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

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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                          |
| Search Term | Database | Hits | Results |
|-------------|----------|------|---------|
| (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**

| Search Term | Database | Hits | Results |
|-------------|----------|------|---------|
| (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 |
| Query                                                                 | PubMed Hits | # of Hits |
|----------------------------------------------------------------------|-------------|-----------|
| (air pollut*) OR (particulate matter) OR (particle poll*) AND (monitor) OR (forecast) OR (index) AND (respiratory) [Title/Abstract] | 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] | 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] | 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] | 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] | 58          | 14        |

**Strategies to protect those most at risk (e.g. children, older people, and people with chronic health problems/co-morbidities)**

| Query                                                                 | PubMed Hits | # of Hits |
|----------------------------------------------------------------------|-------------|-----------|
| (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]) | 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 ... |
| Study (Year, Reference) | Study Type | Methods | Findings |
|-------------------------|------------|---------|----------|
| 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.,      | Non-randomised,      | Healthy adults in       | 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. |
| 2013 [14]            | non-controlled       | California, US (n=15)   |                                                                                                                                                                                                             |
| Park HY et al.,      | Non-randomised,      | Healthy adults in       | 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. |
| 2017 [15]            | non-controlled       | Brisbane, Australia     |                                                                                                                                                                                                             |
| (n=32)               |                      | (n=32)                  |                                                                                                                                                                                                             |
| Sinharay et al.,     | Randomised, crossover| Adults aged ≥60 years   | 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). |
| 2018 [16]            |                      | old with COPD (n=40),   |                                                                                                                                                                                                             |
|                      |                      | ischemic heart disease (n=39) and aged-matched healthy |                                                                                                                                                                                                             |
volunteers (n=40) in London, UK

Improvements in lung function (FVC and FEV₁) 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 PM₂·₅ 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 NO₂, UFP, and PM₂·₅. 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 PM₂·₅ on lung function (measured by spirometry) was greater |
| Study | Study Design | Study Details | Results |
|-------|--------------|---------------|---------|
| **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≤0.05).

| Reference | Design | Population, sample size | Key findings |
|-----------|--------|--------------------------|--------------|
| 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.

| Study Reference          | Study Design                | Study Population                                                                 | Findings                                                                 |
|--------------------------|-----------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 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 FEV₁ 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... |
| Study                          | Study Design                  | Setting/Participants                                                                 | Findings                                                                                                                                                                                                 |
|-------------------------------|-------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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. |
| Study Reference          | Study Design          | Study Population          | Key Findings                                                                                                                                                                                                 |
|-------------------------|-----------------------|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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 µg 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 |
| Reference                  | Design          | Population, sample size                                                                 | Key findings                                                                                                                                                                                                 |
|----------------------------|-----------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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. |
| Reference            | Design                 | Population, sample size                                                                 | Key findings                                                                                                                                                  |
|----------------------|------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 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. |
| Study | Design | Participants | Summary |
|-------|--------|--------------|---------|
| 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 FEV₁/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 O₃, SO₂, 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; FEV₁: 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; NO₂: nitrogen dioxide; O₃: ozone; OR: odds ratio; PEF: peak expiratory flow; PM: particulate matter; PNC: particle number concentration; RCT: randomised controlled trial; SO₂: 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.
References for supplementary material

1. Global Initiative for Asthma. Global Strategy for Asthma Management and Prevention, 2019. https://ginasthma.org/wp-content/uploads/2019/06/GINA-2019-main-report-June-2019-wms.pdf. Date last accessed: Oct 09, 2019.

2. Cherrie JW, Apsley A, Cowie H, Steinle S, Mueller W, Lin C, Horwell CJ, Sleeuwenhoek A, Loh M. Effectiveness of face masks used to protect Beijing residents against particulate air pollution. *Ocup Environ Med* 2018; 75: 446–452.

3. Guan T, Hu S, Han Y, Wang R, Zhu Q, Hu Y, Fan H, Zhu T. The effects of facemasks on airway inflammation and endothelial dysfunction in healthy young adults: a double-blind, randomized, controlled crossover study. *Part Fibre Toxicol* 2018; 15: 30.

4. Yang X, Jia X, Dong W, Wu S, Miller MR, Hu D, Li H, Pan L, Deng F, Guo X. Cardiovascular benefits of reducing personal exposure to traffic-related noise and particulate air pollution: a randomized crossover study in the Beijing subway system. *Indoor Air* 2018; 28: 777–786.

5. Shi J, Lin Z, Chen R, Wang C, Yang C, Cai J, Lin J, Xu X, Ross JA, Zhao Z, Kan H. Cardiovascular benefits of wearing particulate-filtering respirators: a randomized crossover trial. *Environ Health Perspect* 2017; 125: 175–180.

6. Shakya KM, Rupakheti M, Aryal K, Peltier RE. Respiratory effects of high levels of particulate exposure in a cohort of traffic police in Kathmandu, Nepal. *J Occup Environ Med* 2016; 58: e218–e225.

7. Cepeda M, Schoufour J, Freak-Poli R, Koolhaas CM, Dhana K, Bramer WM, Franco OH. Levels of ambient air pollution according to mode of transport: a systematic review. *Lancet Public Health* 2017; 2: e23–e34.

8. Raza W, Forsberg B, Johansson C, Sommar JN. Air pollution as a risk factor in health impact assessments of a travel mode shift towards cycling. *Glob Health Action* 2018; 11: 1429081.

9. Mueller N, Rojas-Rueda D, Cole-Hunter T, de Nazelle A, Dons E, Gerike R, Götschi T, Int Panis L, Kahlmeier S, Nieuwenhuijsen M. Health impact assessment of active transportation: A systematic review. *Prev Med* 2015; 76: 103–114.

10. Xia T, Nitschke M, Zhang Y, Shah P, Crabb S, Hansen A. Traffic-related air pollution and health co-benefits of alternative transport in Adelaide, South Australia. *Environ Int* 2015; 74: 281–290.

11. Tainio M, de Nazelle AJ, Göttschi T, Kahlmeier S, Rojas-Rueda D, Nieuwenhuijsen MJ, de Sá TH, Kelly P, Woodcock J. Can air pollution negate the health benefits of cycling and walking? *Prev Med* 2016; 87: 233–236.

12. Andersen ZJ, de Nazelle A, Mendez MA, Garcia-Aymerich J, Hertel O, Tjønneland A, Overvad K, Raaschou-Nielsen O, Nieuwenhuijsen MJ. 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.

13. Gaffney AW, Hang J-Q, Lee M-S, Su L, Zhang F-Y, Christian DC. Commuting mode and pulmonary function in Shanghai, China. *Eur Respir J* 2016; 47: 733–741.
14. Jarjour S, Jerrett M, Westerdahl D, de Nazelle A, Hanning C, Daly L, Lipsitt J, Balmes J. Cyclist route choice, traffic-related air pollution, and lung function: a scripted exposure study. *Environ Health* 2013; 12: 14.

15. Park H-Y, Gilbreath S, Barakatt E. Respiratory outcomes of ultrafine particulate matter (UFPM) as a surrogate measure of near-roadway exposures among bicyclists. *Environ Health* 2017; 16: 6.

16. Sinharay R, Gong J, Barratt B, Ohman-Strickland P, Ernst S, Kelly FJ, Zhang J, Collins P, Cullinan P, Chung KF. Respiratory and cardiovascular responses to walking down a traffic-polluted road compared with walking in a traffic-free area in participants aged 60 years and older with chronic lung or heart disease and age-matched healthy controls: a randomised, crossover study. *Lancet* 2018; 391: 339–349.

17. Yu N, Shu S, Lin Y, She J, Ip HSS, Qiu X, Zhu Y. High efficiency cabin air filter in vehicles reduces drivers’ roadway particulate matter exposures and associated lipid peroxidation. *PLoS One* 2017; 12: e0188498.

18. Lamichhane DK, Leem JH, Kim HC. Associations between ambient particulate matter and nitrogen dioxide and chronic obstructive pulmonary diseases in adults and effect modification by demographic and lifestyle factors. *Int J Environ Res Public Health* 2018; 15: 363.

19. Zhang Z, Hoek G, Chang L-Y, Chan T-C, Guo C, Chuang YC, Chan J, Lin C, Jiang WK, Guo Y, Vermeulen R, Yeoh E-k, Tam T, Lau AKH, Griffiths S, Lao XQ. Particulate matter air pollution, physical activity and systemic inflammation in Taiwanese adults. *Int J Hyg Environ Health* 2018; 221: 41–47.

20. Fisher JE, Loft S, Ulrik CS, Raaschou-Nielsen O, Hertel O, Tjønneland A, Overvad K, Nieuwenhuijsen MJ, Andersen ZJ. Physical activity, air pollution, and the risk of asthma and chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2016; 194: 855–865.

21. Matt F, Cole-Hunter T, Donaire-Gonzalez D, Kubesch N, Martinez D, Carrasco-Turigas G, Nieuwenhuijsen M. Acute respiratory response to traffic-related air pollution during physical activity performance. *Environ Int* 2016; 97: 45–55.

22. Kubesch NJ, de Nazelle A, Westerdahl D, Martinez D, Carrasco-Turigas G, Bouso L, Guerra S, Nieuwenhuijsen MJ. Respiratory and inflammatory responses to short-term exposure to traffic-related air pollution with and without moderate physical activity. *Occup Environ Med* 2015; 72: 284–293.

23. Laeremans M, Dons E, Avila-Palencia I, Carrasco-Turigas G, Orjuela JP, Anaya E, Cole-Hunter T, de Nazelle A, Nieuwenhuijsen M, Standaert A, Van Poppel M, De Boever P, Int Panis L. Short-term effects of physical activity, air pollution and their interaction on the cardiovascular and respiratory system. *Environ Int* 2018; 117: 82–90.

24. Stergiopoulou A, Katavoutas G, Samoli E, Dimakopoulou K, Papageorgiou I, Karagianni P, Flokas H, Katsouyanni K. Assessing the associations of daily respiratory symptoms and lung function in schoolchildren using an Air Quality Index for ozone: Results from the RESPOZE panel study in Athens, Greece. *Sci Total Environ* 2018; 633: 492–499.

25. Choi J-Y, Baumgartner J, Hamden S, Alexander BH, Town RJ, D'Souza G, Ramachandran G. Increased risk of respiratory illness associated with kerosene fuel use among women and children in urban Bangalore, India. *Occup Environ Med* 2015; 72: 114–122.
26. Lamichhane P, Sharma A, Mahal A. Impact of cleaner fuel use and improved stoves on acute respiratory infections: evidence from India. *Int Health* 2017; 9: 349–366.

27. Lewis JJ, Hollingsworth JW, Chartier RT, Cooper EM, Foster WM, Gomes GL, Kussin PS, MacInnis JJ, Padhi BK, Panigrahi P, Rodes CE, Ryde IT, Singha AK, Stapleton HM, Thornburg J, Young CJ, Meyer JN, Pattanayak SK. Biogas stoves reduce firewood use, household air pollution, and hospital visits in Odisha, India. *Environ Sci Technol* 2017; 51: 560–569.

28. Downward GS, van der Zwaag HP, Simons L, Meliefste K, Tefera Y, Carreon JR, Vermeulen R, Smit LAM. Occupational exposure to indoor air pollution among bakery workers in Ethiopia; a comparison of electric and biomass cookstoves. *Environ Pollut* 2018; 233: 690–697.

29. Yu K, Qiu G, Chan K-H, Lam K-BH, Kurmi OP, Bennett DA, Yu C, Pan A, Lv J, Guo Y, Bian Z, Yang L, Chen Y, Hu FB, Chen Z, Li L, Wu T. Association of solid fuel use with risk of cardiovascular and all-cause mortality in rural China. *JAMA* 2018; 319: 1351.

30. Mortimer K, Ndamala CB, Naunje AW, Malava J, Katundu C, Weston W, Havens D, Pope D, Bruce NG, Nyirenda M, Wang D, Crampin A, Grigg J, Balmes J, Gordon SB. A cleaner burning biomass-fuelled cookstove intervention to prevent pneumonia in children under 5 years old in rural Malawi (the Cooking and Pneumonia Study): a cluster randomised controlled trial. *Lancet* 2017; 389: 167–175.

31. Noonan CW, Semmens EO, Smith P, Harrar SW, Montrose L, Weiler E, McNamara M, Ward TJ. Randomized trial of interventions to improve childhood asthma in homes with wood-burning stoves. *Environ Health Perspect* 2017; 125: 097010.

32. Guarnieri M, Diaz E, Pope D, Eisen EA, Mann J, Smith KR, Smith-Sivertsen T, Bruce NG, Balmes JR. Lung function in rural Guatemalan women before and after a chimney stove intervention to reduce wood smoke exposure. *Chest* 2015; 148: 1184–1192.

33. Heinzerling AP, Guarnieri MJ, Mann JK, Diaz JV, Thompson LM, Diaz A, Bruce NG, Smith KR, Balmes JR. Lung function in woodsmoke-exposed Guatemalan children following a chimney stove intervention. *Thorax* 2016; 71: 421–428.

34. Quansah R, Semple S, Ochieng CA, Juvekar S, Armah FA, Luginaah I, Emina J. Effectiveness of interventions to reduce household air pollution and/or improve health in homes using solid fuel in low-and-middle income countries: a systematic review and meta-analysis. *Environ Int* 2017; 103: 73–90.

35. Thakur M, Nuyts PAW, Boudewijns EA, Flores Kim J, Faber T, Babu GR, van Schayck OCP, Been JV. Impact of improved cookstoves on women’s and child health in low and middle income countries: a systematic review and meta-analysis. *Thorax* 2018; 73: 1026–1040.

36. Das I, Pedit J, Handa S, Jagger P. Household air pollution (HAP), microenvironment and child health: Strategies for mitigating HAP exposure in urban Rwanda. *Environ Res Lett* 2018; 13.

37. Accinelli RA, Llanos O, López LM, Pino MI, Bravo YA, Salinas V, Lazo M, Noda JR, Sánchez-Sierra M, Zárate L, da Silva J, Gianella F, Kheirandish-Gozal L, Gozal D. Adherence to reduced-polluting biomass fuel stoves improves respiratory and sleep symptoms in children. *BMC Pediatr* 2014; 14: 12.

38. Castañeda JL, Kheirandish-Gozal L, Gozal D, Accinelli RA, The Pampa Cangallo Instituto de Investigaciones de la Altura Research Group. Effect of reductions in biomass fuel exposure on symptoms of sleep apnea in children living in the peruvian andes: a preliminary field study: biomass and snoring in children. *Pediatr Pulmonol* 2013; 48: 996–999.
39. Seow WJ, Hu W, Vermeulen R, Hosgood Iii HD, Downward GS, Chapman RS, He X, Bassig BA, Kim C, Wen C, Rothman N, Lan Q. Household air pollution and lung cancer in China: a review of studies in Xuanwei. Chin J Cancer 2014; 33: 471–475.

40. Kim C, Gao YT, Xiang YB, Barone-Adesi F, Zhang Y, Hosgood HD, Ma S, Shu XO, Ji BT, Chow WH, Seow WJ, Bassig B, Cai Q, Zheng W, Rothman N, Lan Q. Home kitchen ventilation, cooking fuels, and lung cancer risk in a prospective cohort of never smoking women in Shanghai, China. Int J Cancer 2015; 136: 632–638.

41. Jin ZY, Wu M, Han RQ, Zhang XF, Wang XS, Li AM, Zhou JY, Lu QY, Kim CH, Mu L, Zhang ZF, Zhao JY. Household ventilation may reduce effects of indoor air pollutants for prevention of lung cancer: a case-control study in a Chinese population. PLoS One 2014; 9: e102685.

42. Mu L, Liu L, Niu R, Zhao B, Shi J, Ji Y, Swanson M, Scheider W, Su J, Chang SC, Yu S, Zhang ZF. Indoor air pollution and risk of lung cancer among Chinese female non-smokers. Cancer Causes Control 2013; 24: 439–450.

43. Hu W, Downward GS, Reiss B, Xu J, Bassig BA, Hosgood HD, 3rd, Zhang L, Seow WJ, Wu G, Chapman RS, Tian L, Wei F, Vermeulen R, Lan Q. Personal and indoor PM2.5 exposure from burning solid fuels in vented and unvented stoves in a rural region of China with a high incidence of lung cancer. Environ Sci Technol 2014; 48: 8456–8464.

44. Zhou Y, Zou Y, Li X, Chen S, Zhao Z, He F, Zou W, Luo Q, Li W, Pan Y, Deng X, Wang X, Qiu R, Liu S, Zheng J, Zhong N, Ran P. Lung function and incidence of chronic obstructive pulmonary disease after improved cooking fuels and kitchen ventilation: a 9-year prospective cohort study. PLoS Med 2014; 11: e1001621.

45. Liu F, Zhao Y, Liu YQ, Liu Y, Sun J, Huang MM, Liu Y, Dong GH. Asthma and asthma related symptoms in 23,326 Chinese children in relation to indoor and outdoor environmental factors: the Seven Northeastern Cities (SNEC) Study. Sci Total Environ 2014; 497-498: 10–17.

46. Langbein J. Firewood, smoke and respiratory diseases in developing countries—the neglected role of outdoor cooking. PLoS One 2017; 12: e0178631.

47. Kile ML, Coker ES, Smit E, Sudakin D, Molitor J, Harding AK. A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII. Environ Health 2014; 13: 71.

48. Lajoie P, Aubin D, Gingras V, Daigneauault F, Ducharme F, Gauvin D, Fogler D, Leclerc JM, Won D, Courteau M, Gingras S, Heroux ME, Yang W, Schleibinger H. The IVAIRE project—a randomized controlled study of the impact of ventilation on indoor air quality and the respiratory symptoms of asthmatic children in single family homes. Indoor Air 2015; 25: 582–597.

49. Salvi D, Limaye S, Muralidharan V, Londhe J, Madas S, Juvekar S, Biswal S, Salvi S. Indoor particulate matter < 2.5 μm in mean aerodynamic diameter and carbon monoxide levels during the burning of mosquito coils and their association with respiratory health. Chest 2016; 149: 459–466.

50. Chen R, Zhao A, Chen H, Zhao Z, Cai J, Wang C, Yang C, Li H, Xu X, Hu S, Li T, Kan H. Cardiopulmonary benefits of reducing indoor particles of outdoor origin. J Am Coll Cardiol 2015; 65: 2279–2287.

51. Cui X, Li F, Xiang J, Fang L, Chung MK, Day DB, Mo J, Weschler CJ, Gong J, He L, Zhu D, Lu C, Han H, Zhang Y, Zhang J. Cardiopulmonary effects of overnight indoor air filtration in healthy non-smoking adults: a double-blind randomized crossover study. Environ Int 2018; 114: 27–36.
52. Shao D, Du Y, Liu S, Brunekreef B, Meliefste K, Zhao Q, Chen J, Song X, Wang M, Wang J, Xu H, Wu R, Wang T, Feng B, Lung CS-C, Wang X, He B, Huang W. Cardiorespiratory responses of air filtration: a randomized crossover intervention trial in seniors living in Beijing. Sci Total Environ 2017; 603-604: 541–549.

53. Karottki DG, Spilak M, Frederiksen M, Gunnarsen L, Brauner EV, Kolarik B, Andersen ZJ, Sigsgaard T, Barregard L, Strandberg B, Sallsten G, Møller P, Loft S. An indoor air filtration study in homes of elderly: cardiovascular and respiratory effects of exposure to particulate matter. Environ Health 2013; 12: 116.

54. Peng RD, Butz AM, Hackstadt AJ, Williams DAL, Diette GB, Breysse PN, Matsui EC. Estimating the health benefit of reducing indoor air pollution in a randomized environmental intervention. J R Stat Soc Ser A Stat Soc 2015; 178: 425–443.

55. Hackstadt AJ, Matsui EC, Williams DAL, Diette GB, Breysse PN, Butz AM, Peng RD. Inference for environmental intervention studies using principal stratification. Stat Med 2014; 33: 4919–4933.

56. Jia-Ying L, Zhao C, Jia-Jun G, Zi-Jun G, Xiao L, Bao-Qing S. Efficacy of air purifier therapy in allergic rhiniti. Asian Pac J Allergy Immunol 2018; 36: 217–221.

57. Park H-K, Cheng K-C, Tetteh AO, Hildemann LM, Nadeau KC. Effectiveness of air purifier on health outcomes and indoor particles in homes of elderly with allergic diseases in Fresno, California: a pilot study. J Asthma 2017; 54: 341–346.

58. Weichenthal S, Mallach G, Kulka R, Black A, Wheeler A, You H, St-Jean M, Kwiatkowski R, Sharp D. A randomized double-blind crossover study of indoor air filtration and acute changes in cardiorespiratory health in a First Nations community. Indoor Air 2013; 23: 175–184.

59. Mirabelli MC, Golan R, Greenwald R, Raysoni AU, Holguin F, Kewada P, Winquist A, Flanders WD, Sarnat JA. Modification of traffic-related respiratory response by asthma control in a population of car commuters. Epidemiology 2015; 26: 546–555.

60. Hasunuma H, Yamazaki S, Tamura K, Hwang YH, Ono R, Amimoto Y, Askew DJ, Odajima H. Association between daily ambient air pollution and respiratory symptoms in children with asthma and healthy children in western Japan. J Asthma 2018; 55: 712–719.

61. Maikawa CL, Weichenthal S, Wheeler AJ, Dobbin NA, Smargiassi A, Evans G, Liu L, Goldberg MS, Pollit KJG. Particulate oxidative burden as a predictor of exhaled nitric oxide in children with asthma. Environ Health Perspect 2016; 124: 1616–1622.

62. Evans KA, Halterman JS, Hopke PK, Fagnano M, Rich DQ. Increased ultrafine particles and carbon monoxide concentrations are associated with asthma exacerbation among urban children. Environ Res 2014; 129: 11–19.

63. Ierodiakonou D, Zanobetti A, Coull BA, Melly S, Postma DS, Boezen HM, Vonk JM, Williams PV, Shapiro GG, McKone EF, Hallstrand TS, Koenig JQ, Schilderout JS, Lumley T, Fuhlbrigge AN, Koutrakis P, Schwartz J, Weiss ST, Gold DR. Ambient air pollution, lung function, and airway responsiveness in asthmatic children. J Allergy Clin Immunol 2016; 137: 390–399.

64. Barchitta M, Maugeri A, Quattrocchi A, Barone G, Mazzoleni P, Catalfo A, De Guidi G, Lemmolo MG, Crimi N, Agodi A. Mediterranean diet and particulate matter exposure are associated with LINE-1 methylation: results from a cross-sectional study in women. Frontiers in Genetics 2018; 9: 514.
65. Steinemann N, Grize L, Pons M, Rothe T, Stolz D, Turk A, Schindler C, Brombach C, Probst-Hensch N. Associations between Dietary Patterns and Post-Bronchodilation Lung Function in the SAPALDIA Cohort. Respiration 2018; 95: 454–463.

66. Egner PA, Chen JG, Zarth AT, Ng DK, Wang JB, Kensler KH, Jacobson LP, Munoz A, Johnson JL, Groopman JD, Fahey JW, Talalay P, Zhu J, Chen TY, Qian GS, Carmella SG, Hecht SS, Kensler TW. Rapid and sustainable detoxication of airborne pollutants by broccoli sprout beverage: results of a randomized clinical trial in China. Cancer Prev Res 2014; 7: 813–823.

67. Heber D, Li Z, Garcia-Lloret M, Wong AM, Lee TY, Thames G, Krak M, Zhang Y, Nel A. Sulforaphane-rich broccoli sprout extract attenuates nasal allergic response to diesel exhaust particles. Food Funct 2014; 5: 35–41.

68. Hansell AL, Bakolis I, Cowie CT, Belousova EG, Ng K, Weber-Chrysochoou C, Britton WJ, Leeder SR, Tovey ER, Webb KL, Toelle BG, Marks GB. Childhood fish oil supplementation modifies associations between traffic related air pollution and allergic sensitisation. Environ Health 2018; 17: 27.

69. Tong H. Dietary and pharmacological intervention to mitigate the cardiopulmonary effects of air pollution toxicity. Biochim Biophys Acta 2016; 1860: 2891–2898.

70. Carlsten C, MacNutt MJ, Zhang Z, Sava F, Pui MM. Anti-oxidant N-acetylcysteine diminishes diesel exhaust-induced increased airway responsiveness in person with airway hyper-reactivity. Toxicol Sci 2014; 139: 479–487.