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Individual-level interventions to reduce personal exposure to outdoor air pollution and their effects on people with long-term respiratory conditions (Review)

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[Intervention Review]

Individual-level interventions to reduce personal exposure to outdoor air pollution and their effects on people with long-term respiratory conditions

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ABSTRACT

Background

More than 90% of the global population lives in areas exceeding World Health Organization air quality limits. More than four million people each year are thought to die early due to air pollution, and poor air quality is thought to reduce an average European's life expectancy by one year. Individuals may be able to reduce health risks through interventions such as masks, behavioural changes and use of air quality alerts. To date, evidence is lacking about the efficacy and safety of such interventions for the general population and people with long-term respiratory conditions. This topic, and the review question relating to supporting evidence to avoid or lessen the effects of air pollution, emerged directly from a group of people with chronic obstructive pulmonary disease (COPD) in South London, UK.

Objectives

1. To assess the efficacy, safety and acceptability of individual-level interventions that aim to help people with or without chronic respiratory conditions to reduce their exposure to outdoor air pollution.

2. To assess the efficacy, safety and acceptability of individual-level interventions that aim to help people with chronic respiratory conditions reduce the personal impact of outdoor air pollution and improve health outcomes.

Search methods

We identified studies from the Cochrane Airways Trials Register, Cochrane Central Register of Controlled Trials, and other major databases. We did not restrict our searches by date, language or publication type and included a search of the grey literature (e.g. unpublished information). We conducted the most recent search on 16 October 2020.

Selection criteria

We included randomised controlled trials (RCTs) and non-randomised studies (NRS) that included a comparison treatment arm, in adults and children that investigated the effectiveness of an individual-level intervention to reduce risks of outdoor air pollution. We included studies in healthy individuals and those in people with long-term respiratory conditions. We excluded studies which focused on non-respiratory long-term conditions, such as cardiovascular disease. We did not restrict eligibility of studies based on outcomes.

Data collection and analysis

We used standard Cochrane methods. Two review authors independently selected trials for inclusion, extracted study characteristics and outcome data, and assessed risk of bias using the Cochrane Risk of Bias tool for RCTs and the Risk Of Bias In Non-randomised Studies -

of Interventions (ROBINS-I) as appropriate. One review author entered data into the review; this was spot-checked by a second author. We planned to meta-analyse results from RCTs and NRS separately, using a random-effects model. This was not possible, so we presented evidence narratively. We assessed certainty of the evidence using the GRADE approach. Primary outcomes were: measures of air pollution exposure; exacerbation of respiratory conditions; hospital admissions; quality of life; and serious adverse events.

Main results

We identified 11 studies (3372 participants) meeting our inclusion criteria (10 RCTs and one NRS). Participants' ages ranged from 18 to 74 years, and the duration of studies ranged from 24 hours to 104 weeks. Six cross-over studies recruited healthy adults and five parallel studies included either people with pre-existing conditions (three studies) or only pregnant women (two studies). Interventions included masks (e.g. an N95 mask designed to filter out airborne particles) (five studies), an alternative cycle route (one study), air quality alerts and education (five studies). Studies were set in Australia, China, Iran, the UK, and the USA.

Due to the diversity of study designs, populations, interventions and outcomes, we did not perform any meta-analyses and instead summarised results narratively. We judged both RCTs and the NRS to be at risk of bias from lack of blinding and lack of clarity regarding selection methods. Many studies did not provide a prepublished protocol or trial registration.

From five studies (184 participants), we found that masks or altered cycle routes may have little or no impact on physiological markers of air pollution exposure (e.g. blood pressure and heart rate variability), but we are very uncertain about this estimate using the GRADE approach. We found conflicting evidence regarding health care usage from three studies of air pollution alerts, with one non-randomised cross-over trial (35 participants) reporting an increase in emergency hospital attendances and admissions, but the other two randomised parallel trials (1553 participants) reporting little to no difference. We also gave the evidence for this outcome a very uncertain GRADE rating. None of our included trials reported respiratory exacerbations, quality of life or serious adverse events.

Secondary outcomes were not well reported, but indicated inconsistent impacts of air quality alerts and education interventions on adherence, with some trials reporting improvements in the intervention groups and others reporting little or no difference. Symptoms were reported by three trials, with one randomised cross-over trial (15 participants) reporting a small increase in breathing difficulties associated with the mask intervention, one non-randomised cross-over trial (35 participants) reporting reduced throat and nasal irritation in the lower-pollution cycle route group (but no clear difference in other respiratory symptoms), and another randomised parallel trial (519 participants) reporting no clear difference in symptoms between those who received a smog warning and those who did not.

Authors' conclusions

The lack of evidence and study diversity has limited the conclusions of this review. Using a mask or a lower-pollution cycle route may mitigate some of the physiological impacts from air pollution, but evidence was very uncertain. We found conflicting results for other outcomes, including health care usage, symptoms and adherence/behaviour change. We did not find evidence for adverse events.

Funders should consider commissioning larger, longer studies, using high-quality and well-described methods, recruiting participants with pre-existing respiratory conditions. Studies should report outcomes of importance to people with respiratory conditions, such as exacerbations, hospital admissions, quality of life and adverse events.

PLAIN LANGUAGE SUMMARY

What can individuals do, especially those with long-term breathing problems, to avoid the effects of air pollution?

Review questions

1. What options are there for people with and without long-term breathing problems to reduce their exposure to outdoor air pollution?

2. Do these options have any impact on the health of people with long-term breathing problems?

Background to the question

Outdoor air pollution is a major problem. The World Health Organization (WHO) estimates that more than 90% of people live in places where air pollution is at harmful levels. It is thought that the average person living in Europe loses one year of life due to poor air quality.

Air pollution tends to have a bigger effect on people who already have breathing conditions, such as asthma and chronic obstructive pulmonary disease (COPD).

Some options to help reduce the effects of air pollution include wearing a mask that filters out pollution when outside, avoiding certain roads with a lot of traffic, or using air pollution alerts. It is not clear how well these options work, and there is also a chance that such options might have unwanted effects or be unpleasant.

We decided to do this piece of research after meeting a group of people with COPD in London. We asked them to tell us their most important questions about their health. Several group members wanted to know if there was any evidence about what they could do themselves to breathe less air pollution.

Study identification and selection

We searched multiple online databases for studies that tried different options, such as masks and air pollution alerts. We looked for studies in any language, published anywhere in the world and at any time, and also unpublished information. Two researchers looked at the lists of studies separately and then agreed on which ones we should include. We carried out our most recent search on 16 October 2020.

Study characteristics

We included any study which tried an individual-level intervention for reducing the amount of air pollution people were exposed to. By this we mean something that a person can do themselves, e.g. wearing a mask, or signing up to receive alerts about air pollution levels. We included studies in healthy adults and children, as well as people with long-term breathing conditions. The main measurements we were interested in were: measures of air pollution exposure; flare-ups of breathing conditions; hospital admissions; quality of life; and serious unwanted side-effects. Most studies were funded by a government or charity grant.

Key results

We found eleven studies to include in this review. The studies tried several different ways to reduce air pollution exposure: five studies used masks that filter out pollution, five studies used air pollution alerts and education, and one study tested a lower-level pollution cycle commute. The studies varied in size from 15 people to over 1000.

Because the studies were all so different, we could not combine the results statistically. We also found that most of the studies could not 'blind' participants or study personnel, which means the people involved in the studies knew whether they were receiving the option that was meant to reduce pollution exposure. This is important because knowing this might influence the way people behave.

Pollution-filtering mask and cycle-route studies

We found that masks and a lower-level pollution cycle route might have a small effect on measures that show you have been exposed to air pollution (e.g. blood pressure), but the results from the different studies were varied and we were very unsure. One study reported that people found breathing slightly more difficult while wearing a mask, but none of the other studies specifically recorded unwanted side-effects. People using a lower-level pollution cycle route had less irritation in their nose and throat, but it did not affect any other breathing symptoms.

Air quality alert studies

One study found that sending people alerts when the air quality is bad may increase the number of times they attend the emergency department or get admitted to hospital. But two other studies which looked at this did not find a clear difference between people who received the alerts and people who did not.

We found that in some studies people who received air pollution alerts and education about avoiding air pollution reported more 'preventative' behaviours, e.g. avoiding outdoor exercise when air quality was bad. But in other studies, the alerts did not appear to make much difference.

Another study reported that there was no clear difference in the breathing symptoms between those who received air pollution alerts and those who did not.

We have provided definitions of key words in a glossary (Table 1).

Bottom line

We did not find many studies to help us answer this question. The studies we found were quite different from one another so we were unable to combine them together to make a clearer picture. This means that we still cannot be sure what the best advice is to give to people who want to reduce the impact of air pollution in their day to day lives.

SUMMARY OF FINDINGS

Summary of findings 1. Individual level interventions vs control

Individual-level intervention compared with control to mitigate the health effects of air pollution

Patient or population: healthy individuals and those with a pre-existing health condition

Settings: community

Intervention: individual-level intervention (masks, cycle routes, air quality alerts plus additional messaging)

Comparison: usual care/no intervention

Outcomes	Intervention and comparator	No of Participants (studies)	Results	Certainty of the evidence (GRADE)	Comments
Measures of air pollution exposure (follow-up range: 24 hours to 4 weeks)	Mask versus no mask, or low traffic cycle route versus high traffic cycle route	N = 173 (6 cross-over studies)	Six studies measured a range of physiological variables and could not be combined. We are very uncertain of any difference between intervention and control conditions with the exception of minor short-term beneficial impact on HR variability (two studies), systolic BP (two studies) and exhaled NO (one study). The minor short-term impacts were: HR variability (LF power): ranged from 899.4 to 919 $msec^2$ (mask group) versus 816 to 838.5 $msec^2$ (no mask group). Systolic BP: ranged from 107.3 to 109 mmHg (mask group) versus 109 to 110 mmHg (no mask group). Exhaled NO: the increase in exhaled NO was 38.3% less in the mask group compared to the control group ($P < 0.005$).	⊕⊖⊖⊖[a,b,c] **very low**	One study was a non-randomised cross-over design.
Health care usage (follow-up range: 1 day to 104 weeks)	Air quality alert with or without additional messaging versus usual care or no additional messaging	N = 2948 (3 parallel studies)	Three studies measured a range of health care usage outcomes. Findings were conflicting, with increased health care usage associated with the intervention identified in one study, but no clear difference in the other studies.	⊕⊖⊖⊖[a,b,c] **very low**	One study was a NRS.
Respiratory exacerbations	Not applicable	No studies	No studies reported this outcome.	Not applicable	

Quality of life	Not applicable	No studies	No studies reported this outcome.	Not applicable
Serious adverse events	Not applicable	No studies	No studies reported this outcome.	Not applicable

GRADE Working Group grades of evidence
High certainty: Further research is very unlikely to change our confidence in the estimate of effect.
Moderate certainty: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low certainty: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low certainty: We are very uncertain about the estimate.

BP: blood pressure; **HR**: heart rate; **LF**: low frequency; **NRS**: non-randomised study

[a]Downgraded once for imprecision (individual study results included possibility of benefit, harm or no difference, and results could not be combined).
[b]Downgraded once for inconsistency (individual studies gave conflicting results and could not be combined).
[c]Downgraded once for risk of bias.

BACKGROUND

Description of the condition

According to a recent World Health Organization (WHO) report, nearly 91% of the global population lives in areas exceeding WHO air quality limits (WHO 2018a). Ambient air pollution is associated with conditions such as stroke, heart disease, lung cancer and chronic respiratory disease (WHO 2018a). The Global Burden of Disease Study estimated that just one type of very small particulate pollutant of a diameter less than 2.5 µm ($PM_{2.5}$) was the fifth-ranking mortality risk factor globally in 2015 (Cohen 2017). Exposure to this pollutant alone is thought to cause approximately 4.2 million premature deaths each year, which represents 7.6% of total global deaths (Cohen 2017). Globally, the main sources of outdoor air pollution include vehicle emissions, power stations, industry, manufacturing and agriculture, residential heating and cooking, and natural processes such as wildfires and volcanic eruptions. Regional and seasonal differences in source activity and meteorological factors can lead to large variations in air quality between locations and over time (IARC 2016).

Harmful pollutants include particulate matter (PM), nitrogen dioxide, sulfur dioxide, carbon monoxide and ozone. A range of adverse health effects are associated with different pollutants. Depending on the size of individual particles, PM can pass deep into the airways and in some cases into the bloodstream, leading to irritation, oxidative stress, inflammation and coagulation activation, impacting on respiratory and cardiovascular health (Anderson 2012; WHO 2013). Inhalation of the toxic gas nitrogen dioxide can lead to inflammation in the airways and has been associated in observational studies with worsening asthma symptoms and increased asthma incidence and prevalence (Guarnieri 2014). In the short term, the highly reactive gas ozone has been associated with increased cardiovascular and respiratory hospital admissions and deaths, and in the longer term it may be associated with increased respiratory mortality, incidence of asthma and worsening asthma symptoms (Atkinson 2016; Nuvolone 2018; Peng 2013; Stedman 1997). Sulfur dioxide causes irritation of the airways and eyes and is associated with bronchoconstriction in susceptible individuals (Guarnieri 2014; WHO 2018b); as well as increase in daily all-cause mortality in 12 European cities (Katsouyanni 1997).

A recent set of systematic reviews and meta-analyses from the WHO further confirms that harms can follow both long- and short-term exposure in the general population. Short-term exposure (hours to days) to PM, nitrogen dioxide, sulfur dioxide and ozone have all been associated with increased all-cause and respiratory mortality (Orellano 2020; Orellano 2021). PM, nitrogen dioxide and ozone have also been associated with increased cardiovascular and cerebrovascular mortality (Orellano 2020). Carbon monoxide exposure is thought to be positively associated with myocardial infarction, although this finding is based on less robust evidence (Lee 2020).

Longer-term exposure (months to years) to both $PM_{2.5}$ and PM_{10} (particulate matter diameter less than 10 µm) is clearly associated with increased all-cause mortality, as well as mortality from cardiovascular disease, respiratory disease and lung cancer (Chen 2020). Longer-term exposure to nitrogen dioxide and ozone may be associated with all-cause mortality, although evidence is less certain (Huangfu 2020).

People with existing respiratory conditions are at higher risk; exposure to $PM_{2.5}$, for example, has been linked to increased pulmonary exacerbations and increased risk of mortality in people with chronic respiratory conditions such as cystic fibrosis (CF) (Brugha 2018; Goss 2004). Daily fluctuations in PM in eight European cities have been positively associated with respiratory hospital admissions (Atkinson 2001). Short-term exposure to harmful gases (ozone, nitrogen dioxide and sulfur dioxide) are positively associated with emergency room visits and hospital admissions in people with asthma (Zheng 2021). A recent systematic review focusing on air pollution and chronic obstructive pulmonary disease (COPD) noted that findings from individual studies are inconsistent, but found associations between COPD exacerbation risk and particulate matter, nitrogen dioxide, sulfur dioxide and ozone (Li 2016). Huangfu 2020 identified a link between long-term nitrogen dioxide exposure and COPD mortality. Similarly, a recent study in Scotland found an association between acute fluctuation in particulate matter and nitrogen dioxide and exacerbations of bronchiectasis (Goeminne 2018).

Children are particularly vulnerable to poor air quality. In 2016, air pollution was linked to over 500,000 deaths globally of children under five years old. Exposure to unsafe levels of air pollution in childhood can lead to lifelong health consequences, especially affecting a child's developing lungs. In low- and middle-income countries (LMICs), 98% of all children under five years old are exposed to levels of $PM_{2.5}$ exceeding WHO air quality guidance (WHO 2018c). A recent publication has suggested that up to 33% of all childhood asthma cases in Europe could be attributable to air pollution (specifically $PM_{2.5}$) (Khreis 2019).

Chronic respiratory conditions are estimated to cause nearly four million deaths globally each year (Global Burden of Disease 2018). COPD is currently ranked as the third leading cause of death worldwide (WHO 2019). Other non-infectious chronic respiratory conditions include asthma, lung cancer, CF, sleep-disordered breathing, pulmonary hypertension, and occupational lung diseases (WHO 2018b). Definitions are listed in the glossary (Table 1), and common chronic respiratory conditions are listed in Table 2.

Although respiratory diseases can manifest in people from all socioeconomic groups, prevalence of these chronic conditions is higher amongst poorer people globally and within particular cities (WHO 2016). Contributing factors include crowding, poverty, increased environmental exposures, and poor living conditions — conditions which people who are more financially stable are able to take steps to avoid or improve (WHO 2018b).

Description of the intervention

Air pollution is an environmental problem, and many organisations have produced guidance and advice about its reduction on a national, regional or city level (e.g. implementation of low-emission vehicles and fuels in cities, or creating green spaces that help to remove particulate matter) (DEFRA 2019a; NICE 2017; COMEAP 2011; Vardoulakis 2018). Furthermore, many organisations (governmental and charitable) also outline advice that individuals can take when the air quality is poor (British Lung Foundation 2017a; European Lung Foundation 2019; NICE 2017; Public Health England 2017). For the purposes of this review, we have defined these as individual-level interventions. Such

interventions may or may not be effective at reducing exposure to air pollution and may or may not lead to improved health outcomes.

Interventions may be physical, behavioural, technological, and pharmacological. Physical interventions might include the use of masks or other physical barriers used by an individual to limit exposure to air pollution. Behavioural interventions may include avoiding extended outdoor physical activity; and adapting transport methods or routes. Technological interventions are varied, but could include the use of air quality alert systems, such as mobile phone applications. Finally, pharmacological interventions may be aimed at reducing the health impact of an unavoidable exposure and could include the prophylactic use of appropriate medication, such as a salbutamol inhaler (British Lung Foundation 2017a; European Lung Foundation 2019; Jiang 2016; Laumbach 2015; NICE 2017; Ren 2016; Sinharay 2018).

A further review article notes that there may be other unwanted consequences of such advice, including: social isolation; a reduction in physical fitness due to staying indoors; or discomfort from wearing a mask (Ren 2016).

How the intervention might work

Physical interventions, such as masks, are intended to reduce an individual's exposure to ambient air pollution when in an area of poor air quality (Cherrie 2018; Langrish 2012). Masks must, however, fit closely and be of an appropriate design to filter out smaller particles, which can increase the resistance to normal breathing. Their use by people with existing respiratory conditions can, therefore, be limited by discomfort, difficulty breathing, disruption to normal activities (such as talking), or feeling claustrophobic (Jiang 2016; Laumbach 2015; Ren 2016). Use of an inappropriate mask might lead to a false sense of security and prolonged exposure to high levels of ambient pollution (Ren 2016).

Behavioural interventions usually involve modifying an individual's routine to limit exposure to air pollution, for example avoiding pollution 'hot spots' at certain times of the day, or limiting outdoor physical activity in urban areas. Such behavioural changes may, however, lead to unwanted consequences, such as social isolation or a reduction in physical fitness due to staying indoors (Ren 2016).

Technological interventions involve the use of specific equipment or digital tools to reduce exposure to air pollution or to modify behaviour in response to pollution, and might include accessing a local weather alert on the radio, using applications and alerts on smartphones, or accessing pollution forecast websites (e.g. the Daily Air Quality Index). However, the safety and clinical benefit of such alerts and the associated behaviour changes to limit exposure to harmful levels of ambient air pollution are unclear. One study showed, for example, that there was an increase of hospital attendance in those with COPD who were given telephone alerts (i.e. the Healthy Outlook telephonic alert system) compared to a matched control group of people with COPD (Steventon 2014).

Pharmacological interventions might involve an individual temporarily increasing their use of preventer or reliever inhaled medication when they anticipate being exposed to higher than usual levels of air pollution, or if they have to undertake physical activity in a polluted environment. The rationale for increasing use includes enhanced anti-inflammatory and bronchodilatory effects to counteract the inflammation and bronchoconstriction triggered by air pollution. While studies have shown that there is an association between increased inhaler use and poorer air quality in people with COPD and asthma, presumably in response to worsening symptoms, it is less clear whether increasing use prophylactically is beneficial (Magzamen 2018; Williams 2019).

Why it is important to do this review

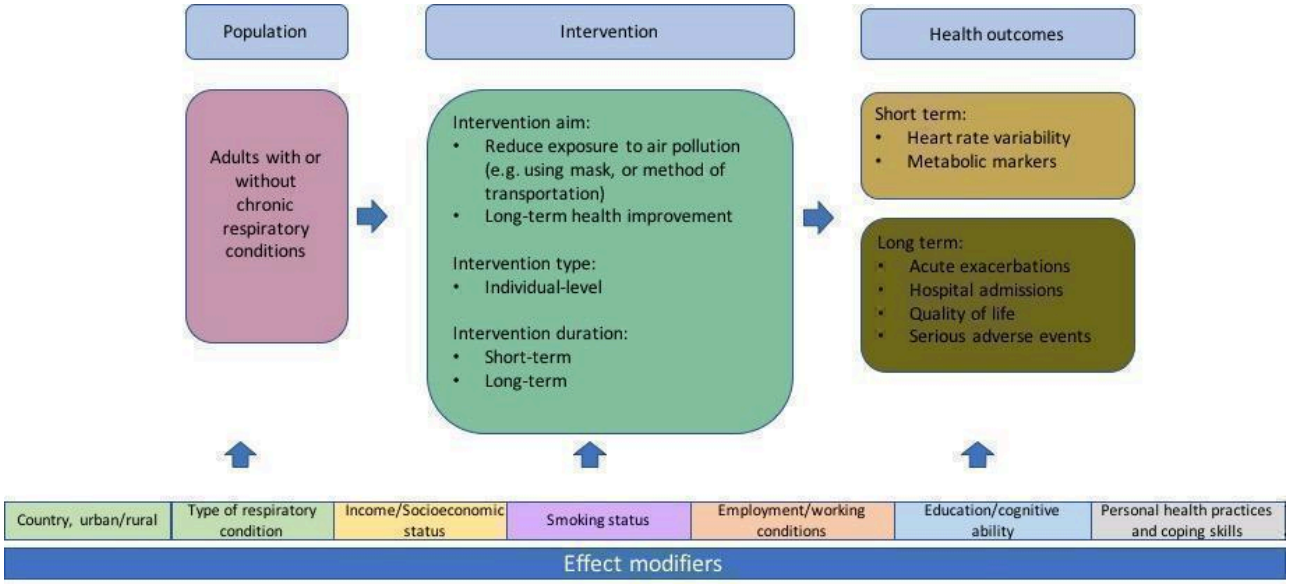
We developed this review question directly from a patient consultation exercise. We asked a group of South London residents with COPD about their unanswered questions related to their condition. Several members of the group reported that they changed their behaviour in response to poor air quality. Changes included avoiding busy roads during rush hour, wearing a scarf across their mouth and nose, closing windows and using air quality alert mobile phone applications. However, the members of the group reported uncertainty about whether their behaviour changes were supported by evidence, and few had been given any advice by the healthcare professionals involved in their care. One group member reported that warnings about air quality on London bus stops made her feel anxious.

Following this meeting, we discussed this topic with clinical experts and representatives from respiratory organisations. They highlighted that, although they were aware of advice about how to limit exposure to air pollution, the evidence base was limited and they saw this as an unmet research need; there is a lack of clear information in clinical guidelines for conditions such as asthma and COPD (GINA 2021; GOLD 2021). Studies suggest that many healthcare professionals lack the necessary knowledge and evidence to advise patients, particularly those with existing respiratory conditions, about reducing their risk while maintaining normal activities of daily life (Powell 2016; Zielonka 2016). Furthermore, a 2019 Expert Consultation conducted by the WHO identified a lack of evidence on personal interventions. The consultation recognised that advice to avoid air pollution exposure may have unintended consequences, highlighting the need for a systematic review of the evidence (WHO 2020).

Another reason that it is important to review the evidence for this question is the issue of equity. Equity may affect whether a particular intervention works or not, which can be more difficult to assess compared to health outcomes (Benmarhnia 2014). Equity refers to "absence of avoidable or remediable differences among groups of people, whether those groups are defined socially, economically, demographically, or geographically" (WHO 2019b). Differences in health can occur within or between population subgroups (Krieger 2008), who are affected disproportionately because they are disadvantaged (Braveman 2006; Frieden 2011; Marmot 2008). These differences can be avoided and are unfair, and there should be an aim to reduce inequity (Whitehead 1992). Such inequity of an intervention can have an impact on health outcomes, where some people may not benefit compared to others: for example, socioeconomic differences in childhood asthma rates due to differential distribution of air pollutants would be considered an inequity (Welch 2019). Equally, some people may not have a choice about exposure (e.g. where a person's job is situated, or if there is no other way of getting to school), and interventions can widen inequality if they are only available to those who are already advantaged enough to be able to make changes. When interpreting the evidence identified by this review we will consider the possible impact of equity on the ability of certain groups to access or benefit

from the interventions identified, and the potential for health inequities to be worsened. We have developed a map to show the influence of modifiers that can affect health outcomes (Figure 1).

Figure 1. Logic model of effect modifiers that can affect whether or not an intervention helps to reduce exposure to air pollution and short-term and long-term health outcomes.



A recent Cochrane Review that investigated whether non-individual level interventions (industrial, residential, vehicular, or multiple) could reduce ambient particulate matter did not reach any overall conclusions for improving air quality or health, because of the diverse nature of the interventions, outcomes, and study methods (Burns 2019).

OBJECTIVES

1. To assess the efficacy, safety and acceptability of individual-level interventions that aim to help people with or without chronic respiratory conditions to reduce their exposure to outdoor air pollution.
2. To assess the efficacy, safety and acceptability of individual-level interventions that aim to help people with chronic respiratory conditions reduce the personal impact of outdoor air pollution and improve health outcomes.

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised controlled trials (RCTs) (e.g. parallel, cluster and cross-over trials) and non-randomised studies (NRS) that included a comparison treatment arm (i.e. any quantitative study that investigated the effectiveness of an intervention aimed to assess either or both of our objectives, and did not use randomisation to allocate participants to intervention or comparator groups; for example, cohort studies or controlled before-and-after studies).

Including NRS as well as RCTs allowed us to include different population subgroups or settings where randomised trials may not provide this evidence, or where randomisation was not feasible or would have been unethical (Reeves 2019). If we found inconsistencies in terminology and naming of study designs, we did not exclude studies on the basis of study design labels (Higgins 2013).

We included studies reported in full text, those published as an abstract only and unpublished data.

Types of participants

We included both healthy children and adults; and children and adults diagnosed according to guidelines, or by a suitably trained healthcare professional, with any chronic respiratory condition (e.g. asthma, bronchiectasis, chronic obstructive pulmonary disease (COPD), cystic fibrosis (CF), sleep apnoea syndrome). We also included studies in which there were mixed populations of people with different chronic respiratory conditions. We anticipated that advice and interventions identified as successful in one long-term respiratory condition were likely to apply to other long-term respiratory conditions.

We excluded studies that recruited participants on the basis of a non-respiratory condition, such as cardiovascular disease, or a non-respiratory malignancy. We also excluded participants solely with rhinitis or rhinosinusitis, or studies assessing influenza and other related viral infectious diseases.

Types of interventions

We included any individual-level interventions that aimed to reduce personal exposure to ambient air pollution. To be eligible, studies must have recruited individuals, implemented a personal intervention and reported individual-level outcomes. Interventions were physical (e.g. wearing a face mask), behavioural (e.g. avoiding outdoor physical activity or choosing a less busy walk route), technological (e.g. alerts on mobile telephone applications to avoid

going outside when air quality is poor) and pharmacological (e.g. use of appropriate inhalers), or a combination, and of any duration. We excluded studies in which the main aim of the intervention was to reduce exposure to environmental tobacco smoke, as we considered this to be outside the scope of this review.

We compared with usual care (as described by the study), a sham intervention, or active control (e.g. an intervention that is not aimed to modify behaviour to reduce exposure to air pollution).

Types of outcome measures

We included studies with an appropriate design, population, intervention and comparator, irrespective of whether they reported one or more outcome of interest. We broadened the hospital admissions outcome to include all descriptions of health care usage.

Primary outcomes

1. Measures of air pollution exposure as reported by trialists, including, but not limited to:
   a. mobile monitoring units; and
   b. physiological measures (e.g. metabolic markers, heart rate variability).
2. Acute exacerbations of respiratory condition*
3. Health care usage (e.g. hospital admissions)
4. Quality of life (preferably measured using a validated scale, e.g. St. George's Respiratory Questionnaire (SGRQ), Chronic Respiratory Disease Questionnaire (CRQ))
5. Serious adverse events**

*Defined as an acute worsening of the underlying respiratory condition necessitating a temporary change in medication or management or an unscheduled visit to a healthcare provider/ hospital admission.

**Any untoward event resulting in death, or which is life-threatening, requiring hospitalisation or prolongation of existing hospitalisation or resulting in persistent or significant disability.

Secondary outcomes

1. Adherence to intervention (as a measure of behaviour change)
2. Adverse events/side effects
3. Anxiety (preferably measured using e.g. Hospital Anxiety and Depression Scale-Anxiety (HADS-A))
4. Symptoms or well-being (preferably measured using a validated scale)

We will extract outcome data reported at all reported follow-up time points in the following categories.

1. During or immediately after the intervention
2. Up to three months from baseline
3. More than three months from baseline

Search methods for identification of studies

Electronic searches

We identified studies from searches of the following databases and trial registries.

1. Cochrane Airways Trials Register (Cochrane Airways 2019), via the Cochrane Register of Studies, all years to 16 October 2020;
2. Cochrane Central Register of Controlled Trials (CENTRAL) in the Cochrane Library, via the Cochrane Register of Studies, all years to 16 October 2020;
3. MEDLINE Ovid SP, 1946 to 16 October 2020;
4. Embase Ovid SP, 1974 to 16 October 2020;
5. Global Health Ovid SP, 1910 to 16 October 2020;
6. Web of Science Core Collection, all years to 16 October 2020;
7. US National Institutes of Health Ongoing Trials Register (www.ClinicalTrials.gov), all years to 16 October 2020;
8. World Health Organization International Clinical Trials Registry Platform (apps.who.int/trialsearch), all years to 11 September 2019.

The database search strategies are detailed in Appendix 1. Search results are summarised in Appendix 2. Population search terms are based on the standard Cochrane Airways search strategy for chronic respiratory conditions. We identified air pollution and intervention search terms from a published search filter (Curti 2016), from manually reviewing the MeSH terms and keywords in a small sample of relevant studies, and textual analysis on relevant articles in the PubMed PubReMiner service (Koster 2014). We did not use study design search filters, as this is not currently recommended for NRS (Hausner 2018). The Cochrane Airways Information Specialist (ES) developed the search strategy in MEDLINE, and another Cochrane Information Specialist peer-reviewed it using the Peer Review of Electronic Search Strategies (PRESS) checklist (McGowan 2016).

We did not restrict our searches by date, language or publication type. We searched for grey literature (e.g. conference abstracts) through CENTRAL, Embase and Web of Science.

Searching other resources

We checked the reference lists of all included studies, related review articles for additional references, and used the PubMed 'similar articles' and 'cited by' features to check for additional references.

We searched on PubMed for errata or retractions from included studies on 23 March 2021.

Data collection and analysis

Selection of studies

Two review authors (SJ, ES) screened the titles and abstracts of the search results independently and coded them as 'retrieve' (eligible or potentially eligible/unclear) or 'do not retrieve'. We retrieved the full-text study reports of all potentially eligible studies and two review authors (SJ, ES) independently screened them for inclusion, recording the reasons for exclusion of ineligible studies. We resolved any disagreement through discussion or, if required, we consulted a third review author (RA). We identified and excluded duplicates and collated multiple reports of the same study so that each study, rather than each report, was the unit of interest in the review. We recorded the selection process in sufficient detail to complete a PRISMA flow diagram and 'Characteristics of excluded studies' table (Moher 2009).

Data extraction and management

We used a data collection form in an Excel spreadsheet to record study characteristics, details of the intervention and comparator, and outcome data. We piloted this form on one study in the review before full deployment. Two review authors (SJ, ES) extracted the following study characteristics from included studies.

1. Methods: country where the study has been conducted, study design, total duration of study, details of any 'run-in' period, number of study centres and location, study setting, withdrawals and date of study.
2. Participants: N, mean age, age range, gender, severity of condition, diagnostic criteria, baseline lung function, smoking history, inclusion criteria and exclusion criteria. We also extracted information about socioeconomic status, deprivation index, and ethnicity of participants.
3. Interventions: intervention (including aim, intensity and dose), comparison, concomitant medications and excluded medications.
4. Outcomes: primary and secondary outcomes specified and collected, and time points reported.
5. Notes: funding for studies and notable conflicts of interest of trial authors.

For NRS we extracted the following additional information from included studies.

1. Participants: comparability of groups based on confounding factors considered.
2. Methods: methods used to control for confounding.
3. Outcomes: multiple effect estimates (unadjusted or adjusted analyses, if available) and the variables included in analyses for adjusted estimates.

Two review authors (SJ, ES) independently extracted outcome data from included studies. We noted in the 'Characteristics of included studies' table if outcome data were not reported in a usable way. We resolved disagreements by discussion or by consensus after involving a third review author (RA). One review author (RF) transferred data into the Review Manager 5 file (Review Manager 2020). We double-checked that data were entered correctly by comparing the data presented in the systematic review with the study reports. Two review authors (SJ, ES) checked study characteristics for accuracy against the study reports.

Assessment of risk of bias in included studies

Two review authors (SJ, ES) assessed risk of bias independently for each study using the criteria outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We resolved any disagreements by discussion or by involving another review author (RF).

Randomised controlled trials

We assessed the risk of bias according to the following domains.

1. Random sequence generation
2. Allocation concealment
3. Blinding of participants and personnel
4. Blinding of outcome assessment
5. Incomplete outcome data
6. Selective outcome reporting
7. Other bias

We judged each potential source of bias as high, low or unclear and provided a quote from the study report together with a justification for our judgement in the risk of bias table. We summarised the risk of bias judgements across different studies for each of the domains listed. We considered blinding separately for different key outcomes where necessary (e.g. for unblinded outcome assessment, risk of bias for all-cause mortality may be very different than for a participant-reported pain scale). Where information on risk of bias related to unpublished data or correspondence with a trialist, we noted this in the risk of bias table.

Non-randomised controlled trials, cohort studies

We assessed NRS using the ROBINS-I tool (Risk of Bias in Non-randomised Studies - of Interventions) (Sterne 2016), which was designed to evaluate risk of bias in estimates of comparative harm or benefit of interventions that did not use randomisation to allocate participants to comparison groups. We assessed risk of bias in the following domains.

1. Confounding (pre-intervention) (as we anticipated a wide variety of study types and interventions, we aimed to identify and assess relevant confounders on a case-by-case basis)
2. Selection of participants into the study (pre-intervention) (e.g. inclusion criteria of participants, time between diagnosis and inclusion in the study, how control participants were selected)
3. Classification of interventions (at intervention)
4. Deviations from intended interventions (post-intervention) (e.g. adherence to intervention, lack of efficacy of intervention, lack of change in participant behaviour)
5. Incomplete or missing data (post-intervention) (e.g. loss to follow-up; or risk of bias due to differences in dropouts between intervention groups)
6. Measurement of outcomes (post-intervention) (e.g. self-report of outcome measures)
7. Selection of the reported result (post-intervention) (e.g. only reporting some, but not all outcomes as planned; type of analysis (univariate rather than multivariate analysis)

We judged each domain as follows.

1. Critical risk of bias: the study was too problematic in this domain to provide any useful evidence on the effects of the intervention.
2. Serious risk of bias: the study had some important problems in this domain.
3. Moderate risk of bias: the study was sound for a non-randomised study with regard to this domain but could not be considered comparable to a well-performed randomised trial.
4. Low risk of bias: the study was comparable to a well-performed randomised trial with regard to this domain.
5. No information: there was no information or insufficient detail in the study on which to base a judgement about risk of bias for this domain.

We reached an overall judgement about the risk of bias for each study and assessed it as critical, serious, moderate or low risk of bias. As most NRS are likely to be at risk of bias from the start due to confounding, we judged them to be at moderate

risk of bias – at least – overall. We assessed each included study based on the characteristics and methods of each study rather than the outcomes (as explained in the *Cochrane Handbook for Systematic Reviews of Interventions*; Higgins 2019). We provided the justification for our judgements in Table 3.

Assessment of bias in conducting the systematic review

We conducted the review according to a published protocol (Janjua 2019), and justified any deviations from it in the Differences between protocol and review section of the systematic review.

Measures of treatment effect

We have presented dichotomous data as an odds ratio (OR) or the incidence rate ratio (IRR) with 95% confidence intervals, and continuous data as the mean difference (MD) with the standard deviation (SD). We did not use the standardised mean difference (SMD) as there were insufficient data.

We planned to perform meta-analyses; however, due to limited data from the included RCT evidence, we reported effects of interventions narratively.

We planned to use adjusted analyses as a preference in our meta-analyses. However, there were insufficient data, so we reported data narratively in additional tables 7 to 11. We were unable to pool data from NRS due to limited evidence so described results narratively.

Unit of analysis issues

For dichotomous outcomes, we planned to use number of participants, rather than events, as the unit of analysis (e.g. number of people admitted to hospital, rather than number of admissions per person). However, if a study reported rate ratios we analysed them on this basis. We planned to only meta-analyse data from cluster-RCTs if the available data had been adjusted (or could be adjusted) to account for the clustering. Similarly, we planned to meta-analyse data from cross-over studies provided they reported data separately for each arm (both pre- and post-cross-over) and a coefficient statistic for within-group correlation. If this was not reported, we planned to use data from the pre-cross-over period.

We were unable to pool data in meta-analyses; therefore, we presented the data narratively.

Where a single study reported multiple trial arms, we included only the relevant arms.

Dealing with missing data

We contacted investigators or study sponsors in order to verify key study characteristics and interventions, and to obtain missing numerical outcome data where possible (e.g. when a study was identified as an abstract only). Where this was not possible, and the missing data were thought to introduce serious bias, we took this into consideration in the risk of bias assessment, and subsequently in the GRADE rating for affected outcomes.

Assessment of heterogeneity

We were unable to test for heterogeneity through subgroup analysis due to insufficient data. We reported all outcomes narratively.

Assessment of reporting biases

We were unable to pool studies to explore possible small study and publication bias, but had we been able to pool 10 or more studies we would have created and examined a funnel plot to explore publication bias

Data synthesis

For RCTs, we aimed to undertake meta-analyses only where this was clinically meaningful; that is if the study design, treatments, participants and outcomes were similar enough for pooling to make sense. However, due to limited studies and the varied nature of the intervention identified, we were unable to perform any meta-analyses.

For NRS, we aimed to assess similarity of studies to assess whether meta-analyses could be performed. For example, a meta-analysis of NRS would only be considered if:

1. study designs were similar;
2. there was low bias across all studies;
3. an adjusted effect estimate was reported that attempted to control for confounding (confounders that were similar across studies).

We were unable to combine any of the data due to limited studies.

We did not plan to combine evidence from randomised trials with evidence from NRS, as the latter may be at higher risk of confounding or imbalance of prognostic factors due to the lack of randomisation.

Due to limited studies, we presented the data in separate tables or as a narrative description. We also included a direction of effect plot, which was a post-hoc decision. We used an upward arrow to indicate studies reporting a clear health benefit for that outcome, a downward arrow for a negative health impact, and a sideways arrow for conflicting or unclear results (Boon 2020).

We planned to use a random-effects model and perform sensitivity analysis with a fixed-effect model.

Subgroup analysis and investigation of heterogeneity

We planned to use the I^2 statistic to measure heterogeneity among the studies in each analysis according to the guidance in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2019). If we identified substantial heterogeneity (I^2 of 40% or more), we planned to report it and explore the possible causes by undertaking prespecified subgroup analysis.

We planned to carry out the following subgroup analyses depending on evidence of heterogeneity. We were unable to perform any subgroup analyses to investigate heterogeneity because we did not undertake any meta-analysis.

1. Chronic respiratory condition (e.g. asthma versus COPD versus CF)
2. Children and adults (aged 12 years and older) versus children (6 to 11 years) versus preschool children (five years and younger).

We narratively summarised other potential sources of heterogeneity (effect modifiers) in a separate table (e.g. income, country (low-, middle-, high-income countries), setting (urban or

rural), components, duration, intensity, aim of intervention, and inequalities (e.g. race, occupation, gender, religion, education, socioeconomic status)).

We were unable to use the following outcomes in subgroup analyses.

1. Respiratory exacerbations
2. Hospital admissions
3. Quality of life
4. Serious adverse events

We were unable to use the formal test for subgroup interactions in Review Manager 5 (Review Manager 2020).

Sensitivity analysis

We were unable to carry out any sensitivity analyses as we did not perform any meta-analysis. Had we been able to, we would have removed the following from the primary outcome analyses.

1. For analyses of randomised trials, we planned to exclude those studies that were at high risk of selection bias (i.e. judged to be high risk for either generation of the randomisation sequence or allocation concealment).
2. For analyses of both randomised and non-randomised trials we planned to exclude studies that were at high risk of attrition bias.

We did not compare the results from a fixed-effect model with the random-effects model separately for RCTs and NRS due to limited data.

Summary of findings and assessment of the certainty of the evidence

We planned to create separate summary of findings tables for randomised trials and non-randomised trials using our primary outcomes: respiratory exacerbations; hospital admissions; quality of life; and serious adverse events. We planned to use GRADEpro GDT to create the summary of findings tables. However, due to paucity of data and a lack of meta-analyses, we created only one summary of findings table without the use of GRADEpro GDT.

We narratively pooled findings from RCTs and NRS. We used the GRADE considerations to assess the quality of the body of evidence as it related to the studies that contributed data for the prespecified outcomes (Higgins 2011; Schünemann 2019). We justified all decisions to downgrade the certainty of the body of evidence by assessing risk of bias, inconsistency, indirectness and imprecision of the evidence. The footnotes were used to provide comments to aid the reader's understanding of the review. When considering treatment effects, we took into account the risk of bias for the studies that contributed to that outcome.

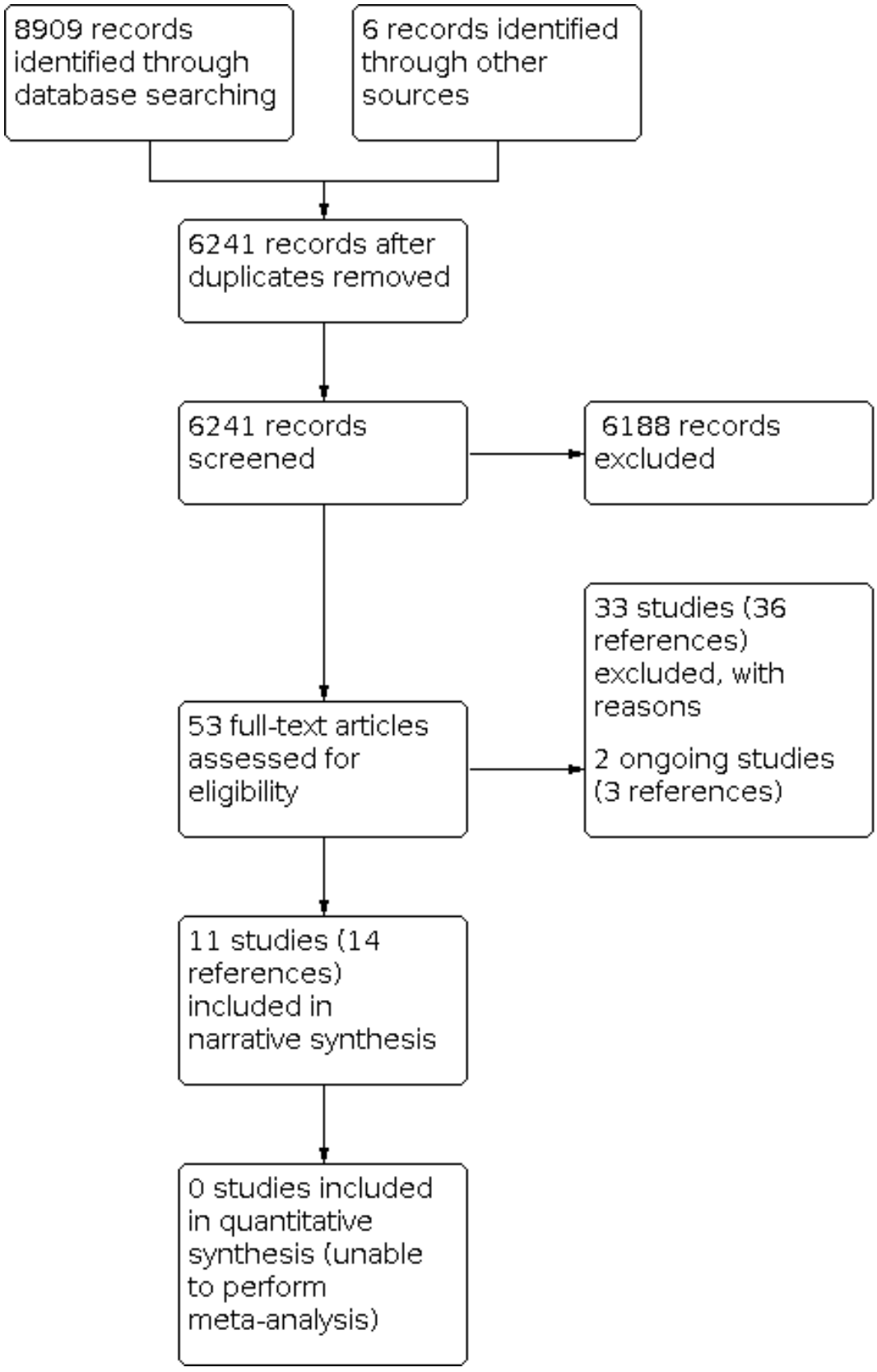
RESULTS

Description of studies

Results of the search

The literature searches retrieved 6241 records after duplicates were removed. We excluded 6188 records after reading the titles and abstracts and assessed 53 full-text reports for inclusion. We excluded 33 studies (36 references) with reasons, identified two ongoing studies, and included eleven studies (14 references). See Figure 2 for the PRISMA study flow diagram.

Figure 2. Flow diagram summarising study selection



Included studies

Eleven studies including 3372 participants met our inclusion criteria. A summary of the characteristics of the included studies is presented in the Characteristics of included studies table, with further information in Table 4; Table 5; and Table 6.

Design and setting

Six studies used a cross-over design (Cole-Hunter 2013; Guan 2018; Langrish 2009; Morishita 2019; Shi 2017; Zhang 2019). In one of the six studies it was not clear if the order of exposure was randomised (Cole-Hunter 2013). All studies were open-label with the exception of one, in which a sham face mask was used (Guan 2018).

Four studies used an individually randomised open-label parallel design (Araban 2017; D'Antoni 2019; Jasemzadeh 2018; Mehiriz 2019). The final study was a non-randomised parallel design comparing those who signed up to an intervention to those who did not (Lyons 2016).

Four studies were conducted in China (Guan 2018; Langrish 2009; Zhang 2019 in Beijing and Shi 2017 in Shanghai), two in Iran (Araban 2017; Jasemzadeh 2018), two in the UK (D'Antoni 2019; Lyons 2016), and one each in the USA (Morishita 2019), Canada (Mehiriz 2019), and Australia (Cole-Hunter 2013).

Participants

Study size ranged from 15 to 1395 participants, with a mean of 307 and a median of 110. All but one study recruited adults only. Lyons 2016 included participants of all ages, but 93% were aged 15 and over. The majority of studies recruited both men and women, but two recruited only pregnant women (Araban 2017; Jasemzadeh 2018). Eight studies recruited healthy adults only, with the remaining studies recruiting 'at risk' individuals as either some or all of their participants (D'Antoni 2019; Lyons 2016; Mehiriz 2019). D'Antoni 2019 defined 'at risk' as having an existing heart or lung problem, and such participants made up 25% of the study population. In Lyons 2016, participants all had asthma, COPD or coronary heart disease. Participants in the study by Mehiriz 2019 had heart or lung conditions, kidney failure or a neurological disorder/mental health issue.

Interventions

Five studies investigated the benefits of face masks by exposing a total of 143 healthy adults to real-world air pollution. In two studies, participants undertook a two-hour walk along a high-traffic road with and without a face mask (Guan 2018; Langrish 2009). In Zhang 2019, participants travelled on the Beijing subway for four hours with and without a face mask. During the intervention condition in the study by Shi 2017, participants wore a face mask as much as possible for 48 hours, including for a one-hour near-road walk, and carried out usual activities during the control condition, but including the same near-road walk. In Morishita 2019, participants undertook multiple two-hour near-roadway exposures during a one-week period, again with and without a face mask. Participants in two studies used an N95 mask during the intervention condition (Guan 2018; Zhang 2019), in the Zhang 2019 study it was the 3M 9002V face mask connected to a pump with an efficient filter. The Shi 2017 study used a 8219V face mask, and the Langrish 2009 study a Dust Respirator 8812 face mask. All masks used in included studies are designed to filter out particulate matter.

Five studies, including 3188 people, investigated the use of air quality alerts or educational interventions to mitigate the risk of air pollution (Araban 2017; D'Antoni 2019; Jasemzadeh 2018; Lyons 2016; Mehiriz 2019). Araban 2017 used a multi-component intervention (motivational interviewing, booklet, daily short message service (SMS)) intended to minimise air pollution exposure. Jasemzadeh 2018 used air pollution alerts encouraging protective behaviours and included a weekly phone call to ensure alerts were being received. In D'Antoni 2019, both groups received UK Air Quality Index (DAQI) alerts, but in the intervention group the alerts included additional messages targeting specific psychological factors. Lyons 2016 compared those who signed up to receive AirAware alerts with those who did not. Participants in Mehiriz 2019 received an automated phone smog warning in the intervention group.

Cole-Hunter 2013 investigated the use of a cycle route with lower proximity to traffic compared to a usual higher-traffic route.

Outcome measures

Included studies used a wide variety of outcome measures. The five face mask studies measured particulate exposure along with a range of physiological and metabolic markers of air pollution exposure, including exhaled cytokines and nitrous oxide, urine metabolites, circulating biomarkers, and blood pressure and heart rate variability (Guan 2018; Langrish 2009; Morishita 2019; Shi 2017; Zhang 2019). Langrish 2009 also reported symptoms using a visual analogue scale and, along with Shi 2017, reported mask comfort/acceptability. Cole-Hunter 2013, a study of the use of a cycle route with lower proximity to traffic compared to a usual higher-traffic route, reported similar outcomes including particulate measurements, respiratory symptoms, lung function and sputum inflammatory cell analysis.

Four studies which investigated air quality alerts and education focused on a range of behaviour-change outcomes, including self-efficacy, perception of risk, action planning and preventative behaviours (Araban 2017; D'Antoni 2019; Jasemzadeh 2018; Mehiriz 2019). Mehiriz 2019 also reported on symptoms, the impact of the alerts on physical activity, and whether participants kept their inhaler with them. Lyons 2016, which also investigated air quality alerts, focused solely on health care utilisation (e.g. emergency department attendances).

Excluded studies

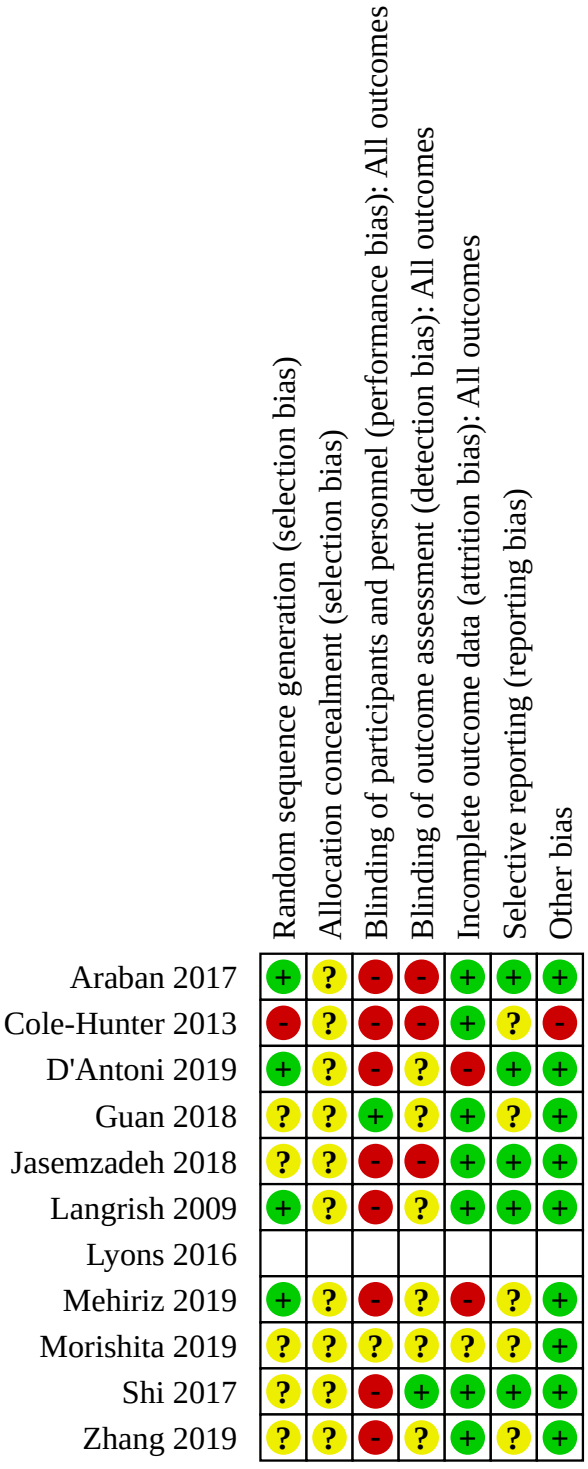
See Characteristics of excluded studies table. We excluded 32 studies for the following reasons: ineligible study design (23); ineligible intervention (9).

Risk of bias in included studies

Randomised studies

To identify possible sources of bias, we assessed 10 studies using the Cochrane Risk of Bias tool for randomised controlled trials (Higgins 2011) (Araban 2017; Cole-Hunter 2013; D'Antoni 2019; Guan 2018; Jasemzadeh 2018; Langrish 2009; Mehiriz 2019; Morishita 2019; Shi 2017; Zhang 2019. A summary of the risk of bias judgements can be found in Figure 3.

Figure 3. Summary of the risk of bias judegments for the 10 randomised controlled trials. We assessed Lyons 2016 using a different tool.



Allocation

We judged four studies to have used low risk methods for the generation of the randomisation sequence (Araban 2017; D'Antoni 2019; Langrish 2009; Mehiriz 2019). We judged one cross-over study to be at high risk as the report did not specify whether the order of exposure to interventions was randomised, although the report states that half of the participants were exposed to each intervention first (Cole-Hunter 2013). The remaining five studies were reported as randomised, but did not provide enough information to make a judgement and we assessed them as being at unclear risk.

None of the studies provided details of how allocation was concealed, so we judged all ten to be at unclear risk.

Blinding

One study used a sham mask in the control condition, and we judged it to be at low risk of performance bias (Guan 2018). Eight studies either did not describe blinding of participants and personnel, or the study intervention was such that blinding was not possible, so we judged them to be at high risk of performance bias (Araban 2017; Cole-Hunter 2013; D'Antoni 2019; Jasemzadeh 2018; Langrish 2009; Mehiriz 2019; Shi 2017; Zhang 2019). One study was reported as "single-blinded" but did not describe who was blinded, so we judged this study to be at unclear risk (Morishita 2019).

We judged three studies to be at high risk of detection bias as some or all outcomes were self-reported and the participants were aware of group allocation (Araban 2017; Cole-Hunter 2013; Jasemzadeh 2018). We judged one study to be at low risk as it stated that outcome assessors were blinded and the majority of outcomes were objective and not self-reported by the unblinded participants (Shi 2017). The remaining six studies did not describe whether or not outcome assessment was blinded, and we judged them to be at unclear risk.

Incomplete outcome data

Seven studies had low or no dropouts, and we assessed them to be at low risk of attrition bias (Araban 2017; Cole-Hunter 2013; Guan 2018; Jasemzadeh 2018; Langrish 2009; Shi 2017; Zhang 2019). We judged two studies to be at high risk due to high or unequal numbers of dropouts (D'Antoni 2019; Mehiriz 2019). One study was at unclear risk (Morishita 2019).

Selective reporting

Five studies provided prospective trial registrations or protocols and reported outcomes as planned, so we judged them to be at low risk of reporting bias (Araban 2017; D'Antoni 2019; Jasemzadeh 2018; Langrish 2009; Shi 2017). The remaining five studies did not provide this information; therefore we judged them to be at unclear risk.

Other potential sources of bias

We judged Cole-Hunter 2013 to be at high risk of other bias as it was unclear whether or not this is a randomised trial. We chose to assess this with the standard risk of bias tool for RCTs as the study closely resembles a randomised cross-over trial. A lack of randomisation of the order of exposure may have impacted the results. For example, participants will have had 'practice' taking their outcome measurement in the first phase and this could impact outcome measurement in the second phase. Although the report states that half the participants completed the high-pollution route first and half the low-pollution route, providing some protection, it is possible that bias was introduced if they were not randomly assigned.

We did not find any other sources of bias in the other nine RCTs.

Non-randomised studies

One trial was non-randomised (Lyons 2016), so we assessed possible sources of bias for the one outcome domain reported in this study (health care usage) using the ROBINS-I tool (Sterne 2016). Judgements are summarised in Table 3.

Overall risk of bias

We judged Lyons 2016 to be at serious risk of bias for health care usage (hospital admissions). Issues included: likely residual confounding; potential deviations from the intended intervention; multiple measurements within an outcome domain; knowledge of intervention assignment likely impacting outcomes; and lack of a protocol or study registration.

The study was at serious risk of confounding. Authors adjusted regression analyses for age, gender, deprivation index and smoking status, but acknowledged that residual confounding likely remained for all outcomes. This study indicated greater utilisation of health care in the intervention group; this may be due partially or entirely to confounding. There was no specific information available about whether intervention switches or discontinuations occurred; however, all but two participants were analysed according to their allocation group. We rated the study as low risk of bias for selection, classification of interventions, and missing data. We could not make a judgement on deviations from the intended interventions due to lack of information. We rated outcome measurements as serious risk of bias because intervention participants decided whether to access health care and were aware of assignment. It is not possible to separate the effects of knowledge of assignment from the effect of the intervention itself (air pollution alerts). We judged Lyons 2016 to be at serious risk of bias for reporting of results. The study reported multiple measures of health care usage (i.e. hospital admissions) without a primary outcome, and we were unable to identify a protocol or study registration.

Effects of interventions

See: **Summary of findings 1** Individual level interventions vs control

We were unable to perform any statistical meta-analyses due to the variation in study designs, populations, interventions and outcome measures. Instead, we have presented a summary of outcome data in Table 7; Table 8; Table 9; Table 10. A direction of effect table summary is presented in Table 11.

Comparison: individual-level interventions versus usual care, a sham intervention, or active control

Primary outcomes

1. Measures of air pollution exposure

This outcome addresses objective one.

For this outcome, we included the following comparisons: masks versus no masks (Guan 2018; Langrish 2009; Morishita 2019; Shi 2017; Zhang 2019), or a cycle route with low proximity to traffic verus high traffic proximity (Cole-Hunter 2013). A total of 184 participants took part in these studies.

Outcome data are summarised in Table 7.

Studies measured this outcome in a number of ways. Cole-Hunter 2013, a cross-over trial of high- and low-pollution bicycle routes, reported peak expiratory flow rate (PEFR) and sputum cell counts as a measure of airway inflammation. They showed little to no difference in these outcomes between the two intervention conditions at any time point. Guan 2018, a cross-over trial of masks, also reported airway inflammation but focused on exhaled biomarkers (interleukins (ILs)) and tumour necrosis factor (TNF)) and nitrous oxide (eNO). Authors report little to no difference in exhaled ILs or TNF between the two conditions, but did note that the increase in eNO was 38.3% less in the mask group compared to the control group ($P < 0.005$). Furthermore, Guan 2018 reported urinary creatinine corrected malondialdehyde as a maker of oxidative stress in the body, but found little to no difference between conditions. Shi 2017 reported circulating biomarker levels that are thought to increase with air pollution exposure, and although levels were lower in the mask condition, we could not be certain of the effects due to wide confidence intervals and P values of > 0.1.

Langrish 2009, another cross-over mask trial, focused on haemodynamic variables as a measure of air pollution exposure. Authors reported little to no difference in 24-hour heart rate or blood pressure between the two conditions. They did, however, note increased heart rate variability (a desirable outcome) in the mask condition and lower systolic blood pressure (again, a desirable outcome) in the mask condition during the two-hour near-traffic walk. Shi 2017 identified similar small increases in heart rate variability and decreased systolic blood pressure during mask use. Morishita 2019, another cross-over mask trial, also reported haemodynamic variables but reported little to no difference between conditions. Furthermore, wearing a mask did not provide any effect modification on the association between particulate concentration and black carbon and haemodynamic changes. Finally, Zhang 2019 reported blood pressure in participants in a cross-over mask trial, but again, found little to no difference between conditions.

We assessed the certainty of this evidence to be very low due to imprecision, inconsistency and risk of bias (Summary of findings 1).

2. Acute exacerbations of respiratory condition

This outcome addresses objective 2, but we did not identify any data.

3. Health care usage

This outcome addresses both objectives 1 and 2.

For this outcome, we included the following comparisons: air quality alerts with or without additional messaging versus usual care, or no additional messaging (D'Antoni 2019; Lyons 2016; Mehiriz 2019). A total of 2948 participants took part in these studies.

Outcome data are summarised in Table 8.

We broadened this outcome to include health care usage, as studies did not always report hospital admissions separately. Three studies reported some measure of health care use during the follow-up period (D'Antoni 2019; Lyons 2016; Mehiriz 2019). It was the main outcome measure in Lyons 2016, a non-randomised study in which intervention participants signed up to receive air quality alerts. The study's trialists reported an increase in emergency attendances (Incidence rate ratio (IRR) 1.89 (95% confidence interval (CI) 1.34 to 2.68)), emergency admissions (IRR 2.04 (95% CI 1.06 to 3.93)) and respiratory emergency admissions (IRR 3.97 (95% CI 1.59 to 9.93)) in the intervention group. They did not detect a clear difference in all-cause hospital admissions (IRR 0.82 (95% CI 0.58 to 1.14)), outpatient attendances (IRR 1.01 (95% CI 0.83 to 1.25)) or GP contacts (respiratory contacts IRR 1.04 (95% CI 0 0.96 to 1.13) or relevant contacts IRR 1.04 (95% CI 0.98 to 1.11)), although confidence intervals did not rule out a difference.

D'Antoni 2019, another trial of air quality alerts, reported emergency medical visits. They asked participants if they had made an emergency medical visit in the past four weeks and measured responses from 1 = strongly disagree to 9 = strongly agree. They found little to no difference of effect between intervention and control groups. Mean scores in both at-risk and general population groups were generally below 2.0, with substantially overlapping confidence intervals. The exception was the at-risk control group, in which the mean score was 2.68 (95% CI 1.50 to 4.21), but again, confidence intervals substantially overlapped with the at-risk intervention group effect estimate.

Finally, the study by Mehiriz 2019, in which intervention participants received a smog warning, reported use of health care system services, comparing intervention to control using odds ratios (OR) and 95% CI. They reported little to no difference of effect between intervention and control (OR 1.03, 95% CI 0.51 to 2.12).

We assessed the certainty of this evidence to be very low due to imprecision, inconsistency and risk of bias (Summary of findings 1).

4. Quality of life

This outcome addresses objectives one and two, but we did not identify any data.

5. Serious adverse events

This outcome addresses objectives one and two, but we did not identify any data.

1. Adherence to the intervention

This outcome addresses objective one.

For this outcome, we included the following comparisons: education and motivational interview (Araban 2017), masks versus no masks (Langrish 2009; Shi 2017), cycle route with low proximity to traffic versus high traffic proximity (Cole-Hunter 2013), and air quality alerts with or without additional messaging versus usual care or no additional messaging (D'Antoni 2019; Jasemzadeh 2018; Mehiriz 2019). A total of 1873 participants took part in these studies.

Outcome data are summarised in Table 9.

We found a diverse range of outcome measures reporting intervention adherence. Langrish 2009 assessed mask tolerance and reported a mean score of 24.8% (95% CI 16.2 to 33.3), with

0% representing completely tolerable and 100% intolerable. Shi 2017 asked participants to rate mask comfort/fit from 0 to 10, with 10 being most comfortable, and found a reported a mean of 5 to 6. Cole-Hunter 2013 reported whether participants preferred the lower- or higher-pollution bicycle commute, with 66% (10/15) preferring the lower-pollution route.

Three studies all reported a measure of action taken or preventive behaviours in response to air pollution alerts and education (Araban 2017; D'Antoni 2019; Jasemzadeh 2018). Participants (pregnant women) in the intervention arm of Araban 2017 self-reported more preventative behaviours than in the control group: 19.4 (standard deviation (SD) 1.75) vs 10.6 (2.1) (scored from 5 to 20 with higher scores indicating more preventative behaviours). However, participants in the intervention arm of Jasemzadeh 2018, also a trial in pregnant women, did not report more protective behaviours than the control group (55.80 (8.29) vs 53.17 (7.34) (scored from 15 to 75 with higher score = more protective behaviours). D'Antoni 2019 reported on action taken to reduce air pollution exposure in the at-risk and general population intervention groups compared to control groups, on a scale of 1 to 9 (1 = not at all and 9 = all the time). There was little to no difference in effect between groups, with substantially overlapping confidence intervals.

Specifically, D'Antoni 2019 reported whether participants checked air quality before outdoor activities or stopped exercise due to receiving alerts, but again there was little to no difference between groups. However, when asked if they had considered a change to a travel route or exercise routine (e.g. time or place), more participants in the at-risk and general population intervention groups (58% and 54%) answered yes, compared to the control groups (43% and 30%).

Two studies, both investigating air quality alerts, reported a measure of whether physical activity or exertion differed between intervention and control groups. D'Antoni 2019 found little to no difference between self-reported physical activity levels between the intervention and control groups. Participants who received the smog warning in Mehiriz 2019 may be less likely to make physical efforts, but the 95% CI were wide and crossed the line of no effect (OR 0.59, 95% CI 0.25 to 1.38).

Mehiriz 2019 reported two further measures of behaviour change in response to the intervention. Trialists found that participants receiving the smog warning were more likely to keep their medication with them (OR 2.15, 95% CI 1.06 to 4.37) and more likely to stay indoors (OR 2.03, 95% CI 1.28 to 3.24).

2. Adverse effects/side effects

This outcome addresses objectives one and two, but we did not identify any data for this outcome.

3. Anxiety

This outcome addresses objectives one and two, but we did not identify any data for this outcome.

4. Symptoms or well-being

This outcome addresses objectives one and two.

For this outcome, the following comparisons were included: a cycle route with low proximity to traffic versus high traffic proximity (Cole-Hunter 2013), masks versus no masks (Langrish 2009), and air quality alerts versus usual care (Mehiriz 2019). A total of 1378 participants took part in these studies.

Outcome data are summarised in Table 10.

Three studies reported a measure of symptoms. Cole-Hunter 2013 reported greater throat and nasal irritation after the higher-pollution cycle route compared to the lower-pollution route (1.9 (SD 0.2) vs 1.5 (SD 0.3); scored 1 to 5 with lower score = fewer symptoms). However, there was little to no difference in any other measure of acute respiratory symptoms (e.g. cough, chest tightness, wheeze). Langrish 2009, a cross-over study involving masks, reported difficulty in breathing and found this increased in the mask condition (3.8 (8.10) vs 0.67 (0.9); measured on a visual analogue scale from 0 to 100 with higher score = more difficulty, reported as mean (SD)). Finally, Mehiriz 2019, found an uncertain effect of receiving smog-warnings on smog-related symptoms (OR 1.05 (95% CI 0.71 to 1.54).

DISCUSSION

Summary of main results

We identified eleven studies that investigated a variety of individual-level interventions to reduce personal exposure to air pollution. Six studies used a cross-over design (i.e. participants receive the intervention and control treatments consecutively), five of which investigated particle-filtering mask use and one an altered cycle route. Five studies used a parallel design (i.e. where two groups receive treatments separately at the same time) and investigated air quality alerts and education. Studies ranged in size from 15 to > 1300 participants and were conducted in four different continents. Most recruited healthy adults, including two studies of pregnant women, but three included older participants or those with pre-existing chronic conditions, which put them at a higher risk from air pollution. Reported outcome measures were varied and we were unable to perform any statistical meta-analysis. We reported the results narratively and in tables.

There was little evidence that an altered cycle route or wearing a mask impacted short-term physiological responses to air pollution, including airway inflammation, oxidative stress (imbalance of oxygen containing radicals in the body) and haemodynamic variables (e.g. blood pressure). However, there was some evidence from individual cross-over trials with small numbers of participants that mask use may reduce exhaled nitric oxide, increase heart rate variability and lower systolic blood pressure when compared to control. However, it should be noted that the studies used four different types of masks.

We found mixed results regarding healthcare service use. One large non-randomised study of air pollution alerts identified increased emergency attendances and admissions and increased respiratory admissions in the intervention group. However, two other trials, also investigating air pollution alerts, found no clear effect on emergency medical visits or healthcare system use, but a difference could not be ruled out.

We found a number of measures of intervention adherence (i.e. people completing treatment). Two studies reported that masks were generally reasonably well tolerated in healthy young individuals, while another study found the majority of

participants preferred a lower-level pollution cycle route. Several studies measured whether participants were more likely to report undertaking preventative behaviours following air pollution alerts or education, with two studies reporting little to no difference and one study reporting more preventative behaviours in the intervention group. However, when specifically asked about whether they had considered a change to a travel route or exercise regimen in response to air pollution, more participants in the intervention arm of one trial responded positively. We found little to no difference between intervention and control groups in the two studies that reported physical activity or exertion levels following an air quality alert. One trial did report that more participants in the intervention group were likely to keep their medication with them and more likely to stay indoors following an air pollution warning.

Three studies reported on symptoms. One study of altered cycle routes reported less nasal and throat irritation in the intervention condition, but little to no difference in other acute respiratory symptoms. One study of masks reported increased difficulty in breathing in the mask group, although scores were low in both conditions. A study of air pollution warnings found an uncertain effect on smog-related symptoms between the intervention and control groups.

Finally, none of the studies reported any adverse events.

Overall completeness and applicability of evidence

Despite considerable worldwide interest in what individuals can do to protect themselves from the negative health impacts of air pollution, we found surprisingly few trials that met our inclusion criteria. Furthermore, we were not able to carry out any meta-analyses due to diversity of trial populations, interventions, comparators and outcomes.

Mask studies were small (143 participants in total across five studies), of short duration and focused on a range of physiological measurements, rather than outcomes important to the individual. Four out of five studies were conducted in large cities in China (Beijing and Shanghai), both known for poor air quality, and recruited young healthy volunteers. The applicability of the findings of these trials to an international population, including those with existing respiratory disease, is limited.

Studies investigating air quality alerts or education were generally larger, longer and included more outcomes important to the individual, such as health care usage and behaviour change. However, two out of the four studies recruited pregnant women in Iran, limiting their generalisability.

Eight out of nine studies recruited adults only, and in the remaining study less than 10% of participants were under the age of 15 years. Therefore, the findings of this review cannot be applied to children. Two large studies of air pollution alerts/warnings (with 1395 and 1328 participants) recruited individuals with existing health conditions. However, their measured outcomes were conflicting and not similar enough to be pooled, thus limiting our confidence in their application to these important vulnerable populations.

We did not identify any outcome data addressing three of our five primary outcomes (acute exacerbations of respiratory condition, quality of life or serious adverse events). This is an important limitation of the data presented and substantially restricts the conclusions we can reach. Studies did not explicitly address equity, but implementation of interventions described in the included studies could result in widening health inequity. Particle-filtering masks may be too costly for many of those most at risk. Air pollution alerts may rely on an individual having access to a smartphone or being able to read the alerts. Not all individuals will live in an environment where they have access to an alternative lower-pollution transport route.

Finally, included studies were conducted in 'real world' settings, in which participants were exposed to a mix of pollutants, and the interventions may impact on exposure to individual pollutants to different extents. This is a limitation when considering applying the evidence to devising policies to reduce pollution, which are often focused on specific particles or gases.

Quality of the evidence

We have created a summary of findings table for our primary outcomes and applied GRADE to the outcomes for which we found data: Summary of findings 1.

Our certainty in the evidence for reduction in air pollution exposure and health care usage is very low. We downgraded both outcomes for imprecision as individual study results included both the possibility of harm or benefit of the intervention and no difference between intervention and control, and results could not be combined. We downgraded both outcomes for inconsistency as individual studies reported differing directions of effect, or no clear direction of effect. Finally, we downgraded for risk of bias as most trials were unblinded and we had concerns about selection bias and selective reporting. Methods were not clearly described and we could not identify study protocols or trial registrations.

Potential biases in the review process

We conducted our review according to standard Cochrane methods and our prepublished protocol (Janjua 2019). Any deviations from our protocol are reported and justified in the Differences between protocol and review section. It is possible that we have not identified all relevant studies, but we carried out a comprehensive search, the strategy for which was peer-reviewed by an independent Information Specialist. We did not restrict our search by date, language or publication type, and we included a search of the grey literature. We screened the search result in duplicate and resolved disagreements by discussion. We extracted outcome data and assessed risk of bias in duplicate and consulted a third review author to resolve disagreements if necessary.

A weakness of the review is that we did not prespecify a narrative synthesis method as we did not anticipate that we would not be able to perform any statistical synthesis; the decision to include a direction of effect plot was post-hoc.

Agreements and disagreements with other studies or reviews

Despite clear evidence of the association between outdoor air pollution and adverse health outcomes, there is little evidence informing what individuals can do to mitigate these effects.

A 2015 review article addresses what individuals can do to reduce personal risk from air pollution (Laumbach 2015). That review concludes that evidence is limited and interventions may have unwanted consequences, e.g. a reduction in physical activity from

advice to limit outdoor recreation. This is in keeping with the limited evidence of efficacy we identified and limited reporting of adverse effects. Our findings are also in keeping with Burns 2019, a systematic review addressing non-individual level interventions. This review could not reach overall conclusions due to diversity in interventions, outcomes and study methods.

Carlsten 2020 provides an overview of advice for providers, patients and the public regarding personal strategies to minimise the effects of air pollution, and recognises that the overall quality of evidence on which to base recommendations is lacking. Until such a time as more high-quality studies are available, the authors supplement suboptimal evidence with expert opinion.

The most recent guidelines from the Global Initiative for Asthma state that, during unfavourable environmental conditions, "it may be helpful to stay indoors in a climate-controlled environment, and to avoid strenuous outdoor physical activity; and to avoid polluted environments during viral infections, if feasible" (GINA 2021). However, this advice appears to be based on the known association between outdoor pollution and asthma exacerbations, rather than on evidence that staying indoors or avoiding activity is beneficial at an individual level. Indeed, this recommendation is based on a panel consensus judgement, rather than a body of evidence, in keeping with our review and with Carlsten 2020. Similarly, the international Global Initiative for Obstructive Lung Disease (GOLD) report for the management of COPD also graded the evidence to "avoid continued exposure to potential irritants, if possible" as level D (panel consensus judgement) (GOLD 2021).

Finally, Powell 2016 identified evidence for individual-level interventions as an important research gap both for healthcare practitioners and patients. Unfortunately, this review confirms that the research gap still exists.

AUTHORS' CONCLUSIONS

Implications for practice

Limited evidence and study diversity means we cannot draw clear conclusions to guide practice about the efficacy and safety of individual-level interventions to reduce the health impacts of air pollution.

Using a mask or avoiding busy roads during a cycle commute may mitigate some of the physiological impacts, but evidence is limited to small trials in healthy individuals and findings cannot be applied to people with respiratory conditions or longer-term clinical outcomes.

Studies suggest that air pollution alerts may have some benefits in terms of behaviour changes to limit the effects of pollution (e.g. staying indoors more), but may also increase health care usage in people with pre-existing health conditions.

We found little evidence of any impact on other patient-important outcomes in the individual studies we identified.

Implications for research

There is a need for larger, longer trials to investigate individual-level interventions, especially in people with pre-existing respiratory conditions, including asthma and chronic obstructive pulmonary disease (COPD). Trials should ideally be randomised, international and involve children and young people. Trialists may want to prioritise recruiting children whose homes or schools are near busy roads. Standardised methods and outcomes would facilitate comparison and combination in meta-analyses. Where observational studies are conducted, key confounders should be included in the analysis, including medication use, symptom history, other risk factors for exacerbations and socioeconomic status.

Interventions of interest would include:

- long-term regular use of a particle-filtering mask when outdoors and during other times of potentially high exposure to air pollution, e.g. while on an underground train;
- air quality alerts with a nested qualitative study to understand the reasons for any impact on health care usage, quality of life and anxiety;
- tailored education that takes into account an individual's personal circumstances, e.g. realistic route planning; and
- air filters/purifiers to reduce exposure to outdoor air pollution while in the home or workplace.

Outcomes of interest would include validated measures of:

- individual air pollution exposure;
- health care usage;
- respiratory exacerbations/symptoms;
- quality of life;
- acceptability;
- impact on physical fitness;
- equity; and
- worsening of symptoms.

They also need to include better monitoring for actual individual air pollution exposure.

Although outside the scope of this review question, future research should include trials in other groups with increased vulnerability to air pollution, including the elderly, the pregnant and the very young.

Robust evidence will help healthcare providers to advise people with long-term respiratory conditions about effective and safe ways of reducing personal exposure to air pollution and its negative impact on health. Furthermore, policy makers will be able to use the information when considering population-level interventions, such as providing pedestrian and cycle routes separated from motor traffic, and wider availability evidence-based air quality alert systems.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies *[ordered by study ID]*

Araban 2017

Study characteristics	
Methods	**Intervention assignment:** individually-randomised parallel trial **Blinding:** open-label **Duration:** 13 weeks **Setting:** prenatal care ward in Tehran, Iran
Participants	**No. of participants randomised:** 110 (55 intervention, 55 control) **No. of participants completing:** 104 (53 intervention, 51 control) **Age:** 20 to 35 years (intervention mean 27 years, control mean 22 years) **% male:** 0 **Existing health condition:** no **Inclusion criteria:** pregnant women aged 18 to 35 years with normal obstetric history without any adverse outcomes (e.g. preterm labour); not living with any chronic disease (e.g. diabetes, hypertension, kidney or cardiovascular problems); no previous history of infertility, gestational age between 20 and 24 weeks, and having a mobile phone for receipt of daily messages. **Exclusion criteria:** experiencing complications during their pregnancy such as bleeding, hypertension, or any other complication resulting in permanent bed rest or hospitalisation
Interventions	**Intervention:** educational intervention consisting of 1. 1-hour group motivational interview session on behaviours towards air pollution exposure and to gain information on barriers and facilitators; 2. daily SMS for 1 month; and 3. educational booklet about air pollution. The aim was to get participants from a contemplation stage to an action stage. **Control:** usual maternity care
Outcomes	Stages of behavioural changes for prevention of exposure to air pollution, self-efficacy, decisional balance, preventative behaviour towards air pollution exposure in the last month
Notes	**Funding:** Tarbiat Modares University **Registration:** IRCT2012091010804N1

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Reported as random assignment, sequence generated by random numbers using a computer programme.
Allocation concealment (selection bias)	Unclear risk	Participants were assigned according to an order number. Odd numbers were given to women enrolled in the control arm. It is unclear whether study staff were aware of the allocation.

Araban 2017 *(Continued)*

Blinding of participants and personnel (performance bias) All outcomes	High risk	Assumed that it is not possible to blind participants or personnel due to the nature of the intervention.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Outcomes were participant-reported and we assume that they were not blinded.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Attrition was low in both groups (< 10%).
Selective reporting (reporting bias)	Low risk	Outcomes were reported as planned. Authors state in the limitations that the stages had to be collapsed into two categories due to small sample size.
Other bias	Low risk	We did not identify any other sources of bias.

Cole-Hunter 2013

Study characteristics	
Methods	**Intervention assignment:** cross-over trial, order not randomised **Blinding:** open-label **Duration:** 2 days **Setting:** Brisbane, Australia
Participants	**No. of participants recruited:** 35 **No. of participants completing:** 35 **Age:** mean 39 (SE 11) years **% male:** 71 **Existing health condition:** no **Inclusion criteria:** healthy adults with no history of cardiopulmonary disease and no recent history of smoking (cessation > 24 months prior) or respiratory infection (symptoms > 2 weeks prior) **Exclusion criteria:** not reported
Interventions	**Intervention:** altered bicycle route for commute to reduce air pollution exposure via proximity to traffic **Control:** usual bicycle route for commute
Outcomes	In-commute heart rate, in-commute particle concentration and diameter, climate, physiological inflammatory responses, symptom questionnaire, peak expiratory flow rates, sputum sampling and cell counts
Notes	**Funding:** not reported **Trial registration:** not reported

Cole-Hunter 2013 *(Continued)*

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	The trial report states that "An equal number of participants performed HIGH or LOW first, to counterbalance and negate any influence of the order of the route condition". However, there is no description of whether this was determined randomly, so we assume it was not formally randomised.
Allocation concealment (selection bias)	Unclear risk	No further information given.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding is not described, but given the nature of the intervention blinding of participants and personnel is not possible.
Blinding of outcome assessment (detection bias) All outcomes	High risk	Outcome measures of relevance to this review were mostly self-administered by non-blinded participants, and while some are 'objective' (e.g. PEFR), they are also effort-dependent and would rely on accurate recording by the participant. Subjective outcomes, such as symptoms, are at high risk.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Dropout was not specifically reported, but report suggests that all participants completed the study.
Selective reporting (reporting bias)	Unclear risk	No trial registration or prospective publication of protocol identified, so we cannot confirm that outcomes were reported as planned a priori.
Other bias	High risk	Trial is a cross-over design, but the order of exposure does not appear to have been randomised and this may have impacted the results. For example, participants will have had 'practice' taking their outcome measurement in the first phase and this could impact outcome measurement in the second phase. Although the report states that half the participants completed the high pollution route first and half the low pollution route, it is possible that bias was introduced if they were not randomly assigned.

D'Antoni 2019

Study characteristics

Methods	**Intervention assignment:** individually randomised; parallel **Blinding:** "single blind" **Duration:** 4 weeks **Setting:** London, UK
Participants	**No. of participants randomised:** 225 (intervention: 34 "at risk" and 84 general population; control: 24 "at risk" and 83 general population) **No. of participants completing:** 82 (intervention: 12 "at risk" and 29 general population; control: 7 "at risk" and 34 general population) **Age:** 18 to 64 years **% male:** 62

D'Antoni 2019 *(Continued)*

	Existing health condition: mixed population; 25% had pre-existing conditions placing them at higher risk **Inclusion criteria:** Aged 18 years and above, English speaking, working/living in Greater London, new or existing customers to the City Air smartphone app **Exclusion criteria:** not reported
Interventions	**Intervention:** real-time notification via CityAir about real air pollution episodes and additional messages targeting specific psychological factors **Control:** real-time notification via CityAir about real air pollution episodes
Outcomes	Intentions to adhere to recommendations in high levels of air pollution, behaviour change and action planning, behaviour change in response to real moderate air pollution, mediators of behaviour change and format of information, greater behaviour change
Notes	**Funding:** National Institutes for Health Research, Protection Research Unit (NIHR HPRU) **Trial registration:** NCT03552198

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Participants were randomised via an algorithm run by CityAir to either treatment or control group. No further information provided.
Allocation concealment (selection bias)	Unclear risk	No further information given.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Not possible to blind participants or personnel due to nature of the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information given.
Incomplete outcome data (attrition bias) All outcomes	High risk	Overall attrition was 64%, ranging from 59% to 71% across the groups. At 4 weeks, loss to follow-up was due to participants not submitting the final questionnaire. A technical problem with the app in week 3 may also have contributed to attrition.
Selective reporting (reporting bias)	Low risk	The trial is registered on NCT website, outcomes were reported as planned.
Other bias	Low risk	We did not identify any other sources of bias.

Guan 2018

Study characteristics

Methods	**Intervention assignment:** individually randomised cross-over trial **Blinding:** double-blinded

Guan 2018 *(Continued)*

	Duration: 24 hours with 1 month wash-out before cross-over **Setting:** Peking University, Beijing, China
Participants	**No. of participants randomised:** 15 **No. of participants completing:** 15 **Age:** mean 20 (SD 1) years **% male:** 47 **Existing health condition:** no **Inclusion criteria:** non-smokers, not on regular medication, no history of coronary or respiratory conditions, no upper airway infection symptoms 4 weeks prior to study start **Exclusion criteria:** not reported
Interventions	**Intervention:** walk along a designated route with busy traffic for 2 hours wearing an N95 face mask **Control:** walk along a designated route with busy traffic for 2 hours with sham face mask (no filter)
Outcomes	Air pollution monitoring, face mask filtration efficiency, biomarker measurements (NO, interleukins, TNFa, urinary creatinine-corrected malondialdehyde (MDA), pulse wave analysis, arterial stiffness, oxidative stress and endothelial dysfunction
Notes	**Funding:** Natural Science Foundation of China, Ministry of Science and Technology project, Collaborative Innovation Centre for Regional Environmental Quality **Trial registration:** ChiCTR1800016099 (retrospectively registered)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Described as randomised, but no further information given.
Allocation concealment (selection bias)	Unclear risk	No information given.
Blinding of participants and personnel (performance bias) All outcomes	Low risk	Reported as double blind; participants were given a sham mask in the control condition.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Reported as double blind, but not clear whether outcome assessors were blinded.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Not specifically reported, but we assumed that all participants completed the trial.
Selective reporting (reporting bias)	Unclear risk	Trial was registered on the Chinese registry. Outcomes were not reported as per phase, and there were no inter-group statistics to determine differences. Retrospectively registered.
Other bias	Low risk	We did not identify any other sources of bias.

Jasemzadeh 2018

Study characteristics	
Methods	**Intervention assignment:** individually-randomised, parallel **Blinding:** open-label **Duration:** 2 months **Setting:** multiple health care sites, Iran
Participants	**No. of participants randomised:** 130 (intervention: 65, control: 65) **No. of participants completing:** 125 (intervention: 64, control: 61) **Age:** 18 to 35 years **% male:** 0 **Existing health condition:** no **Inclusion criteria:** singleton pregnancy, gestational age 12 to 20 weeks, age 18 to 35 years, healthy (no chronic conditions), consented to participate, communicable via SMS, able to speak fluent Persian, able to read. **Exclusion criteria:** not reported
Interventions	**Intervention:** SMS with information about air pollution, including data from an air pollution monitoring station in Naderi. The number of messages to participants increased as the air pollution levels increased. Weekly phone calls to check that participants were receiving the messages. **Control:** usual care
Outcomes	Perceived severity air pollution exposure, response efficacy, self-efficacy, air pollution protective behaviours
Notes	**Funding:** Vice Chancellor for research, Ahvaz Jundishapur University of Medical Sciences **Registration:** IRCT2016102810804N8

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants randomised by random numbers; unclear how the random numbers were generated.
Allocation concealment (selection bias)	Unclear risk	No information given.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Open-label
Blinding of outcome assessment (detection bias) All outcomes	High risk	Open-label, investigator not blinded

Jasemzadeh 2018 *(Continued)*

Incomplete outcome data (attrition bias) All outcomes	Low risk	Greater attrition in the standard care group (6%) compared to the intervention group (1%), but high level of completion in both groups.
Selective reporting (reporting bias)	Low risk	All outcomes were reported as planned in the protocol.
Other bias	Low risk	We did not identify any other sources of bias.

Langrish 2009

Study characteristics	
Methods	**Intervention assignment:** individually-randomised cross-over trial **Blinding:** open-label **Duration:** 24 hours **Setting:** Beijing, China
Participants	**No. of participants randomised:** 15 **No. of participants completing:** 15 **Age:** 20 to 45 years **% male:** 13 **Existing health condition:** no **Inclusion criteria:** non-smokers, healthy, not receiving medication, no other illnesses **Exclusion criteria:** current smokers, significant occupational exposure to air pollution, regular medication use (except oral contraceptive pill), inter-current illness
Interventions	**Intervention:** Dust respirator 8812 3M mask worn for 24 hours before the study start and for 24 hours of the duration of the study. Participants wore the mask all the time when outside and as much as possible indoors. On the study day, participants were asked to walk for 2 hours in a city centre location along the inner ring road in Beijing between 8 and 10am **Control:** participants followed the same route without a mask
Outcomes	Particulate measurements, physical activity, average heart rate, heart rate variability, blood pressure, symptom questionnaire (VAS)
Notes	**Funding:** British Heart Foundation **Trial registration:** NCT00809432

Risk of bias		
Bias	**Authors' judgement**	**Support for judgement**
Random sequence generation (selection bias)	Low risk	A random number generator was used to randomise participants.

Langrish 2009 *(Continued)*

Allocation concealment (selection bias)	Unclear risk	No information
Blinding of participants and personnel (performance bias) All outcomes	High risk	Open-label
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information
Incomplete outcome data (attrition bias) All outcomes	Low risk	Not specifically reported, but we assumed that all completed the trial.
Selective reporting (reporting bias)	Low risk	The protocol for the trial was found on the trial website.
Other bias	Low risk	We did not identify any other sources of bias.

Lyons 2016

Study characteristics	
Methods	**Intervention assignment:** non-randomised study. Intervention group formed by those signing up for alerts **Blinding:** open-label **Duration:** 2 years **Setting:** 4 general practices in Cardiff, Wales
Participants	**No. of participants recruited:** 1395 (intervention: 180; control: 1215) **No. of participants completing:** 1393 (intervention: 179; control: 1214) **Age:** 0 to 85+ years; modal age 65 to 74 years **% male:** intervention: 48, control: 52 **Existing health condition:** majority adults with asthma, COPD or coronary heart disease **Inclusion criteria:** Asthma, COPD, or CHD diagnosis, residing in an industrial area of south Wales, registered at 1 of 4 general practices **Exclusion criteria:** not reported
Interventions	**Intervention:** real-time AirAware alerts via text, email or pre-recorded voice, depending on participant preference. The alerts were automatically triggered based on pollution levels, and provided advice on change in air quality, self-care and healthy behaviour (based on COMEAP air quality index health advice). Messages were sent between 7am and 10pm, and when air quality was normal, an alert was sent. A maximum of 3 alerts per day were allowed, and only one alert was sent if the air pollution was normal. **Control:** normal care

Lyons 2016 *(Continued)*

Outcomes	Validity of alerts issued by the airAware system, effect of the intervention by incidence rate ratio of GP contacts, GP respiratory contacts, GP CHD contact, GP MH contact, prescribed medication, all admissions to hospital, ED admissions, respiratory ED admissions, CHD ED admissions, OP attendance, ED attendances
Notes	**Funding:** European Social Fund, additional support from Farr institute and Thematic Research Network for emergency and UNScheduled Trauma care (TRUST) **Trial registration:** not reported **Risk of bias assessment:** see Table 3

Mehiriz 2019

Study characteristics	
Methods	**Intervention assignment:** individually-randomised, parallel **Blinding:** not stated **Duration:** 1 day (one-off smog alert) **Setting:** Municipalities and community organisations of the City of Longueuil, Canada
Participants	**No. of participants randomised:** 1328 (intervention: 662, control: 666) **No. of participants completing:** 519 (intervention 268, control: 251) **Age:** > 85% 65 years and over **% male:** 25 **Existing health condition:** yes, as per inclusion criteria. Intervention: CVD 51%, lung disease 22%, diabetes 19.4%, kidney failure 4.9%, neurological conditions 7.8%. Control: CVD 52.9%, lung disease 22.5%, diabetes 20%, kidney failure 4.9%, neurological conditions 7.3% **Inclusion criteria:** 'vulnerable' individuals with at least one of the following characteristics: aged 65 years or older; having a heart or lung condition; or having diabetes, kidney failure, or a mental health or neurological disorder **Exclusion criteria:** not reported
Interventions	**Intervention:** Automated phone warning and advisory system that sends participants personalised smog alerts and advice to protect them from air pollution, as provided by the Air Health Quality index for Canada. The index was divided into 2 categories (moderate and high) as a trigger for alerts **Control:** usual care
Outcomes	Risk Perception; Adoption of Recommended Behaviours; health symptoms
Notes	**Funding:** Quebec Government's Fond Vert **Trial registration:** not reported
Risk of bias	

Mehiriz 2019 *(Continued)*

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	The random assignment was performed using STATA software and based on telephone numbers to preclude the risk of inter-group contamination (i.e. people with the same phone number were randomly assigned to the experimental or control).
Allocation concealment (selection bias)	Unclear risk	No information given.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Open-label
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information
Incomplete outcome data (attrition bias) All outcomes	High risk	Approximately 50% attrition in both groups.
Selective reporting (reporting bias)	Unclear risk	Could not find a protocol for the study, so it was not clear if the outcomes were reported as planned.
Other bias	Low risk	We did not identify any other sources of bias.

Morishita 2019

Study characteristics	
Methods	**Intervention assignment:** individually-randomised cross-over trial **Blinding:** "single blind" **Duration:** 2 weeks **Setting:** Ann Arbor, Michigan, USA
Participants	**No. of participants randomised:** 50 **No. of participants completing:** 50 **Age:** 19 to 64 years, mean age 36 (SD 14) years **% male:** 28 **Existing health condition:** no **Inclusion criteria:** non-smokers/non-smoking household, 18 to 65 years, without CVD, or risk factors (hypertension, diabetes or hyperlipidaemia) **Exclusion criteria:** medication that could affect BP or responsiveness to exposure, e.g. cholesterol- or BP-lowing medication, fish oil, anti-oxidant, folate

Morishita 2019 *(Continued)*

Interventions	**Intervention:** On Monday of each week, participants rested seated for 2 hours in a clean indoor room wearing an N95 mask. Tuesday to Friday from 8 to 10am, participants were exposed to a near-road location. **Control:** same as intervention but without a mask
Outcomes	Cardiovascular: brachial BP, aortic haemodynamics, heart rate variation metrics Environmental: temperature, PM 2.5, black carbon, particle count, sound level, relative humidity
Notes	**Funding:** National Institutes of Environmental Health (2R01 ES015146) and an investigator-initiated grant from author Robert Brook **Trial Registration:** not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Described as randomised, but no further information given.
Allocation concealment (selection bias)	Unclear risk	No information given.
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Stated to be single-blind, but unclear who was blinded.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Stated to be single-blind, but unclear who was blinded.
Incomplete outcome data (attrition bias) All outcomes	Unclear risk	This was not reported, but we assumed that all completed the trial.
Selective reporting (reporting bias)	Unclear risk	No registry information or protocol. Results were not reported from phase 1 or 2 separately. Washout probably not needed in this case.
Other bias	Low risk	We did not identify any other sources of bias.

Shi 2017

Study characteristics

Methods	**Intervention assignment:** individually-randomised cross-over trial **Blinding:** open-label **Duration:** 4 weeks **Setting:** Shanghai, China
Participants	**No. of participants randomised:** 30

Shi 2017 *(Continued)*

	No. of participants completing: 24 **Age:** 18 to 35 years; mean 23 (SD 2) years **% male:** 54 **Existing health condition:** no **Inclusion criteria:** healthy adults; no smoking history or alcohol addiction; no chronic conditions or cardiopulmonary diseases, including asthma or rhinitis; no recent infections **Exclusion criteria:** current smokers, chronic drug use (cardiovascular or respiratory)
Interventions	**Intervention:** Participants wore a 8219V disposable respirator mask for 48 hours all the time they were outside, including a 1-hour walk on a fixed route exposed to traffic, and also as much as they could indoors. **Control:** as for intervention, but without a mask
Outcomes	Heart rate variability, ambulatory blood pressure, circulating biomarkers (endothelin-1, P-selectin, vascular cell adhesion molecule-1, fibrinogen, von Willebrand factor), environmental data (PM 2.5), comfort.
Notes	**Funding:** Shanghai 3 year Public Health Action Plan **Trial registration:** NCT02238028

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Reported as randomised but no further information given about generation of the randomisation sequence.
Allocation concealment (selection bias)	Unclear risk	No further information given.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Not possible to blind participants or personnel due to the nature of the intervention, and a sham mask was not used in the control condition.
Blinding of outcome assessment (detection bias) All outcomes	Low risk	Outcome assessor was blinded. The majority of outcomes were objectively measured and not self-reported by participants.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Six out of 30 participants did not complete the cross-over trial, but dropout appeared unrelated to the intervention or outcomes.
Selective reporting (reporting bias)	Low risk	Trial registration identified and further details of outcomes assessed. Outcomes were reported as planned.
Other bias	Low risk	We did not identify any other sources of bias.

Zhang 2019

Study characteristics

Zhang 2019 *(Continued)*

Methods	**Intervention assignment:** individually-randomised cross-over trial **Blinding:** open-label **Duration:** 2 weeks **Setting:** Beijing, China
Participants	**No. of participants randomised:** 39 **No. of participants completing:** 39 **Age:** 21 and over; mean 21.6 (SD 1.7) years **% male:** 54 **Existing health condition:** no **Inclusion criteria:** healthy young adults, non-smokers, not taking any medication, consent to participate in the study **Exclusion criteria:** not reported
Interventions	**Intervention:** participants wearing a 3M respirator (9002V) mask travelled on the underground subway line 10 from 9am to 1pm without transferring lines on 5 non-consecutive days; ECG and BP was monitored throughout the whole riding period. **Control:** as for intervention, but without a mask
Outcomes	ECG measurement, ambulatory BP, metabolic outputs from urine sample, PM exposure
Notes	**Funding:** National Key R&D Program of China (2017YFC0211600, 2017YFC0211606), National Natural Science Foundation of China (81571130090) **Trial registration:** not reported

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Study reported as randomised, but no further information given.
Allocation concealment (selection bias)	Unclear risk	No information given.
Blinding of participants and personnel (performance bias) All outcomes	High risk	Not possible to blind participants or personnel due to nature of the intervention.
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	No information given.
Incomplete outcome data (attrition bias) All outcomes	Low risk	Only one participant was excluded from the study.

Zhang 2019 *(Continued)*

Selective reporting (reporting bias)	Unclear risk	Could not find a protocol for the study, so it was not clear if the outcomes were reported as planned.
Other bias	Low risk	We did not identify any other sources of bias.

BP: blood pressure; CHD: coronary heart disease; COMEAP: Committee on the Medical Effects of Air Pollutants; COPD: chronic obstructive pulmonary disease; CVD: cardiovascular disease; ECG: electrocardiogram; ED: emergency department; GP: general practice/practitioner; MH: mental health; OP: outpatient; PEFR: peak expiratory flow rate; PM: particulate matter; SD: standard deviation; SE: standard error; SMS: short message service ('text message'); TNFa: tumour necrosis factor alpha; VAS: visual analogue scale

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Anurekha 2015	Ineligible study design
Basavaraju 2014	Ineligible study design
Chen 2018	Ineligible study design
ChiCTR1900026757	Ineligible intervention
Dorevitch 2008	Ineligible intervention
Habre 2018	Ineligible study design
Ho 2018	Ineligible study design
Honkoop 2017	Ineligible intervention
Jarjour 2013	Ineligible study design
Jia 2017	Ineligible study design
Johnston 2018	Ineligible study design
Koh 2018	Ineligible study design
Kumar 2018	Ineligible study design
Laumbach 2019	Ineligible study design
Licskai 2013	Ineligible study design
Lin 2011	Ineligible intervention
Loh 2002	Ineligible study design
Lovinsky Desir 2018	Ineligible study design
Lucas 2015	Ineligible study design
McCreanor 2007	Ineligible study design: this study does not test a viable alternative route to get to the same place, rather two separate walking areas.

Study	Reason for exclusion
NCT03083067	Ineligible intervention
Nethery 2014	Ineligible study design
NTR7200	Ineligible intervention
Padovan 2017	Ineligible study design
Patel 2016	Ineligible study design
Quinn 2018	Ineligible intervention
Saberian 2017	Ineligible study design
Sinharay 2018	Ineligible study design: this study does not test a viable alternative route to get to the same place, rather two separate walking areas
Steventon 2015	Ineligible intervention. The Healthy Outlook app focusses on cold weather forecasting, not air pollution
Weichenthal 2014	Ineligible study design
Wheeler 2008	Ineligible intervention
Wheeler 2011	Ineligible intervention
Yao 2013	Ineligible study design

Characteristics of ongoing studies *[ordered by study ID]*

Kouis 2019

Study name	The LIFE MEDEA Asthma study
Methods	Parallel-group randomised controlled trial to investigate impact of behavioural interventions during desert dust storms
Participants	Children aged 6 to 11 years
Interventions	1. Outdoor intervention 2. Outdoor and indoor intervention 3. No intervention
Outcomes	Asthma control test, medication usage, spirometry, fractional expired nitric oxide
Starting date	September 2018
Contact information	panagiotis.kouis@cut.ac.cy
Notes	Funding: European Union LIFE project MEDEA

NCT02729129	
Study name	Face Masks to Reduce the Adverse Effects of Diesel Exhaust Inhalation (FM-RADIO)
Methods	Cross-over randomised controlled trial investigating filtered face mask
Participants	Healthy males aged 18 to 60 years
Interventions	1. Diesel exhaust exposure with filtered face mask 2. Diesel exhaust exposure with sham mask
Outcomes	Vascular vasomotor function, fibrinolytic function, blood pressure, heart rate variability
Starting date	2014
Contact information	Jenny A Bosson, MD, PhDUmeå University
Notes	Despite being listed as "completed", no publication identified and no study results posted

ADDITIONAL TABLES

Table 1. Glossary

Term	Definition
Ambient air	The air (or concentration of a pollutant) that occurs at a particular time and place outside of built structures. Often used interchangeably with 'outdoor air' (DEFRA 2019b).
Bias	A systematic error in a research study which leads to one outcome or answer being made more likely than the alternative; e.g. if the method of recruiting people to the study results in more unwell people receiving the intervention than the control, it may lead to the benefits of the intervention being diluted.
Bronchoconstriction	The narrowing of the airways in the lungs due to tightening of the muscles that surround the airway. Typically leads to shortness of breath, coughing and wheezing.
Chronic	Long-term or constantly recurring.
Claustrophobic	Having an extreme or irrational fear of confined places.
Coagulation activation	The activation of a process leading to the blood changing to a solid or semi-solid state.
Cohort study	A study that follows a group of people over time to see how certain risk factors (e.g. exposure to air pollution) affects their health.
Comparator	The thing to which an intervention is compared. It may be an alternative intervention intended to have a similar effect, standard care or a placebo.
Correlation	A relationship or connection between two or more things; e.g. in humans, height and weight are correlated (on average, as one increases, the other increases).
Deviations from intended interventions	Occurs when a participant in a study does not receive the intervention as planned; e.g. a participant may not take a medicine as prescribed or may take an additional medicine that was not part of the study plan.

Table 1. Glossary *(Continued)*

Dichotomous	An outcome that can take one of two options, e.g. dead or alive, admitted to hospital or not admitted to hospital, cured or not cured.
Forest plot	A graph which displays the results of a number of different studies that are all asking the same question. May also include a diamond-shape at the bottom which combines the results from all the studies.
Generic inverse variance	A statistical method by which results from different studies can be combined in a meta-analysis. Allows greater emphasis or 'weight' to be given to studies that provide more information.
Heterogeneity	Relates to variation or diversity. For example, heterogeneity between study populations means the people recruited into each study differed from one another.
Interventions	Something that aims to make a change and can be tested through research. May be anything from a new drug through to an information leaflet for patients.
Meta-analysis	Combining the results of different studies statistically to give an overall, or 'average' result. Can be presented in a forest plot.
Observational studies	A study in which researchers do not attempt to make a change or introduce an intervention, but rather observe the course of events.
Oxides of nitrogen (NO_X)	Nitrogen oxides result from combustion processes. Nitric oxide is rapidly converted to nitrogen dioxide in the atmosphere. Nitrogen dioxide impacts on the environment and health. It can cause respiratory irritation which may cause asthma breathing difficulties, and increase susceptibility of infections. Nitrogen dioxide reacts with sunlight and hydrocarbons to produce, for example, ozone. Nitrogen dioxide can also be converted in the air to acidic gases that contribute to formation of acid rain (DEFRA 2019b).
Ozone	A secondary pollutant generated when nitrogen dioxide, hydrocarbons and sunlight react together. Nitrogen dioxide acts as a source of ozone, but nitric oxide destroys ozone. For this reason ozone concentrations are lower in urban areas (where nitric oxide is emitted from vehicles) compared to rural areas. Ambient concentrations of ozone are usually higher in rural areas, especially when the weather is hot, still and sunny, which can result in summer 'smog' (DEFRA 2019b).
Particulate matter (PM)	Refers to a wide range of particle sizes and different components of chemicals in the air. Primary components are emitted directly into the atmosphere, and secondary components are formed within the atmosphere as a result of chemical reactions. Small particles that can be inhaled in the deepest part of the lung are of particular concern to public health. Air Quality Objectives are in place for the protection of human health for PM_{10} and $PM_{2.5}$; these are particles of less than 10 and 2.5 micrometres in diameter, respectively (DEFRA 2019b).
Placebo	A substance or procedure that has no therapeutic benefit. Often used a control when testing a new drug or intervention.
Pooling	In the context of this protocol pooling refers to the combining of results from multiple different studies.
Prognostic factor	Something which can be measured that helps predict the course of a disease; e.g. for some conditions age may be a prognostic factor.
Randomised controlled trial (RCT)	A study in which researchers allocate participants at random to either receiving one treatment or intervention, or another. In many cases, a new treatment or intervention will be compared to standard care, or a placebo. Sometimes two (or more) alternative treatment options will be compared.
Sulfur dioxide	An acidic and corrosive gas formed by oxidation of sulfur found in fossil fuel (COMEAP 2011). When combined with water vapour in the atmosphere it produces acid rain. Sulfur dioxide is associated with asthma and chronic bronchitis (DEFRA 2019b).

Table 2. Description and prevalence of chronic respiratory conditions

Chronic respiratory disease	Description	Prevalence	Reference
Alpha1-antitrypsin deficiency	A rare genetic (inherited) disorder which primarily affects the lungs and the liver. People with this condition lack an enzyme that helps to protect the lungs from damage and so are particularly vulnerable to air pollution, as well as smoking, dust and fumes.	Approximately 25,000 people in the UK have the condition, although many have not been diagnosed.	British Lung Foundation 2017b
Asthma	Airways carrying air in and out of the lungs become narrow, and the airway lining becomes inflamed causing sputum or phlegm build-up. This in turn causes further narrowing of the airways, making it difficult to get air in and out of the lungs.	Nearly 339 million people affected, highest prevalence (approximately 20%) is in Australasia, parts of Europe and North America, and parts of Latin America. Lowest prevalence (approximately 5%) is observed in the Indian subcontinent, Asia-Pacific, Eastern Mediterranean, and Northern and Eastern Europe.	Global Asthma Report 2018 British Lung Foundation 2019a; WHO (GARD)
Bronchiectasis	Airways that become scarred and inflamed with thick mucus. The build-up of mucus can cause bacterial infections resulting in chest infections.	Heterogeneous global distribution. In the UK it was estimated that the prevalence in women was 556/100,000 and 486/100,000 in 2013.	Quint 2016
Chronic Obstructive Pulmonary Disease (COPD)	Group of lung conditions including chronic bronchitis and emphysema. Both conditions make it difficult to get air in and out of the lungs due to narrowing and inflammation, or damage to alveoli, causing loss of elasticity and making it difficult to breathe.	251 million cases globally in 2015 (Global Burden of Disease 2015).	British Lung Foundation 2019b; Global Burden of Disease 2015; WHO (GARD)
Cystic fibrosis (CF)	CF is a genetic condition that occurs as a result of an inherited faulty CF gene. It causes a build-up of thick mucus in the lungs, digestive system and other organs. CF can cause symptoms that affect the entire body. For example, lung function is reduced and people with CF are more susceptible to infections and cross-infection. People with CF may also encounter other respiratory conditions including asthma, aspiration, allergies and in some cases a collapsed lobe or pneumothorax.	Prevalence of CF globally is varied. It affects around 100,000 people world wide. In the European Union, 1 in 2000 to 3000 new born babies are affected by CF. In the USA, the incidence is 1 in 3500 births. Existing evidence shows that in Asia the prevalence of CF is rare, although it is severely under-diagnosed. In the UK, nearly 10,500 people have CF. 1 in every 2500 babies are born with CF.	Cystic Fibrosis Trust 2019; WHO 2019c
Hypersensitivity pneumonitis (extrinsic allergic alveolitis)	Refers to a condition in which the lungs become hypersensitive and develop an immune response, causing inflammation in the lung tissue, also known as pneumonitis. Long-term hypersensitivity results in breathlessness over many years as a result of permanent scarring of the lungs.	Prevalence is varied: in the US prevalence has been estimated from 4% to 15% of all ILDs, whereas in Denmak the prevalence was 7%, and in Brazil, 15%.	Galeazzo 2017
Lung cancer	Occurs when abnormal cells divide in an uncontrolled way leading to formation of a tumour in	2.09 million cases of lung cancer have been reported worldwide.	British Lung Foundation 2017c;

Table 2. Description and prevalence of chronic respiratory conditions *(Continued)*

	the lung, leading to symptoms of cough, breathlessness and weight loss.The most common form of lung cancer is non-small-cell lung cancer. Small-cell lung cancer is less common but spreads more quickly.	In the UK there were 47,235 new cases of lung cancer from 2014 to 2016.	Cancer Research UK 2019
Pulmonary fibrosis	IPF occurs as a result of scarring of lungs, reducing breathing capacity. Scarring of the lung tissue reduces lung elasticity and limits air intake and inflation of the lungs.	In the UK 32,500 people had the condition as reported in 2012.	British Lung Foundation 2019c; British Lung Foundation 2019d
Chronic pleural diseases	Refers to the membrane separating the lungs from the chest wall; e.g. pleural effusion, which occurs as a result of increased fluid formation and/or reduced fluid resorption	Affects over 3000 people per million population each year in the UK	British Thoracic Society 2010
Pneumoconiosis (e.g. silicosis)	Also known as occupational ILD, this group of conditions is caused by dust in the workplace (e.g. mining, processing, manufacturing), leading to scarring of the lungs. It can cause shortness of breath, persistent cough, tiredness, difficulty in breathing, chest pain and coughing up phlegm.	Silicosis and other pneumoconioses may affect up to 30%, or even 50%, of workers in primary industries, and in high-risk sectors in developing countries, but the condition is under-diagnosed and under-reported. The incidence of TB increases with severity of silicosis, for example, and the WHO estimated 30,000 deaths occur every year due to pneumoconiosis.	British Lung Foundation 2019e; WHO 2007
Pulmonary eosinophilia	Characterised by an increased number of eosinophils in the pulmonary airways and parenchyma, and can be caused by exposure to parasites, medications, history of asthma and allergy.	Rare condition, less than 2.5% of ILD cases reported in Europe.	Campos 2009; Thomeer 2001
Pulmonary heart disease and diseases of pulmonary circulation (e.g. pulmonary hypertension, cor pulmonale)	Refers to altered structure or function of the right ventricle occurring in association with abnormal respiratory function. For example, PH is an increase in pressure in the arteries of the lung.	Prevalence of PAH ranges from 5 to 52 cases per million adults in Scotland and France. Overall prevalence of PH varies from 0.3 to 6%.	Forfia 2013; Humbert 2006; Peacock 2007
Sarcoidosis	Refers to a condition in which the cells in any part of the body form granulomas (small lumps), but more common in the lungs and lymph glands.	Between 2008 and 2012, the prevalence of sarcoidosis increased by 8% in the UK. African Americans and Northern Europeans are most affected. A Swedish study reported a prevalence of 152 to 215 per 100,000 (depending on requirement of a visit by a specialist or just one visit).	Arkema 2016; British Lung Foundation 2019f
Sleep apnoea syndrome	This condition causes frequent temporary cessation of breathing during sleep, and is accompanied by loud snoring. The pauses in breathing lead to the oxygen supply to the body being cut off for a couple of seconds and carbon dioxide not being removed. As a result, the brain briefly wakes up the person, allowing the air-	The prevalence of sleep apnoea in the UK is approximately 1.5 million, with 330,000 being treated. However, evidence suggests that 85% of people with OSA are under-diagnosed and are not treated. The prevalence of OSA is increas-	British Lung Foundation 2015; WHO (GARD); WHO 2019a

Table 2. Description and prevalence of chronic respiratory conditions *(Continued)*

	ways to re-open and re-start breathing. The condition can cause lack of sleep; and during the day can cause sleepiness, reduced concentration or headaches.
	ing, due to a rise in prevalence of obesity and the increasing age of the population.

ILD: interstitial lung disease; IPF: idiopathic pulmonary fibrosis; OSA: obstructive sleep apnoea; PAH: pulmonary arterial hypertension; PH: pulmonary hypertension; TB tuberculosis; WHO: World Health Organization

Table 3. Risk of bias assessment for Lyons 2016

Domain	Judgement	Explanation
Overall risk of bias	Serious risk	Issues included: likely residual confounding; potential deviations from the intended intervention; multiple measurements within an outcome domain; knowledge of intervention assignment likely impacting outcomes; and lack of a protocol or study registration.
Bias due to confounding	Serious risk	The authors adjusted their regression analyses for age, gender, deprivation index and smoking status, but acknowledged that residual confounding likely remained.
Bias in selection of participants into the study	Low risk	Prospective sample drawn from population of interest; all eligible participants were identified from electronic medical records and invited to participate.
Bias in classification of interventions	Low risk	Intervention and control groups clearly defined at start of intervention and unaffected by outcomes.
Bias due to deviations from the intended interventions	Unclear risk	We could not make a judgement about this domain due to lack of information in the study report.
Bias due to missing data	Low risk	Study used routinely collected health care usage data for both intervention and control over the same time period. Outcome data available for over 99% of participants.
Bias in measurement of outcomes	Serious risk	Participants decided whether to access health care and were aware of assignment. It is not possible to separate the effects of knowledge of assignment from the effect of the intervention itself (air pollution alerts).
Bias in selection of reported results	Serious risk	Multiple measures of health care usage reported without a defined primary outcome and we were unable to identify a prospective study registration or published protocol.

Lyons 2016 reported one outcome of interest: health care usage. The above risk of bias judgements relate to this outcome. Risk of bias assessed using the ROBINS-I tool (Sterne 2016).

Table 4. Face mask interventions

Study ID	Participants	Setting	Design	Intervention	Control	Outcomes of interest reported	Key results
Guan 2018	N = 15 healthy adults	Beijing, China	Double-blind randomised cross-over trial	2-hour walk along busy road wearing N95 face mask	2-hour walk along busy road wearing sham face mask	Measures of air pollution exposure (exhaled cytokines and NO, urinary MDA, PWA)	Short-term greater increase in markers of airway inflammation (eNO, IL-1α and IL-1β) in controls. No difference in markers for oxidative stress (urinary MDA) or endothelial dysfunction (PWA).
Langrish 2009	N = 15 healthy adults	Beijing, China	Open-label randomised cross-over trial	Use of Dust Respirator 8812 face mask for 24 hours prior to study day and on study day, including 2-hour walk along busy road	2-hour walk along busy road on study day as per intervention. No face mask	Particulate measurements, physical activity, average HR, HR variability, BP, symptom questionnaire (VAS), acceptability.	Increased HR variability and LF power over 24 hours and lower SBP during 2-hour walk in intervention condition. No other differences noted. The mask was generally well tolerated.
Morishita 2019	N = 50 healthy adults	USA	Open-label randomised cross-over trial	Multiple 2-hour near-roadway exposures during 1 week wearing N95 face mask	Multiple 2-hour near-roadway exposures during 1 week. No face mask	Particulate measurements, BP, aortic haemodynamics, HR variability, endothelial function	Small improvements in aortic haemodynamics associated with mask use. Other outcomes unaffected.
Shi 2017	N = 30 healthy adults	Shanghai, China	Open-label randomised cross-over trial	8219V mask use for 48 hours both indoors and outdoors, including a 1-hour near-road exposure	Normal activities for 48 hours, including 1-hour near-road exposure. No face mask	Particulate measurements (PM 2.5), HR variability, BP, circulating biomarkers (endothelin-1, P-selectin, vascular cell adhesion molecule-1, fibrinogen, von Willebrand factor), comfort.	Short-term improved HR variability and decreased BP. No other differences noted. Mask tolerance generally acceptable.
Zhang 2019	N = 39 healthy adults	Beijing, China	Open-label randomised cross-over trial	4-hour journey on underground subway wearing 3M 9002V face mask connected to a pump with an efficient filter	4 hours on underground subway. No face mask	Particulate measurements, HR and HR variability, BP, urine metabolites	Results presented separately for men and women. Some effect on HR variability seen in both genders, but more in men. Urine metabolites indicated greater oxidative damage to DNA and cardiovascu-

Table 4. Face mask interventions *(Continued)*

							lar dysregulation in control condition.

Abbreviations: BP: blood pressure; DNA: deoxyribonucleic acid; eNO: exhaled nitric oxide; HR: heart rate; IL-1a: interleukin 1 alpha; IL-1b: interleukin 1 beta; LF: low frequency; MDA: urinary creatinine-corrected malondialdehyde; NO: nitric oxide; PM 2.5: particulate matter with aerodynamic diameter less than 2.5 µg; PWA: pulse wave analysis; SBP: systolic blood pressure; VAS: visual analogue scale

Table 5. Air quality alert/education interventions

Study ID	Participants	Setting	Design	Intervention	Control	Outcomes of interest reported	Key results
Araban 2017	N = 110 pregnant women	Tehran, Iran	Open-label individually-randomised trial	Multi-component intervention to minimise air pollution exposure including motivational interviewing, a booklet and daily SMS	Usual maternity care	Stages of behavioural changes for prevention of exposure to air pollution, self-efficacy, decisional balance, preventative behaviour towards air pollution exposure	Increased stages of change, self-efficacy, perceived benefits and practice in intervention group
D'Antoni 2019	N = 58 "at-risk" adults and N = 167 general population participants	London, UK	Individually-randomised trial, blinding not stated	UK Air Quality Index (DAQI) alerts with additional messages targeting specific psychological factors	UK Air Quality Index (DAQI) alerts	Intentions to adhere to recommendations in high levels of air pollution, behaviour change and action planning, behaviour change in response to real moderate air pollution, mediators of behaviour change and format of information	More respondents in the intervention group considered making permanent changes to their daily travel route, exercise location or exercise time. Of those with lung conditions, more indicated they had used their preventer inhaler in response to the real air pollution alert.
Jasemzadeh 2018	N = 130 pregnant women	Iran	Open-label individually-randomised trial	SMS air pollution alerts encouraging protective behaviours and weekly telephone calls to ensure receiving alerts	Usual maternity care	Perceived severity air pollution exposure, response efficacy, self-efficacy, air pollution protective behaviours	Perceived severity, response efficacy, and self-efficacy and protective behaviours were higher in the intervention group.
Lyons 2016	N =1395 majority adults with asthma, COPD or coro-	South Wales, UK	Non-randomised study comparing	AirAware air pollution alert system	Usual care	Alert accuracy and healthcare utilisation	Intervention was associated with a 4-fold increase in admissions for respiratory conditions and near doubling of

Table 5. Air quality alert/education interventions *(Continued)*

	nary heart disease		those who signed up to AirAware alerts to those who did not				emergency department attendance
Mehiriz 2019	N = 1328 adults with heart or lung condition, diabetes, kidney failure, or neurological disorder/mental health issue	Canada	Individually randomised trial, blinding not stated	Automated phone smog warnings encouraging protective behaviour change	Usual care	Awareness, knowledge of protective behaviours, perception of risk, adoption of recommended behaviours, impact on physical activity and inhaler proximity, symptoms	Alerts increased awareness of a smog episode and improved adherence to protective behaviours, but did not effect other outcomes

COPD: chronic obstructive pulmonary disease; DAQI: daily air quality index; N: number of people; SMS: short message service

Table 6. Altered transport route interventions

Study ID	Participants	Setting	Design	Intervention	Control	Outcomes of interest reported	Key results
Cole-Hunter 2013	N = 35 healthy adults	Australia	Non-randomised cross-over trial	Return bicycle commute using a lower proximity to traffic route	Return bicycle commute using typical higher proximity to traffic route	Particulate measurements, respiratory symptoms, lung function and sputum inflammatory cell analysis	Lower-proximity route associated with reduced particular concentration and nasopharyngeal irritation. Other outcomes not affected.

N: number of people

Table 7. Primary outcome: measures of air pollution exposure

Study ID	Heart rate	Heart rate variability	Blood pressure mmHg	Urine metabolites	Airway inflammation	Circulating biomarkers
Cole-Hunter 2013	–	–	–	–	**PEFR:** no difference at any time point between high- and low-exposure routes. Mean intra-individual difference between PEFR was 20.3 (SD 11.3) L/min **Sputum cell counts:** no difference at any time point between high- and low-exposure routes.	–
Guan 2018	–	–	–	Urinary creatinine corrected MDA: no difference between conditions	**Exhaled TNF and interleukins:** no difference in biomarkers between mask vs sham mask during the walk **Exhaled NO:** concentration of eNO increased ($P < 0.005$) after the 2-hour walk in all participants, but increase in the mask group was 38.3% less than the sham group ($P < 0.005$).	–
Langrish 2009	No differences over 24 hours between conditions.	Increased variability in mask condition (SDNN: 65.6 (SD 11.5) vs 61.2 (SD 1.4) ms, $P < 0.05$; LF-power: 919 (SD 352) vs 816 (SD 340) ms^2, $P<0.05$)	No differences over 24 hours between conditions. Lower systolic BP during 2-hour walk in intervention condition (114 (SD 10) vs 121 (SD 11) mmHg, $P < 0.01$)	–	–	–
Morishita 2019	–	–	No difference between conditions. No effect modification of wearing mask while near roadway on the associations of BC and PC exposures with aortic haemodynamic changes.	–	–	–
Shi 2017	–	Increased variability in mask condition (SDNN 177.5 (SD 29.9) vs 173.2 (SD 40.1)	Intervention: mean systolic BP 107.3 (SD 8) and diastolic 70 (SD 5)	–	–	Circulating fibrinogen, P-selectin, VCAM-1, Endothelin-1 and

Table 7. Primary outcome: measures of air pollution exposure *(Continued)*

		ms, P = 0.467; LF-power: 899.4 (SD 601.3) vs 838.5 (SD 562.4) ms^2,P = 0.250)	Control: mean systolic BP 109 (SD 7.4) and diastolic 70.8 (SD 4.8)			vWF lower in mask condition, but results uncertain.
Zhang 2019	–	–	Intervention: mean systolic BP 116.1 (SD 6.8) and diastolic BP 74.3 (SD 12.5) Control: mean systolic BP 117.15 (SD 6.3) and diastolic BP 74.4 (SD 5.1)	–	–	–

AP: augmentation pressure; BC: black carbon; BP: blood pressure LF-power: low frequency power; MDA: malondialdehyde; mmHg: millimetres of mercury; ms: milliseconds; NO: nitrous oxide; PC: particulate count; PEFR: peak expiratory flow rate; PP: pulse pressure; SD: standard deviation; SDNN: standard deviation of NN intervals; TNF: tumour necrosis factor; VCAM-1: vascular cell adhesion protein-1; vWF: Von Willebrand factor

Table 8. Primary outcome: hospital admissions/health care access

Study ID	Hospital admissions - all cause IRR (95% CI)	Relevant emergency admissions IRR (95% CI)	Respiratory emergency admissions IRR (95% CI)	Outpatient attendances IRR (95% CI)	Emergency attendances IRR (95% CI)	GP respiratory contacts IRR (95% CI)	GP relevant contacts IRR (95% CI)	Emergency medical visit [a]	Accessed health system services OR (95% CI)
Lyons 2016	0.82 (0.58 to 1.14)	2.04 (1.06 to 3.93)	3.97 (1.59 to 9.93)	1.01 (0.83 to 1.25)	1.89 (1.34 to 2.68)	1.04 (0.96 to 1.13)	1.04 (0.98 to 1.11)	-	-
D'Antoni 2019	-	-	-	-	-	-	-	ARI: 1.67 (0.63 to 2.70) ARC: 2.86 (1.50 to 4.21) GPI: 1.35 (0.68 to 2.01) GPC: 1.29 (0.68 to 1.91)	-
Mehiriz 2019	-	-	-	-	-	-	-	-	1.03 (0.51 to 2.12)

[a]Participants were asked if they had made an unplanned emergency medical visit due to air pollution in the last 4 weeks. Responses were measured from 1 = strongly disagree to 9 = strongly agree. Mean result and confidence interval for each of the 4 groups presented.
ARC: at-risk control; ARI: at-risk intervention; CI: confidence interval; GP: general practice/practitioner; GPC: general population control; GPI: general population intervention; IRR: incidence rate ratio; OR: odds ratio

Table 9. Secondary outcome: adherence to intervention

Study ID	Tolerance of mask	Action taken to reduce exposure	Air quality checked before outdoor activities	Exercise stopped due to receiving alerts	Considered a change to travel route or exercise routine	Self-efficacy	Keeping medication to hand	Stayed indoors	Physical activity	Patient preference
Araban 2017	–	Intervention: 19.4 (1.75)	–	–	–	–	–	–	–	–

Table 9. Secondary outcome: adherence to intervention *(Continued)*

		Control: 10.6 (2.1)[a]								
Cole-Hunter 2013	–	–	–	–	–	–	–	–	–	66% of participants preferred the low air pollution route
D'Antoni 2019	–	ARI: 3.65 (2.21 to 5.36) ARC: 4.29 (1.98 to 6.49) GPI: 4.25 (3.38 to 5.10) GPC: 3.67 (2.68 to 4.65)[b]	ARI: 4.37 (2.85 to 5.97) ARC: 3.79 (1.77 to 5.63) GPI: 3.51 (2.83 to 4.19) GPC: 3.18 (2.46 to 3.88)[b]	ARI: 1.17 (0.4 to 1.89) ARC: 2.14 (1.20 to 3.09) GPI: 1.59 (1.12 to 2.05) GPC: 1.74 (1.31 to 2.16)[c]	ARI: 58% ARC: 43% GPI: 54% GPC: 30%[d]	–	–	–	ARI: 5.18 (4.15 to 6.09) ARC: 5.12 (3.93 to 6.09) GPI: 5.76 (5.22 to 6.25) GPC: 5.85 (5.34 to 6.34)[e]	–
Jasemzadeh 2018	–	Intervention: 55.80 (8.29) Control: 53.17 (7.34)[f]	–	–	–	–	–	–	–	–
Langrish 2009	24.8% (16.2 to 33.3%)[g]	–	–	–	–	–	–	–	–	–
Mehiriz 2019	–	–	–	–	–	–	OR 2.15 (1.06 to 4.37)[h]	OR 2.03 (1.28 to 3.24)[i]	OR 0.59 (0.25 to 1.38)[j]	–
Shi 2017	Mean 5 to 6 out of 10[k]	–	–	–	–	–	–	–	–	–

[a]Mean and SD. Total scores ranged from 5 to 20, with higher values indicating more preventive behaviour
[b]Mean and 95% CI. Measures: from 1 = not at all to 9 = all of the time
[c]Mean and 95% CI. Measured from 1 = strongly disagree to 9 = strongly agree
[d]Percentage of participants in each group answering yes (unsure/no answer excluded from analysis)
[e]Mean and 95% CI. How physically active were you in the last week? 1 = not at all, to 7 = > 150 min

[f]Mean and SD. Scored from 15 to 75 with higher score = more protective behaviours
[g]Mean and 95% CI (intervention group only). 0% = completely tolerable, 100% = intolerable
[h]OR and 95% CI. Frequency of keeping medication on him/herself; intervention vs control
[i]OR and 95% CI. Stayed indoors more than usual after smog warning; intervention vs control
[j]OR and 95% CI. Made physical efforts after smog warning; intervention vs control
[k]Scale from 0 to 10 with 0 = the worst fit/comfort and 10 = best fit/comfort
Abbreviations: ARC: at-risk control; ARI: at-risk intervention; CI: confidence interval; GP: general practice/practitioner; GPC: general population control; GPI: general population intervention; IRR: incidence rate ratio; OR: odds ratio

Table 10. Secondary outcome: symptoms or well-being

Study ID	Nasal/throat irritation[a]	Acute respiratory symptoms	Difficulty breathing[b]	Smog-related symptoms[c]
Cole-Hunter 2013	Lower pollution route: 1.5 (0.3) Higher pollution route: 1.9 (0.2)	"All other specific acute respiratory symptoms were not significantly different: P > 0.10"	–	–
Langrish 2009	–	–	Intervention: 3.8 (8.10) Control: 0.67 (0.9)	–
Mehiriz 2019	–	–	–	1.05 (0.71 to 1.54)

[a]Mean and standard deviation. 1 = very low, 5 = very high.
[b]Mean and standard deviation. Visual analogue scale 0 to 100, lower = better
[c]Odds ratio and 95% confidence interval (CI). Suffered smog-related symptoms. Intervention vs control

Table 11. Direction of effect summary

Study ID	Measures of air pollution	Acute exacerbation of respiratory condition	Health care usage	Quality of life	Serious adverse events	Adherence/ behaviour change	All adverse events	Anxiety	Symptoms
Araban 2017 (1)	–	–	–	–	–	↑	–	–	–
Cole-Hunter 2013 (2)	↔ ↔	–	–	–	–	↑	–	–	↑ ↔
D'Antoni 2019 (3)	–	–	↔	–	–	↔ ↔ ↔ ↔ ↑	–	–	–
Guan 2018 (4)	↔ ↔ ↔ ↑	–	–	–	–	–	–	–	–
Jasemzadeh 2018 (5)	–	–	–	–	–	↔	–	–	–
Langrish 2009 (6)	↔ ↔ ↑ ↑	–	–	–	–	–	–	–	↓
Lyons 2016 (7)	–	–	↔ ↔ ↔ ↓ ↓ ↓	–	–	–	–	–	–
Mehiriz 2019 (8)	–	–	↔	–	–	↔ ↔ ↔	–	–	↔
Morishita 2019 (9)	↔	–	–	–	–	–	–	–	–
Shi 2017 (10)	↑ ↑ ↔ ↔ ↔	–	–	–	–	–	–	–	–

Table 11. Direction of effect summary *(Continued)*

Zhang 2019 (11)	↔	–	–	–	–	–	–	–	–

Each arrow reflects a separate outcome measured within this domain
↔ little to no difference between intervention and control
↑ outcome improved with intervention compared to control
↓ outcome worsened with intervention compared to control
– not reported
Numbers refer to the intervention and comparator in each study:
1. Education and motivational interview
2. Cycle route with low proximity to traffic verus high traffic proximity
3. Air quality alerts with additional messaging versus air quality alerts alone
4. Mask versus sham mask
5. Air quality alerts versus usual care
6. Mask versus no mask
7. Air quality alerts versus normal care
8. Air quality alerts versus usual care
9. Mask versus no mask
10. Mask versus no mask
11. Mask versus no mask

APPENDICES

Appendix 1. Database search strategies

Database/search platform/date of last search	Search strategy	Results
Airways Register (via Cochrane Register of Studies) Date of most recent search: 16 October 2020	1 MESH DESCRIPTOR Lung Diseases, Obstructive EXPLODE ALL AND INREGISTER 2 MESH DESCRIPTOR Lung Diseases, Interstitial EXPLODE ALL AND INREGISTER 3 MESH DESCRIPTOR Pulmonary Fibrosis EXPLODE ALL AND INREGISTER 4 MESH DESCRIPTOR hypertension, pulmonary EXPLODE ALL AND INREGISTER 5 MESH DESCRIPTOR Pleural Diseases EXPLODE ALL AND INREGISTER 6 MESH DESCRIPTOR Pulmonary Eosinophilia AND INREGISTER 7 MESH DESCRIPTOR Lung Diseases AND INREGISTER 8 MESH DESCRIPTOR Sleep Apnea, Obstructive EXPLODE ALL AND INREGISTER 9 MESH DESCRIPTOR Chronic Disease EXPLODE ALL AND INREGISTER 10 MESH DESCRIPTOR Lung Neoplasms EXPLODE ALL AND INREGISTER 11 MESH DESCRIPTOR Pleural Neoplasms EXPLODE ALL AND INREGISTER 12 MESH DESCRIPTOR Carcinoma, Non-Small-Cell Lung AND INREGISTER 13 MESH DESCRIPTOR Small Cell Lung Carcinoma AND INREGISTER 14 MESH DESCRIPTOR Cystic Fibrosis AND INREGISTER 15 (asthma* or wheez*):ti,ab,kw AND INREGISTER 16 ((chronic* or obstruct*) NEAR3 (pulmonary or lung* or airway* or airflow* or bronch* or respirat*)):ti,ab,kw AND INREGISTER 17 (COPD or AECOPD or AECB):ti,ab,kw AND INREGISTER 18 bronchiectasis:ti,ab,kw AND INREGISTER 19 (interstitial* NEAR3 (lung* or disease* or pneumon*)):ti,ab,kw AND INREGISTER 20 ((pulmonary* or lung* or alveoli*) NEAR3 (fibros* or fibrot*)):ti,ab,kw AND INREGISTER 21 (pneumoconiosis or silicosis):ti,ab,kw AND INREGISTER 22 (pulmonary NEAR3 eosinophi*):ti,ab,kw AND INREGISTER 23 (pulmonary NEAR2 hypertensi*):ti,ab,kw AND INREGISTER 24 (OSA or OSAHS):ti,ab,kw AND INREGISTER 25 (pulmonary NEAR3 sarcoid*):ti,ab,kw AND INREGISTER 26 ((lung* or pulmonary) NEAR3 (cancer or tumor or tumour)):ti,ab,kw AND INREGISTER 27 (NSCLC or SCLC):ti,ab,kw AND INREGISTER 28 (cystic* NEAR3 fibros*):ti,ab,kw AND INREGISTER 29 (healthy NEAR3 (volunteer* or particpant* or recruit* or group* or cohort* or subject* or control*)):ti,ab,kw AND INREGISTER 30 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 AND INREGISTER 31 MESH DESCRIPTOR Air Pollutants EXPLODE ALL AND INREGISTER 32 MESH DESCRIPTOR Air Pollution AND INREGISTER 33 MESH DESCRIPTOR Environmental Exposure AND INREGISTER 34 MESH DESCRIPTOR Particulate Matter EXPLODE ALL AND INREGISTER 35 MESH DESCRIPTOR Vehicle Emissions AND INREGISTER 36 MESH DESCRIPTOR Nitrogen Oxides EXPLODE ALL AND INREGISTER 37 MESH DESCRIPTOR Ozone AND INREGISTER 38 MESH DESCRIPTOR Sulfur Dioxide AND INREGISTER 39 MESH DESCRIPTOR Fossil Fuels EXPLODE ALL AND INREGISTER 40 (environment* NEAR3 (expos* or toxic* or contaminat*)):ti,ab,kw AND INREGISTER 41 (particulate* NEAR3 (matter or air)):ti,ab,kw AND INREGISTER	September 2019 = 40 October 2020 = 10

(Continued)

	42 ((smog or fume* or exhaust* or diesel) and air):ti,ab,kw AND INREGISTER 43 ((vehicle or traffic) NEAR3 (emission* or pollut*)):ti,ab,kw AND INREGISTER 44 ((air or ambient) NEAR3 (pollut* or quality)):ti,ab,kw AND INREGISTER 45 fossil fuel*:ti,ab,kw AND INREGISTER 46 ("PM10" or "PM2.5"):ti,ab,kw AND INREGISTER 47 (SO2 or NO2 or O3 or CO):ti,ab,kw AND INREGISTER 48 #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 AND INREGISTER 49 MESH DESCRIPTOR Environmental Monitoring EXPLODE ALL AND INREGISTER 50 ((environment* or air or atmospher* or pollut*) near3 (alarm* or monitor* or alert* or surveillance or forecast* or warning or messag* or smartphone or mobile or text* or SMS)):ti,ab,kw AND INREGISTER 51 MESH DESCRIPTOR Masks AND INREGISTER 52 MESH DESCRIPTOR Respiratory Protective Devices AND INREGISTER 53 MESH DESCRIPTOR Protective Clothing AND INREGISTER 54 (face NEAR2 mask*):ti,ab,kw AND INREGISTER 55 ((personal* or individual*) and ((reduc* or avoid* or lower* or control* or modif* or prevent*) NEAR3 (exposure* or pollut*))):ti,ab,kw AND INREGISTER 56 MESH DESCRIPTOR Wearable Electronic Devices EXPLODE ALL AND INREGISTER 57 MESH DESCRIPTOR Smartphone AND INREGISTER 58 MESH DESCRIPTOR Health Communication AND INREGISTER 59 MESH DESCRIPTOR Text Messaging AND INREGISTER 60 #49 OR #50 OR #51 OR #52 OR #53 OR #54 OR #55 OR #56 OR #57 OR #58 OR #59 AND INREGISTER 61 #30 AND #48 AND #60 AND INREGISTER	
CENTRAL (via Cochrane Register of Studies) Date of most recent search: 16 October 2020	1 MESH DESCRIPTOR Lung Diseases, Obstructive EXPLODE ALL AND CENTRAL:TARGET 2 MESH DESCRIPTOR Lung Diseases, Interstitial EXPLODE ALL AND CENTRAL:TARGET 3 MESH DESCRIPTOR Pulmonary Fibrosis EXPLODE ALL AND CENTRAL:TARGET 4 MESH DESCRIPTOR hypertension, pulmonary EXPLODE ALL AND CENTRAL:TARGET 5 MESH DESCRIPTOR Pleural Diseases EXPLODE ALL AND CENTRAL:TARGET 6 MESH DESCRIPTOR Pulmonary Eosinophilia AND CENTRAL:TARGET 7 MESH DESCRIPTOR Lung Diseases AND CENTRAL:TARGET 8 MESH DESCRIPTOR Sleep Apnea, Obstructive EXPLODE ALL AND CENTRAL:TARGET 9 MESH DESCRIPTOR Chronic Disease EXPLODE ALL AND CENTRAL:TARGET 10 MESH DESCRIPTOR Lung Neoplasms EXPLODE ALL AND CENTRAL:TARGET 11 MESH DESCRIPTOR Pleural Neoplasms EXPLODE ALL AND CENTRAL:TARGET 12 MESH DESCRIPTOR Carcinoma, Non-Small-Cell Lung AND CENTRAL:TARGET 13 MESH DESCRIPTOR Small Cell Lung Carcinoma AND CENTRAL:TARGET 14 MESH DESCRIPTOR Cystic Fibrosis AND CENTRAL:TARGET 15 (asthma* or wheez*):ti,ab,kw AND CENTRAL:TARGET 16 ((chronic* or obstruct*) NEAR3 (pulmonary or lung* or airway* or airflow* or bronch* or respirat*)):ti,ab,kw AND CENTRAL:TARGET 17 (COPD or AECOPD or AECB):ti,ab,kw AND CENTRAL:TARGET 18 bronchiectasis:ti,ab,kw AND CENTRAL:TARGET 19 (interstitial* NEAR3 (lung* or disease* or pneumon*)):ti,ab,kw AND CENTRAL:TARGET 20 ((pulmonary* or lung* or alveoli*) NEAR3 (fibros* or fibrot*)):ti,ab,kw AND CENTRAL:TARGET 21 (pneumoconiosis or silicosis):ti,ab,kw AND CENTRAL:TARGET 22 (pulmonary NEAR3 eosinophi*):ti,ab,kw AND CENTRAL:TARGET 23 (pulmonary NEAR2 hypertensi*):ti,ab,kw AND CENTRAL:TARGET 24 (OSA or OSAHS):ti,ab,kw AND CENTRAL:TARGET 25 (pulmonary NEAR3 sarcoid*):ti,ab,kw AND CENTRAL:TARGET	September 2019 = 129 October 2020 = 19

(Continued)

	26 ((lung* or pulmonary) NEAR3 (cancer or tumor or tumour)):ti,ab,kw AND CENTRAL:TARGET 27 (NSCLC or SCLC):ti,ab,kw AND CENTRAL:TARGET 28 (cystic* NEAR3 fibros*):ti,ab,kw AND CENTRAL:TARGET 29 (healthy NEAR3 (volunteer* or particpant* or recruit* or group* or cohort* or subject* or control*)):ti,ab,kw AND CENTRAL:TARGET 30 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 31 MESH DESCRIPTOR Air Pollutants EXPLODE ALL AND CENTRAL:TARGET 32 MESH DESCRIPTOR Air Pollution AND CENTRAL:TARGET 33 MESH DESCRIPTOR Environmental Exposure AND CENTRAL:TARGET 34 MESH DESCRIPTOR Particulate Matter EXPLODE ALL AND CENTRAL:TARGET 35 MESH DESCRIPTOR Vehicle Emissions AND CENTRAL:TARGET 36 MESH DESCRIPTOR Nitrogen Oxides EXPLODE ALL AND CENTRAL:TARGET 37 MESH DESCRIPTOR Ozone AND CENTRAL:TARGET 38 MESH DESCRIPTOR Sulfur Dioxide AND CENTRAL:TARGET 39 MESH DESCRIPTOR Fossil Fuels EXPLODE ALL AND CENTRAL:TARGET 40 (environment* NEAR3 (expos* or toxic* or contaminat*)):ti,ab,kw AND CENTRAL:TARGET 41 (particulate* NEAR3 (matter or air)):ti,ab,kw AND CENTRAL:TARGET 42 ((smog or fume* or exhaust* or diesel) and air):ti,ab,kw AND CENTRAL:TARGET 43 ((vehicle or traffic) NEAR3 (emission* or pollut*)):ti,ab,kw AND CENTRAL:TARGET 44 ((air or ambient) NEAR3 (pollut* or quality)):ti,ab,kw AND CENTRAL:TARGET 45 fossil fuel*:ti,ab,kw AND CENTRAL:TARGET 46 ("PM10" or "PM2.5"):ti,ab,kw AND CENTRAL:TARGET 47 (SO2 or NO2 or O3 or CO):ti,ab,kw AND CENTRAL:TARGET 48 #31 OR #32 OR #33 OR #34 OR #35 OR #36 OR #37 OR #38 OR #39 OR #40 OR #41 OR #42 OR #43 OR #44 OR #45 OR #46 OR #47 49 MESH DESCRIPTOR Environmental Monitoring EXPLODE ALL AND CENTRAL:TARGET 50 ((environment* or air or atmospher* or pollut*) near3 (alarm* or monitor* or alert* or surveillance or forecast* or warning or messag* or smartphone or mobile or text* or SMS)):ti,ab,kw AND CENTRAL:TARGET 51 MESH DESCRIPTOR Masks AND CENTRAL:TARGET 52 MESH DESCRIPTOR Respiratory Protective Devices AND CENTRAL:TARGET 53 MESH DESCRIPTOR Protective Clothing AND CENTRAL:TARGET 54 (face NEAR2 mask*):ti,ab,kw AND CENTRAL:TARGET 55 ((personal* or individual*) and ((reduc* or avoid* or lower* or control* or modif* or prevent*) NEAR3 (exposure* or pollut*))):ti,ab,kw AND CENTRAL:TARGET 56 MESH DESCRIPTOR Wearable Electronic Devices EXPLODE ALL AND CENTRAL:TARGET 57 MESH DESCRIPTOR Smartphone AND CENTRAL:TARGET 58 MESH DESCRIPTOR Health Communication AND CENTRAL:TARGET 59 MESH DESCRIPTOR Text Messaging AND CENTRAL:TARGET 60 #49 OR #50 OR #51 OR #52 OR #53 OR #54 OR #55 OR #56 OR #57 OR #58 OR #59 61 #30 AND #48 AND #60	
MEDLINE (Ovid) Date of most recent search: 16 October 2020	1 exp Lung Diseases, Obstructive/ 2 exp Lung Diseases, Interstitial/ 3 exp Pulmonary Fibrosis/ 4 exp hypertension, pulmonary/ 5 exp Pleural Diseases/ 6 Pulmonary Eosinophilia/ 7 Lung Diseases/ 8 exp Sleep Apnea, Obstructive/ 9 exp chronic Disease/	September 2019 = 2437 October = 136

(Continued)

10 exp Lung Neoplasms/
11 exp Pleural Neoplasms/
12 carcinoma, non-small-cell lung/ or small cell lung carcinoma/
13 Cystic Fibrosis/
14 (asthma$ or wheez$).ti,ab.
15 ((chronic$ or obstruct$) adj3 (pulmonary or lung$ or airway$ or airflow$ or bronch$ or respirat$)).ti,ab.
16 (COPD or AECOPD or AECB).ti,ab.
17 bronchiectasis.ti,ab.
18 (interstitial$ adj3 (lung$ or disease$ or pneumon$)).ti,ab.
19 ((pulmonary$ or lung$ or alveoli$) adj3 (fibros$ or fibrot$)).ti,ab.
20 (pneumoconiosis or silicosis).ti,ab.
21 (pulmonary adj3 eosinophi$).ti,ab.
22 (pulmonary adj2 hypertensi$).ti,ab.
23 (sleep$ adj3 (apnea$ or apnoea$)).ti,ab.
24 (OSA or OSAHS).ti,ab.
25 (pulmonary adj3 sarcoid$).ti,ab.
26 ((lung$ or pulmonary) adj3 (cancer or tumor or tumour)).ti,ab.
27 (NSCLC or SCLC).ti,ab.
28 (cystic$ adj3 fibros$).ti,ab.
29 (cystic$ adj3 fibros$).ti,ab.
30 (healthy adj3 (volunteer$ or particpant$ or recruit$ or group$ or cohort$ or subject$ or control$)).ti,ab.
31 or/1-30
32 exp Air Pollutants/
33 Air Pollution/
34 Environmental Exposure/
35 exp Particulate Matter/
36 Vehicle Emissions/
37 Traffic-Related Pollution/
38 exp Nitrogen Oxides/
39 Ozone/
40 Sulfur Dioxide/
41 exp Fossil Fuels/
42 (environment$ adj3 (expos$ or toxic$ or contaminat$)).ti,ab.
43 (particulate$ adj3 (matter or air)).ti,ab.
44 ((smog or fume$ or exhaust$ or diesel) and air).ti,ab.
45 ((vehicle or traffic) adj3 (emission$ or pollut$)).ti,ab.
46 ((air or ambient) adj3 (pollut$ or quality)).ti,ab.
47 fossil fuel$.ti,ab.
48 ("PM10" or "PM2.5").ti,ab.
49 (SO2 or NO2 or O3 or CO).ti,ab.
50 or/32-49
51 Environmental Monitoring/
52 ((environment$ or air or atmospher$ or pollut$) adj3 (alarm$ or monitor$ or alert$ or surveillance or forecast$ or warning or messag$ or smartphone or mobile or text$ or SMS)).ti,ab.
53 Masks/
54 Respiratory Protective Devices/
55 Protective Clothing/
56 (face adj2 mask$).ti,ab.
57 ((personal$ or individual$) and ((reduc$ or avoid$ or lower$ or control$ or modif$ or prevent$) adj3 (exposure$ or pollut$))).ti,ab.
58 exp Wearable Electronic Devices/
59 Smartphone/
60 Health Communication/
61 Text Messaging/
62 or/51-61
63 31 and 50 and 62
64 Animals/ not (Animals/ and Humans/)

(Continued)

	65 63 not 64	
Embase (Ovid) Date of most recent search: 16 October 2020	1 exp obstructive airway disease/ 2 exp interstitial lung disease/ 3 exp lung fibrosis/ 4 exp pulmonary hypertension/ 5 exp pleura disease/ 6 lung disease/ 7 exp sleep disordered breathing/ 8 exp chronic disease/ 9 exp lung tumor/ 10 exp pleura tumor/ 11 exp non small cell lung cancer/ 12 exp small cell lung cancer/ 13 cystic fibrosis/ 14 (asthma$ or wheez$).ti,ab. 15 ((chronic$ or obstruct$) adj3 (pulmonary or lung$ or airway$ or airflow$ or bronch$ or respirat$)).ti,ab. 16 (COPD or AECOPD or AECB).ti,ab. 17 bronchiectasis.ti,ab. 18 (interstitial$ adj3 (lung$ or disease$ or pneumon$)).ti,ab. 19 ((pulmonary$ or lung$ or alveoli$) adj3 (fibros$ or fibrot$)).ti,ab. 20 (pneumoconiosis or silicosis).ti,ab. 21 (pulmonary adj3 eosinophi$).ti,ab. 22 (pulmonary adj2 hypertensi$).ti,ab. 23 (sleep$ adj3 (apnea$ or apnoea$)).ti,ab. 24 (OSA or OSAHS).ti,ab. 25 (pulmonary adj3 sarcoid$).ti,ab. 26 ((lung$ or pulmonary) adj3 (cancer or tumor or tumour)).ti,ab. 27 (NSCLC or SCLC).ti,ab. 28 (cystic$ adj3 fibros$).ti,ab. 29 normal human/ 30 (healthy adj3 (volunteer$ or particpant$ or recruit$ or group$ or cohort$ or subject$ or control$)).ti,ab. 31 or/1-30 32 exp air pollutant/ 33 air pollution/ 34 environmental exposure/ 35 particulate matter/ 36 exhaust gas/ 37 nitrogen oxide/ 38 ozone/ 39 sulfur dioxide/ 40 fossil fuel/ 41 (environment$ adj3 (expos$ or toxic$ or contaminat$)).ti,ab. 42 (particulate$ adj3 (matter or air)).ti,ab. 43 ((smog or fume$ or exhaust$ or diesel) and air).ti,ab. 44 ((vehicle or traffic) adj3 (emission$ or pollut$)).ti,ab. 45 ((air or ambient) adj3 (pollut$ or quality)).ti,ab. 46 fossil fuel$.ti,ab. 47 ("PM10" or "PM2.5").ti,ab. 48 (SO2 or NO2 or O3 or CO).ti,ab. 49 or/32-48 50 environmental monitoring/ or air monitoring/ 51 ((environment$ or air or atmospher$ or pollut$) adj3 (alarm$ or monitor$ or alert$ or surveillance or forecast$ or warning or messag$ or smartphone or mobile or text$ or SMS)).ti,ab. 52 mask/ or face mask/ 53 protective equipment/ 54 protective clothing/ 55 (face adj2 mask$).ti,ab.	September 2019 = 2788 October 2020 = 314

(Continued)

	56 ((personal$ or individual$) and ((reduc$ or avoid$ or lower$ or control$ or modif$ or prevent$) adj3 (exposure$ or pollut$))).ti,ab. 57 electronic device/ 58 smartphone/ 59 medical information/ 60 text messaging/ 61 or/50-60 62 31 and 49 and 61	
Global Health (Ovid) Date of most recent search: 16 October 2020	1 exp respiratory diseases/ 2 chronic diseases/ 3 exp lung cancer/ 4 (asthma$ or wheez$).ti,ab. 5 ((chronic$ or obstruct$) adj3 (pulmonary or lung$ or airway$ or airflow$ or bronch$ or respirat$)).ti,ab. 6 (COPD or AECOPD or AECB).ti,ab. 7 bronchiectasis.ti,ab. 8 (interstitial$ adj3 (lung$ or disease$ or pneumon$)).ti,ab. 9 ((pulmonary$ or lung$ or alveoli$) adj3 (fibros$ or fibrot$)).ti,ab. 10 (pneumoconiosis or silicosis).ti,ab. 11 (pulmonary adj3 eosinophi$).ti,ab. 12 (pulmonary adj2 hypertensi$).ti,ab. 13 (sleep$ adj3 (apnea$ or apnoea$)).ti,ab. 14 (OSA or OSAHS).ti,ab. 15 (pulmonary adj3 sarcoid$).ti,ab. 16 ((lung$ or pulmonary) adj3 (cancer or tumor or tumour)).ti,ab. 17 (NSCLC or SCLC).ti,ab. 18 (cystic$ adj3 fibros$).ti,ab. 19 (healthy adj3 (volunteer$ or particpant$ or recruit$ or group$ or cohort$ or subject$ or control$)).ti,ab. 20 or/1-19 21 exp air pollutants/ 22 air pollution/ 23 exposure/ 24 air quality/ 25 vehicle emissions/ 26 exp nitrogen oxides/ 27 ozone/ 28 sulfur dioxide/ 29 fossil fuels/ 30 (environment$ adj3 (expos$ or toxic$ or contaminat$)).ti,ab. 31 (particulate$ adj3 (matter or air)).ti,ab. 32 ((smog or fume$ or exhaust$ or diesel) and air).ti,ab. 33 ((vehicle or traffic) adj3 (emission$ or pollut$)).ti,ab. 34 ((air or ambient) adj3 (pollut$ or quality)).ti,ab. 35 fossil fuel$.ti,ab. 36 ("PM10" or "PM2.5").ti,ab. 37 (SO2 or NO2 or O3 or CO).ti,ab. 38 or/21-37 39 monitoring/ 40 ((environment$ or air or atmospher$ or pollut$) adj3 (alarm$ or monitor$ or alert$ or surveillance or forecast$ or warning or messag$ or smartphone or mobile or text$ or SMS)).ti,ab. 41 masks/ 42 exp protective clothing/ 43 (face adj2 mask$).ti,ab. 44 ((personal$ or individual$) and ((reduc$ or avoid$ or lower$ or control$ or modif$ or prevent$) adj3 (exposure$ or pollut$))).ti,ab. 45 information technology/ 46 mobile telephones/ 47 communication/	September 2019 = 1096 October 2020 = 182

(Continued)

	48 or/39-47 49 20 and 38 and 48	
Web of Science Core Collection Date of most recent search: 16 October 2020	# 37 #36 AND #29 AND #17 # 36 #35 OR #34 OR #33 OR #32 OR #31 OR #30 # 35 TOPIC: ("text messag*") # 34 TOPIC: (Smartphone) # 33 TOPIC: ((wearable) NEAR/3 (electronic OR device* OR technology)) # 32 TOPIC: (((personal* OR individual*) AND ((reduc* OR avoid* OR lower* OR control* OR modif* OR prevent*) NEAR/3 (exposure* OR pollut*)))) # 31 TOPIC: ((face NEAR/2 mask*)) # 30 TOPIC: (((environment* OR air OR atmospher* OR pollut*) NEAR/3 (alarm* OR monitor* OR alert* OR surveillance OR forecast* OR warning OR messag* OR smartphone OR mobile OR text* OR SMS))) # 29 #28 OR #27 OR #26 OR #25 OR #24 OR #23 OR #22 OR #21 OR #20 OR #19 OR #18 # 28 TOPIC: (PM10 OR PM2.5) # 27 TOPIC: ("fossil fuel*") # 26 TOPIC: (((air OR ambient) NEAR/3 (pollut* OR quality))) # 25 TOPIC: (((vehicle OR traffic) NEAR/3 (emission* OR pollut*))) # 24 TOPIC: (((smog OR fume* OR exhaust* OR diesel) AND air)) # 23 TOPIC: ((particulate* NEAR/3 (matter OR air))) # 22 TOPIC: ((environment* NEAR/3 (expos* OR toxic* OR contaminat*))) # 21 TOPIC: ("Fossil Fuels") # 20 TOPIC: ("Sulfur Dioxide") # 19 TOPIC: (Ozone) # 18 TOPIC: ("Nitrogen Oxides") # 17 #16 OR #15 OR #14 OR #13 OR #12 OR #11 OR #10 OR #9 OR #8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1 # 16 TOPIC: ((healthy NEAR/3 (volunteer* OR particpant* OR recruit* OR group* OR cohort* OR subject* OR control*))) # 15 TOPIC: ((cystic* NEAR/3 fibros*)) # 14 TOPIC: ((NSCLC OR SCLC)) # 13 TOPIC: (((lung* OR pulmonary) NEAR/3 (cancer OR tumor OR tumour))) # 12 TOPIC: ((pulmonary NEAR/3 sarcoid*)) # 11 TOPIC: ((OSA OR OSAHS)) # 10 TOPIC: ((sleep* NEAR/3 (apnea* OR apnoea*))) # 9 TOPIC: ((pulmonary NEAR/2 hypertensi*))	September 2019 = 1202 October 2020 = 188

(Continued)	# 8 TOPIC: ((pulmonary NEAR/3 eosinophi*) # 7 TOPIC: ((pneumoconiosis OR silicosis)) # 6 TOPIC: (((pulmonary* OR lung* OR alveoli*) NEAR/3 (fibros* OR fibrot*))) # 5 TOPIC: ((interstitial* NEAR/3 (lung* OR disease* OR pneumon*))) # 4 TOPIC: (bronchiectasis) # 3 TOPIC: (COPD OR AECOPD OR AECB) # 2 TOPIC: ((chronic* OR obstruct*) NEAR/3 (pulmonary OR lung* OR airway* OR airflow* OR bronch* OR respirat*)) # 1 TOPIC: (asthma* OR wheez*)	
ClinicalTrials.gov Date of most recent search: 19 October 2020	Study type: Interventional Condition: Respiratory disease Intervention: alarm OR monitor OR alert OR surveillance OR forecast OR warning OR message OR text OR smartphone OR mobile OR reduce OR avoid OR prevent OR control OR mask OR protective OR personal OR individual Other terms: air pollution OR air pollutant OR particulate OR emmision OR nitrogen oxide OR sulfur OR fossil fules OR exhaust OR fumes OR smog OR diesel OR environment	September 2019 = 254 October = 100
WHO trials portal Date of most recent search: 11 September 2019	(air pollution OR air pollutant OR particulate OR emmision OR nitrogen oxide OR sulfur OR fossil fules OR exhaust OR fumes OR smog OR diesel OR environment) AND (COPD OR asthma OR cystic fibrosis OR ILD or IPF or bronchiectasis OR sleep apnea OR lung cancer OR lung disease OR respiratory)	September 2019 = 14 October 2020 = *not searched*

Appendix 2. Summary search record

Source	Searched from	Date of most recent search	Results (before duplicates removed)		Totals
			September 2019	October 2020	
Airways Register (via CRS*)	Inception	16 October 2020	40	10	50
CENTRAL (via CRS*)	Inception	16 October 2020	129	19	148
MEDLINE (Ovid) ALL	1946	16 October 2020	2437	136	2573
Embase (Ovid)	1974	16 October 2020	2788	314	3102
Global Health (Ovid)	1937	16 October 2020	1096	182	1278
Web of Science Core Collection	1970	16 October 2020	1202	188	1390
Clinicaltrials.gov	Inception	19 October 2020	254	100	354
WHO trials portal	Inception	11 September 2019	14	-	14

(Continued)

Totals	**7960**	**949**	**8909**

*CRS: Cochrane Register of Studies

HISTORY

Protocol first published: Issue 10, 2019

CONTRIBUTIONS OF AUTHORS

SJ: Performed study sifting, data extraction, risk of bias assessment, data analysis, GRADE assessment, and write-up of full review.

PP: Provided conceptual and expert advice, interpretation of findings, editing, critical review and approval of the final draft.

RA: Provided conceptual and expert advice, interpretation of findings, editing, critical review and approval of the final draft.

ES: Conducted and periodically updated all searches and wrote up search results, sifted search results, extracted study data, carried out risk of bias assessment.

RF: Performed data extraction, risk of bias assessment, data analysis, GRADE assessment, and write-up of full review.

Contributions of editorial team

Chris Cates (Co-ordinating Editor): checked the planned methods; advised on study inclusion.

Ian Yang (Contact Editor): edited the full review; advised on content; sign-off of the review for publication.

Sarah Hodgkinson: assisted with sign-off of the review.

Emma Dennett (Managing Editor): co-ordinated the editorial process; advised on content; edited the review; assisted with sign-off of the review..

Emma Jackson (Assistant Managing Editor): conducted peer-review and edited the references and other sections of the review.

DECLARATIONS OF INTEREST

SJ: is employed full-time as a systematic reviewer by an NIHR Programme Grant to complete work on this review.

PP: is employed by the European Lung Foundation as director of the organisation, has received payment to educate the public and patients about impact of air quality on lung health, has received travel and accommodation costs from World Health Organization for being part of the air quality guidelines working group and attending a workshop held by them on interventions for protections from poor air quality.

RA: is employed by St George's, University of London. He has acted as a consultant for the Health Effects Institute Traffic Pollution Systematic Reviews and COMEAP, has received payment for a lecture on systematic review and meta-analysis; St George's received payment from the Health Effects Institute, Medical Research Council, Defra and the World Health Organization.

ES: is employed part-time as the Information Specialist at Cochrane Airways.

RF: is employed part-time by an NIHR Programme Grant to complete work on this Cochrane Review, and is a qualified general practitioner.

SOURCES OF SUPPORT

Internal sources

- Richard Atkinson, UK

  Supported by St George's, University of London (employer)

External sources

- National Institute for Health Research, UK

  Cochrane Programme Grant 16/114/21: NHS priorities in the management of chronic respiratory disease

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

We included mixed populations of chronic conditions.

We extracted all health care usage data.

The background information has been updated with new evidence.

Methods that we were unable to use because the data were not pooled were removed from 'Measures of treatment effect' and 'Unit of analysis issues.'

Where we could not analyse data, we presented them narratively.

The outcome for hospital admissions was broadened to health care usage as we did not find evidence for hospital admissions.

We clarified our exclusion criteria to specify that studies assessing influenza and other related viral infectious diseases were not eligible for inclusion.