10}, $PM_{2.5}$ and PM_1 ($p<0.01$) versus baseline. HEPA filtration was associated with improvements in activity limitation and nasal symptoms ($p<0.001$) versus baseline.
Park HK et al., 2017 [57]	Randomised, non-crossover	Children with asthma and/or allergic rhinitis (n=17), aged 6–18 years in California, US	HEPA filter air cleaners with activated carbon were placed in the living room and bedroom for 12 weeks. Indoor $PM_{2.5}$ levels were reduced by 43% and there was an improvement in asthma control scores ($p=0.041$) and PEF ($p=0.037$) over the duration as well as total nasal symptoms scores at Week 12 ($p=0.011$) as well as in the intervention group versus the non-intervention group.
Weichenthal et al., 2013 [58]	RCT	Adults and children (n=37) aged 11–64 years at a First Nation reserve in Canada	On average, air filter use was associated with a 217 mL (95% CI: 23, 410; $p<0.05$) increase in FEV_1 versus placebo filter. Despite reductions of >40% in indoor concentrations of PM with use of a portable air cleaner for 3 weeks, the levels remained higher than outdoors because of a high prevalence of indoor smoking.

9. Treat and manage respiratory conditions

Reference	Design	Population, sample size	Key findings
Mirabelli, 2015 [59]	Epidemiologic analysis	Adults with self-reported asthma (n=18) and adults without self-reported asthma (n=21) in Atlanta, US	An analysis from the Atlanta Commuter Exposure study found that an individual's level of asthma control (evaluated using the 7-item Asthma Control Questionnaire) influenced respiratory response to in-vehicle exposures during a 2-hour rush-hour commute; the largest postcommute increases in exhaled NO occurred in participants with below-median asthma control, and higher $PM_{2.5}$ was associated with lower FEV_1 % predicted in this group.

Hasunuma et al., 2018 [60]	Case-crossover design	Children with asthma (n=71) and children without asthma (n=138) in Japan	Exacerbation of respiratory signs and symptoms (% max PEF and coughing) was greater in those children who were not using long-term medications.
Maikawa et al., 2016 [61]	Observational study	Children with asthma (n=62), aged 8–12 years, in Montreal, Canada	FeNO was used as a predictor of airway inflammation. Children with asthma not using corticosteroid medications experienced the greatest increase in FeNO per interquartile range increase of $PM_{2.5}$ oxidative burden versus children using the medication regularly.
Evans et al., 2014 [62]	Case-crossover design	Children with asthma (n=74), aged 3–10 years, in the US	The effects of UFPs and CO on asthma exacerbation were greater among children receiving preventive asthma medications (through a school-based asthma therapy trial) than among those receiving usual care; medication adherence alone may be insufficient to protect this vulnerable group.
Ierodiakonou et al., 2016 [63]	Randomised, longitudinal, observational	Children with asthma (n=1,003), aged 5–12 years, in North America	Daily use of asthma controller medications (budesonide and nedocromil versus placebo) augmented the negative short-term effect of CO on airway responsiveness.

10. Modify diet and supplement with antioxidants or anti-inflammatory agents

Reference	Design	Population, sample size	Key findings
Barchitta et al., 2018 [64]	Cross-sectional	Healthy women (n=299), aged 15–80 years, in Catania, Italy	There was an inverse association between adherence to Mediterranean diet and exposure to PM_{10} with LINE-1 methylation; higher monthly PM_{10} exposure decreased LINE-1 methylation level ($p=0.037$), the adherence to Mediterranean diet increased it ($p<0.001$). Mediterranean diet may reduce aberrant DNA methylation, associated with cancer and cardiovascular disease, following PM exposure.
Steinemann et al., 2018 [65]	Epidemiological	Adults (n=2,178), aged 18–60 years, in Switzerland	A diet rich in fruit, vegetables, fish, and nuts was positively associated with FEV_1 ($p<0.001$).
Egner et al., 2014 [66]	RCT	Healthy adults (n=267), aged 21–65 years, in Qidong, China	Consumption of a broccoli sprout beverage consistently increased the excretion of the glutathione-derived conjugates of benzene and acrolein

			($p \leq 0.01$) over a 12-week period suggesting intervention with broccoli sprouts enhanced the detoxication of some airborne pollutants.
Heber et al., 2014 [67]	Controlled, non-randomised	Healthy adults (n=29) positive for cat allergens, aged ≤18 years, in Los Angeles, US	Average nasal WBC counts increased by 85% over the control levels 24 hours after DEP exposure and total cell counts decreased by 54% when DEP challenge was preceded by daily broccoli extract administration for 4 days ($p<0.001$), suggesting broccoli extracts attenuated nasal allergic response to DEP in atopic individuals with baseline airway DEP hypersensitivity.
Hansell et al., 2018 [68]	Cohort, secondary cross-sectional analysis	Children (n=400), aged 8 years, in New South Wales, Australia	Children were randomised to fish oil supplementation or placebo from early life to 5 years of age. Fish oil supplementation protected against the effect of TRAP exposure on pre-bronchodilator FEV_1/FVC ratio versus no supplementation ($p=0.031$) in children who did not move home between age 5 and 8 years.
Tong, 2016 [69]	Review	RCTs and panel studies mainly in healthy adults	In some RCTs, dietary supplementation with vitamins C and E reduced lung function decrements and bronchoconstriction induced by short-term exposure to O_3, SO_2, and PM; and reduced airway inflammation and improved lung function in ozone-exposed patients with asthma.
Carlsten et al., 2014 [70]	RCT	Healthy adults (n=26), aged ≤18 years, in Vancouver, Canada	Pre-treatment with N-acetylcysteine (600 mg, t.i.d.) versus placebo for 6 days abrogated DEP-induced airway responsiveness in participants with baseline airway hyperresponsiveness.

AP: air pollution; AQI: air quality index; ARI: acute respiratory infection; BC: black carbon; CI: confidence interval; CO: carbon monoxide; COPD: chronic obstructive pulmonary disease; DEP: diesel exhaust particles; dPFV: diurnal peak flow variability; FeNO: fractional exhaled nitric oxide; FEV_1: forced expiratory volume in 1 second; FVC: forced vital capacity; HEPA: high efficiency particulate air; HR: hazard ratio; IL-8: interleukin-8; LINE-1: long interspersed nucleotide elements 1; LPG: liquid petroleum gas; MC: mosquito coils; MDA: malondialdehyde; NO: nitric oxide; NO_2: nitrogen dioxide; O_3: ozone; OR: odds ratio; PEF: peak expiratory flow; PM: particulate matter; PNC: particle number concentration; RCT: randomised controlled trial; SO_2: sulphur dioxide; t.i.d.: three times a day; TRAP: traffic-related air pollution; UFP: ultrafine particles; UFPM: ultrafine particulate matter; UK: United Kingdom; US: United States; WBC: white blood cells; WHO: World Health Organization.

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