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REVIEW

Addressing equity in interventions to reduce air pollution in urban areas: a systematic review

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Abstract
Objectives We did a systematic review to assess quantitative studies investigating the association between interventions aiming to reduce air pollution, health benefits and equity effects.
Methods Three databases were searched for studies investigating the association between evaluated interventions aiming to reduce air pollution and heath-related benefits. We designed a two-stage selection process to judge how equity was assessed and we systematically determined if there was a heterogeneous effect of the intervention between subgroups or subareas.
Results Of 145 identified articles, 54 were reviewed in-depth with eight satisfying the inclusion criteria. This systematic review showed that interventions aiming to reduce air pollution in urban areas have a positive impact on air quality and on mortality rates, but the documented effect on equity is less straightforward.
Conclusions Integration of equity in evidence-based public health is a great challenge nowadays. In this review we draw attention to the importance of considering equity in air pollution interventions. We also propose further methodological and theoretical challenges when assessing equity in interventions to reduce air pollution and we present opportunities to develop this research area.

Keywords Air pollution · Equity · Evaluation

Introduction

In the large literature that is devoted to urban outdoor air pollution and health, the link between them is unequivocal, although some specific associations are still debated (Cohen et al. 2005; Schikowski et al. 2013). A significant body of epidemiological evidence as reported in many

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reviews (Brunekreef and Holgate 2002; Mehta et al. 2013; Shah et al. 2013; van Bree et al. 2007), has amassed over the last 50 years for the health effects of both acute and chronic exposures to a wide range of air pollutants.

The increased awareness of the public and policy makers of the adverse health effects of air pollution has logically led to the development of air quality legislation, and many interventions have been implemented to reduce urban air pollution concentrations (Giles et al. 2011; Henschel et al. 2012). The implementation of air quality standards such as the US EPA Clean Air Act and European Commission air quality directives, have allowed great gains in air pollution reduction over the last few decades (Kunzli et al. 2003). Interventions aiming to reduce urban traffic, promote active transport, control fuel additives, and encourage technical innovations have also been implemented in many urban contexts (van Erp et al. 2008).

Even if the call for intervening on urban outdoor air pollution to improve population health has been recognized, there have been relatively few studies that have investigated the beneficial health effects of air quality interventions compared to other determinants of health. To our knowledge, only one literature review (Henschel et al. 2012) has assessed relevant published studies, though not systematically, for the health impact of changes in air quality due to interventions. They mainly found that air pollution interventions have succeeded at improving air quality but provide limited evidence about health benefits related to these interventions. Furthermore, they did not explore potential differences in the intervention's benefits among different populations or geographical areas.

Yet many international reports have recommended that population health should be assessed not only by the average health status but also by the extent to which health varies within the population (Marmot et al. 2008). Inequities in health are health disparities that "systematically put groups of people who are already socially disadvantaged at further disadvantage with respect to their health" (Braveman and Gruskin 2003). Thus, it is necessary, even essential, to make sure that an intervention's benefits do not contribute to exacerbating existing inequalities, and to make sure that interventions explicitly aim to reduce inequalities. In this way interventions which can act on avoidable differences and do not, can be considered as not equitable (Lorenc et al. 2013). Accordingly, in the context of intervention effectiveness research, the fair distribution of intervention benefits and the measurement of changes in health inequalities constitute the intervention's effects on health equity (Welch et al. 2010). Assessing health equity requires a comparison of health and its social determinants between more and less advantaged social groups. These comparisons are essential to assess whether policies are leading toward or away from greater social justice in health (Braveman and Gruskin 2003).

The characterization of inequities in health related to air pollution has emerged these last years as an important public health concern (Forastiere et al. 2007; Makri and Stilianakis 2008; O'Neill et al. 2003). Two main mechanisms exist to describe these social inequities in health: differential exposure, when there is a social gradient in the spatial distribution of air pollutants within a city; and differential vulnerability, when two individuals may be exposed to similar air pollution levels but the health effects for one may be more pronounced, due to other determinants of health. Many vulnerable populations have been characterized in the recent literature according to socioeconomic status (SES), age (e.g., elderly or children) or pre-existing morbidity conditions (e.g., people suffering from cardiovascular or respiratory diseases) (Makri and Stilianakis 2008). These characterizations can be connected to the PROGRESS framework (O'Neill et al. 2013) which defines personal and population characteristics across which equity might be important.

No review has assessed the fair distribution of the benefits of interventions aiming at reducing air pollution, or the evolution of health inequalities (or inequities) resulting from a public health intervention, even if the need to do so has been pointed out several times (O'Neill et al. 2008; Wheeler and Ben-Shlomo 2005). Systematic reviews are increasingly recognized as a valuable source of evidence for decision-making, yet very few systematic reviews report effects on health equity (Petticrew et al. 2013; Tugwell et al. 2010; Welch et al. 2012).

The aim of this paper is to present a systematic review of the equity effects of the quantitative studies that have investigated the association between interventions aiming to reduce air pollution and health benefits.

Methods

Search strategy

We sought to identify all quantitative studies investigating the association between evaluated interventions aiming to reduce air pollution and health-related benefits up to January 2013. To do so, we adapted the PRISMA statement to develop and report items for this systematic review (Moher et al. 2009). The strategy used consisted of a grouping of keywords representing three categories: air pollution, evaluation or intervention, and health effects. Keywords, titles, and abstracts were searched for in PubMed, Cochrane Library and Embase Elsevier Embase on the Ovid SP portal to identify published articles in English from 1980 to

January 2013. The keywords used for the literature search were: (“Air pollut*” OR “air quality” OR “urban pollut*” OR “ambient air pollution” OR “atmospheric pollut*” OR “air contamination” OR “ambient particulate matter” OR “air pollution control” OR “air-pollution” OR “sources” OR “contribut*”) AND (“evaluat*” OR “program evaluation” OR “process evaluation” OR “comparative evaluation” OR “performance evaluation” OR “evaluation study” OR “Management” or “strateg*” OR “intervention”) AND “health benefits” OR “health effects” OR “health impacts” OR “morbidity” OR “mortality” OR “death” OR “hospital” OR “respir*” OR “card*”. The terms involving equity were not included at this stage to avoid being too restrictive. Instead, we proposed agreed-upon criteria to judge the equity assessment (see below). In addition, the reference sections of studies identified in this way were searched by hand. No restrictions were put on geographical location.

Selection of studies

The first two authors reviewed the abstracts of all studies and studies potentially eligible for inclusion were retrieved. Each author independently assessed each paper against agreed criteria, based only on the objectives and methods section of each paper. The two agreed criteria were as follows:

In the first stage, studies were included if they identified a specific intervention to reduce air pollution, with air pollutant concentration measures and a health outcomes reduction assessment.

In the second stage, among studies selected in the first stage, those evaluating effects simultaneously on different populations or areas were included for the final analysis.

Data extraction

Selected articles were reviewed separately by the first two authors, documenting: the period, the geographic context, the intervention, the population targeted (e.g., specific areas with vulnerable populations), direct and indirect health effects evaluated, the air pollutants measured or modeled, the evaluation framework and statistical methods, the equity assessment and finally the findings (air pollution reduction, health benefits and/or equity).

Data analysis

In this review, we deemed that an intervention aiming at reducing air pollution levels was equitable when the benefits were greater for more vulnerable populations or areas (i.e., a measured heterogeneous effect) and contributed to reducing health inequities (Forastiere et al. 2007; Makri and Stilianakis 2008; O’Neill et al. 2008). To assess if there was a heterogeneous effect of the intervention between subgroups or subareas, we compared the results in different strata. We assessed this heterogeneity in selected papers by examining statistical tests or the significance of interaction terms, when available. When no test was available, and if it was possible (i.e., when the CI were presented) we conducted a Cochran Q test (Kaufman and MacLehose 2013) to assess the heterogeneity between different strata. Thus, on this criterion, we assessed the potential equity on the intervention benefits.

Results

Selection of studies

Figure 1 presents the inclusion and exclusion of studies. Altogether, 856 abstracts from three databases were reviewed based on the keyword searches. 124 studies were selected based on the abstract review, objectives and methods sections. These 124 studies were then considered for assessment by the two agreed criteria.

54 studies were selected on the first criterion (including a specific intervention to reduce air pollution, with air pollutant concentration measures and health outcomes reduction assessment). Among these 54 studies, seven were identified through reference searching. Among these 54 studies 20 studies were conducted in Europe, 22 in America (17 in North America, and 5 in Latin and South America) and 12 in Asia. 46 of these 54 studies were finally excluded based on the second selection criterion because they did not assess effects simultaneously on different populations or areas. Among these 46 excluded papers, 43 were excluded because they include only the whole study area’s population and did not compare subgroups; two papers (Friedman et al. 2001; Wong et al. 2004) were excluded because they only assessed the intervention’s health effects on children, and did not include the adult group for comparison and one paper (Gan et al. 2010) was excluded because the changes in exposure to air pollution were not presented by SES and age (they adjusted for these variables but did not present the stratified results). We finally retained eight studies.

Description of selected studies

The characteristics of the included studies are presented in Table 1. The eight studies were published from 2002 to 2011. Five studies were conducted in Europe, one in North America and two in Asia. The interventions that were evaluated can be classified into two groups: those within the purview of general regulation with air quality

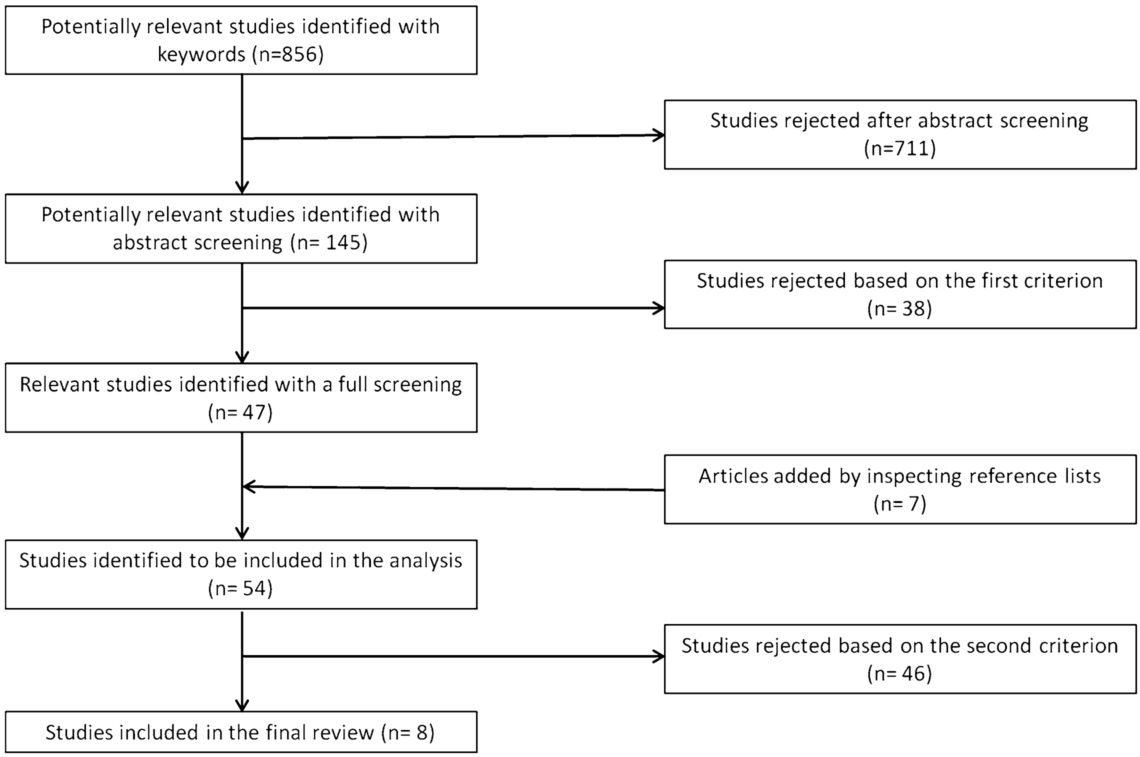

Fig. 1 Stages of the selection of studies for analysis

guidelines or standards, and those with a specific action such as a low emission zone, a ban on coal sales or a congestion charging scheme. These studies were sometimes conducted using only observational data during the study period, when measuring air pollutant levels and health effects. Others were totally simulated using a hypothetical scenario of air pollution abatement (i.e., the intervention) and the health effects were estimated using published dose response relationships. Finally, several studies were mixed, only measuring air pollutants while simulating the health effects, or vice versa.

The characteristics of vulnerability used in the included studies were age for 6 studies and socio-economic status for three studies (one study assessed both age and SES). Socio-economic status was measured using an ecological social deprivation index at the census tract level. The air pollutants measured or modelled were PM10 or PM2.5 (6 studies), NO2 (2 studies), Ozone (2 studies) and black smoke in one study. The health effects measured were mortality rates, respiratory health function, hospital admissions (respiratory and cardiovascular), bronchitis, asthma and years of life gained. The statistical methods used varied from times series models to quantitative health impact assessment. The evaluation frameworks were mostly a before/after design. The heterogeneity effect between the intervention and health effects between strata was assessed comparing estimates among strata. Only one study based its conclusion on a test of heterogeneity (Foster and Kumar 2011). Information given in one study allowed us to calculate a heterogeneity test (Cochran *Q* test) (Perez et al. 2009). For the other studies, we qualitatively compared the estimates between strata.

Findings

Among the observational studies, they systematically concluded that there was a reduction of air pollutant concentrations after the intervention no matter what the pollutant or the intervention. For the simulated studies, the initial condition in their model was an air pollution concentration reduction.

All of the studies estimated better health outcomes after the intervention. Six out of the eight studies documented a reduction in mortality and three studies estimated an improvement in respiratory health. However, the magnitude of these health effects varied among the studies. Some studies concluded that there was a sizable health improvement (Bae and Park 2009; Cesaroni et al. 2012; Clancy et al. 2002; Hall et al. 2008; Mindell and Joffe 2004; Perez et al. 2009) while others established modest health gains in intervention implementation (Foster and Kumar 2011; Tonne et al. 2008).

Furthermore, health benefits did not affect all the people in the same way. Two studies documented the smallest

Table 1 Articles included in the study

References	Study area	Study period	Intervention	Observation study/ simulation study/mixed	Population targeted and vulnerable population or areas
Clancy et al. (2002)	Dublin, Ireland	1984–1996	Ban on coal sales in Dublin (intervention in 1990)	Observation study	All population, stratified by age (younger than 60, 60–74 years, 75 years or older)
Cesaroni et al. (2012)	Rome, Italy	2001–2005	Policy implemented by City Council of Rome in two low-emission zones to reduce traffic-related air pollution	Observation study	All residents of Rome. Areas were stratified in 5 groups according to a SEP ecologic index
Bae and Park (2009)	Seoul, Korea	1999–2004 for observations. 2005 and 2015 for effects estimates	Simulation of health benefits atteigning WHO Air quality guidelines	Mixed: relationships between air pollution and mortality were calculated, and interventions goals simulated	All residents of Seoul stratified by age (0–64 and 65+ years)
Foster and Kumar (2011)	Delhi, India	1997–2002 for intervention. 2004 for data collection	Air quality regulations (including the conversion of all commercial vehicles to compressed natural gas (CNG), and the closure of polluting industries in residential	Mixed: health effects were directly estimated with a survey, and air pollution local levels were modeled	Sampled households in Delhi and surroundings. Individual data about sex, age and capita expenditure were collected
Hall et al. (2008)	San Joaquin Valley, USA	2002–2004	Simulation of health benefits if San Joaquin Valley meets the National Ambient Air Quality Standards (NAAQS)	Mixed: Air pollutions levels were measured and health effects	Residents of the SJV stratified by age (0–65, 65+)
Mindell and Joffe (2004)	London, UK	1996–1998	Regulation (UK National Air Quality Strategy objectives)	Mixed: Air pollutions levels were measured and health effects indirectly estimated	Residents stratified by age (0–14, 15–64, 65+)
Perez et al. (2009)	Barcelona, Spain	2004	Regulation (two scenarios of improved air quality)	Simulation study	All population and children (<1 year and <15 years)
Tonne et al. (2008)	London, UK	2003–2007	Congestion charging Scheme (CCS)	Simulation study	All residents of London. Areas were stratified in 5 groups according to a ecologic deprivation index

Air pollutants	Health effects evaluated	Evaluation framework and statistical methods	Equity assessment	Findings	Potential equity
BS and SO2	Directly standardised non-trauma, respiratory and cardiovascular death rates	Interrupted time-series analysis. Death rates/concentrations of air pollution were compared 72 months before and after the ban	Heterogeneity between strata according to age (H test presented)	The intervention conducted to a air pollution reduction associated with a decrease in mortality rates. This decrease in mortality was larger for younger people (<60 years) than elderly people (60–74 years, 75 years or older)	No

Table 1 continued

Air pollutants	Health effects evaluated	Evaluation framework and statistical methods	Equity assessment	Findings	Potential equity
NO2 and PM10	Standardized mortality rates per 100 000 population and years of life gained (YLG)	Pre post difference calculation with scenarios (an optimistic and a pessimistic)	Heterogeneity between strata according to SEP position (H test not presented)	The internation had beneficial effects on all population in terms of mortality rates decrease and YLG. These benefits were systematically more important for the highest SEP areas following a social gradient)	No
PM10 and ozone	Mortality. A health impact function was used to estimate deaths prevented	Time series analysis (GAM) to estimate relationship between AP and mortality. Intervention benefits were simulated for 2005 and 2015	Heterogeneity between strata according to age (*H* test not presented)	The targetted pollutants levels conducted to a diminution of mortality caused by air pollution. The number of simulated deaths prevented were systematically more important for elderly people whatever the pollution level targetted	Yes
PM 2.5	Respiratory health function	Cross sectional study. Modelisation of air pollution levels to produce before and after levels	Age and sex were included into the model. Heterogeneity between strata according to capita expenditure (*H* test not presented)	The results suggest that the changes in air quality regulations in Delhi that were put in place over the 1997–2002 period, had a substantial effect on respiratory health. The intervention effects were associated with growing age, and for women. These benefits were more concentrated among low-expenditure households	Yes
Ozone	Respiratory Hospital Admission	Health impact assessment using published dose response relationships and different air pollution levels (measured vs. NAAQS standards)	Heterogeneity between strata according to age (*H* test not presented)	There are reductions of respiratory hospital admissions related reaching the standards. This reduction is less important for elderly people (65+)	No

Table 1 continued

Air pollutants	Health effects evaluated	Evaluation framework and statistical methods	Equity assessment	Findings	Potential equity
PM10	Mortality, Hospital admissions	Health impact assessment using published dose response relationships and different air pollution levels (measured vs. UK standards)	Heterogeneity between strata according to age (H test not presented)	Reaching UK National Air Quality Strategy objectives leads mortality and hospital admissions (for different causes) reduction. These reductions were more important for elderly for mortality but not for hospital admissions	Yes for mortality reduction. No for hospital admissions
PM10	Mortality, bronchitis and asthma	Health impact assessment using published dose response relationships and different air pollution levels (2 scenarios considered)	Heterogeneity between strata according to age (H test not presented). A heterogeneity test has been conducted	Annual reduction in air pollutants levels conducted systematically to health benefits. These benefits were more important for children except for asthma	Yes for Mortality and bronchitis. No for Asthma
NO2 and PM10	YLG	Health impact assessment using published dose response relationships was conducted. Air pollution levels were modelled to produce before and after levels	Heterogeneity between strata according to age (H test not presented)	A modest increase in YLG associated with the intervention was found. These small gains followed a socioeconomic pattern benefying slightly more to the more deprived areas	Yes

Summary of air pollution intervention studies (source, study area, study period, intervention, study design, population targeted, air pollutants, health effects, evaluation framework and statistical methods, equity assessment, findings, potential equity) benefit to the elderly (Clancy et al. 2002) or the greatest benefit to the wealthiest (Cesaroni et al. 2012) hence with adverse effects of equity. Six out of eight studies documented a positive effect on equity. Nevertheless, in each study, different groups were affected positively by the intervention: the elderly (Bae and Park 2009; Hall et al. 2008; Mindell and Joffe 2004), women (Hall et al. 2008), the most socially deprived (Hall et al. 2008), children (Perez et al. 2009), and groups in deprived areas (Tonne et al. 2008). The Perez et al. study shows potential equity in health benefits for mortality and bronchitis but the opposite for asthma. Another study documented an increase in hospitalization admissions for the elderly after the intervention but at the end a positive effect on mortality rates for the same group, with positive equity impacts suggesting that medical coverage can have a moderating effect on the causal relation between the intervention and health effects (Mindell and Joffe 2004). Among the studies presenting equitable potential benefits in air pollution interventions, all of them used a partial or total simulation design. On the other hand, the two studies (Cesaroni et al. 2012; Clancy et al. 2002) that assessed intervention impacts with an observational design both found non-equitable potential benefits of the intervention.

Discussion

Summary and discussion of results

This systematic review shows that interventions aiming to reduce air pollution in urban areas have a positive on impact air quality and on mortality rates, but the documented effect on equity is less straightforward. Indeed, we observed that not all interventions have a positive distribution of health benefits. We found no systematic evidence on whether air pollution reduction interventions tended to reduce health inequalities, since results were mixed. Depending on the health outcome(s) under study and intervention type/study design (simulations in the air pollution concentrations or real interventions), more vulnerable groups like the elderly and deprived households were found to benefit more (Bae and Park 2009; Foster and Kumar 2011; Tonne et al. 2008), equally (Clancy et al. 2002), or less (Cesaroni et al. 2012; Hall et al. 2008) than socially better-off counterparts.

Policies related to air quality improvement have been mostly based on spatial uniform interventions focusing on legislative instruments such as bans on specific polluting sources [e.g., coal (Clancy et al. 2002)], and new regulation of traffic zones (Cesaroni et al. 2012; Foster and Kumar, 2011; Tonne et al. 2008). By tackling environmental determinants of health, such interventions have often shown a laudable improvement of population health as a whole (as shown by our review). However, most of them did not consider modifying factors, such as differential vulnerability or the spatial distribution of risk exposure, that mitigate the relationship between interventions and health responses, with the consequence of randomly affecting certain groups and potentially reinforcing health inequities, as stated by our results. This could be explained by the presence of various moderating factors, one being the geographical distribution of intervention targets such as road traffic or industrial plants. Some other elements, such as universal medical coverage, can also moderate the differential impact of air quality on health, facilitating recovery and reducing expected mortality after an event that impacts the more deprived. Given the complexity of pathways between intervention targets and health responses, both other related social determinants of health and intervention co-benefits could contribute to the difficulty of the evaluation process. For example, urban noise is a determinant of cardiovascular health (Basner et al. 2013) just as some air pollutants (e.g., PM) are, and it could be an indirect target of an intervention aiming to reduce road traffic. Secondly, the health outcomes investigated in the identified studies were mostly related to mortality. This could explain the difficulty of emphasizing attributable health benefits, and consequently their equitable distribution.

Furthermore, we found that in this context, the study design can be essential in terms of producing equity findings. Indeed, only two of the selected papers conducted an observational study and both found non-equitable intervention benefits, while all of the studies finding that the most vulnerable populations benefited more from the intervention impacts were conducted using simulations of air pollution concentrations or dose–response relationships. Using simulations inevitably leads to assumptions. First, when an evaluator uses a simulation design to represent reductions in air pollution levels (e.g., air quality guidelines implementation) he makes the assumption of both the full responsibility of the intervention (the results are totally attributable to the intervention) as well as of the homogeneous spatial distribution of the intervention's benefits. Second, when an evaluator uses published epidemiological dose–response relationships, by definition, these associations (e.g., RR for 10 $\mu g/m^3$ increase) will be systematically greater for more vulnerable populations (e.g., children, the elderly or socially deprived people). Thus, assuming that every population will benefit from exactly the same air pollution levels reduction and using published associations based on the hypothesis that there are some groups that are more affected by air pollution than others will predictably lead to findings of equitable outcomes. Yet the assumptions made in simulation studies in the context of assessing equity in these ecological interventions carry weighty consequences. Assumptions made during simulations may overlook the complexity of the mechanisms leading from environmental changes brought by the intervention to health, and erroneously conclude an intervention is equitable. Given the complexity of these processes, such assumptions should be avoided. Observational studies may be promoted. On the other hand, observational studies are not always feasible due to their elevated costs and long durations. Yet, methodological developments are needed for simulation studies to address the assumptions listed above.

Limits of the review

This review is subject to a number of limitations. First, unpublished studies by research groups (e.g., not already published material or gray literature) may be under-represented. Second, of the 54 studies identified that assessed health benefits of air pollution interventions, only eight presented results for different subpopulations or sub-areas permitting an evaluation of equity and were included in our systematic review. If we were able to estimate potential equity benefits in air pollution interventions in all 54 studies, our results could be substantively different. Further studies should present interventions benefits for different subpopulations to enable consideration of equity in air pollution interventions. With the exception of one study where an interaction term was included (Foster and Kumar 2011) and another where we conducted a heterogeneity test (Perez et al. 2009), we were obligated to estimate the heterogeneity in intervention benefits qualitatively between strata, because data presented in papers did not allow us to conduct a heterogeneity test, mainly since CI were not presented. This could have led to bias in the effect heterogeneity estimations. Further studies should include interaction terms in their models or conduct heterogeneity tests between strata (e.g., Cochran Q test or Wald test) or at the very least, present confidence intervals in their results for future systematic reviews.

General discussion and propositions

Achieving social equity in environmental planning policies requires not only documentation of the extent of health inequities, but also a demonstration that they are avoidable through equity-focused interventions. Unfortunately, we found that only a few studies looked at equity in health when evaluating intervention delivery. A greater use of subgroup analysis is therefore required to explore whether policies are leading toward or away from greater equity in health (Petticrew et al. 2012) and to provide guidance for evidence-based interventions (Braveman et al. 2000; Braveman et al. 2001).

Such statements should, however, be interpreted in light of contextual factors. First, equity is actually open to interpretation, as different social, political, economic and cultural contexts suggest different ways of conceptualizing equity (Braveman and Gruskin 2003). Second, understanding the nature of the causal pathways leading from underlying environmental and social determinants to health inequities, and figuring out how policies can impact such inequities, are complex—i.e., dynamic and contextual (Waters et al. 2011).

Evaluating health equity in interventions presents major challenges (Potvin et al. 2008), and requires a profound involvement of three often disconnected domains: "science—the research into the complex causation of health inequities; practice—the application of scientific knowledge to the delivery and management of health; and policy—the course of action or system of interventions adopted as a result of scientific and practical knowledge or experience" (Ruffin 2010).

Health promotion as a domain of research and practice that puts health on the agenda of policy makers in all governmental sectors and at all levels, and that embraces equity as a core value (WHO 1986b) could provide a comprehensive framework to help evaluate health inequities in complex interventions and orient action towards more equitable policies. Its basic principles such as community participation (Baum 2007; Minkler et al.1997) and intersectoriality (WHO 1986a, b), as well as its adherence to the complexity paradigm (Tremblay and Richard 2011), have for instance led to the increasing importance of logic modeling and intervention theory analysis in the field of evaluation (Dubois et al. 2012; Patton 2011).

Particularly, in the case of ecological interventions (such air pollution interventions), many developments are still required, in terms of evaluative research tools and theories. This is even truer when considering equity in interventions. One promising family of tools for prospective assessment of an intervention or policy's potential impacts on health inequalities is Health Equity Impact Assessment [which can take such forms as health equity assessment (Cram and Ashton 2008) or equality impact assessment (Trust and Data 2008)]. Theory-based evaluation also offers an opportunity for program evaluators to elucidate mechanisms by which interventions benefit certain populations to differing degrees (Whitehead 2007).

Collecting indicators that could be used in further equity-oriented evaluations studies to assess heterogeneity in intervention benefits constitutes a necessary approach with different steps. First, it is important, in a given context, to survey health issues separately for vulnerable populations (as defined in the introduction section), and for their counterpart (i.e., non vulnerable population). The health issues that should be surveyed are those for which epidemiologic evidence is strong enough. These health effects can be either acute or chronic, but they will require different designs. Yet studies investigating chronic health benefits from an intervention aiming at reducing air pollution will require more elevated costs and long durations. Second, to assess heterogeneity in intervention benefits, further studies could use direct health inequality measures instead of stratifying estimates for subpopulations. For example Index of Disparity (Pearcy and Keppel 2002), Mean Log Deviation (Firebaugh 1999) or simply ratios or differences between subgroups (Harper et al. 2010) could be used.

Integrating health equity concerns in the planning of interventions involves both universal and targeted approaches. Typically, environmental interventions such as those on air quality are categorized solely as universal interventions, which according to Geoffrey Rose's population approach would shift the distribution curve from a level of higher risk of health effects due to air pollution to a lower level by the same amount no matter where a given person is situated along the curve (Frohlich and Potvin 2008). The two studies for which we have equity effect results show that in the case of air pollution interventions, the health benefits are not homogeneously distributed across risk exposure levels, which can be explained by the existence of vulnerable populations who may experience less benefit for a given reduction in pollution exposure. This supports the theorization of Frohlich and Potvin 2008, and further endorses the application of blended intervention strategies like proportionate universalism (Marmot and Bell 2012) and targeting within universalism (Lawrence et al. 2013; Skocpol 1991) to environmental interventions. However, the evidence base must first be strengthened in terms of characterizing and locating vulnerable populations within geographical areas as well as including specific and proportionate individual's interventions when designing air pollution policies.

Conducting systematic reviews is essential in public health to identify promising interventions. Over the past few years, there have been many calls to integrate equity in evidence-based public health, (Lorenc et al. 2013) particularly in systematic reviews (Petticrew et al. 2013). This review does not presume to identify effective ways to ensure equity in air pollution interventions, but to provide an overview of this kind of ecological intervention where the equity literature is lacking, and to draw attention to the importance of considering equity in air pollution interventions. This reasoning applies to any public health intervention, such as heat action plans or neighborhoods interventions aimed at increasing physical activity.

In conclusion, our results strongly suggest that we should pay particular attention to potential impacts on equity when implementing interventions aiming to reduce air pollution in urban areas. This systematic review underlines the complex relationship between air quality and equity. Further, our results advocate for trying to better anticipate differential health impacts among diverse groups or areas. This could be done by better understanding the underlying influencing factors that will foster or mitigate the health impacts of interventions as well as widening research in methods and theories evaluating ecological public health interventions such as those on air pollution.

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