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**Review article** 

Effectiveness of interventions to reduce household air pollution and/or improve health in homes using solid fuel in low-and-middle income countries: A systematic review and meta-analysis

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# ABSTRACT

*Background:* Cookstove intervention programs have been increasing over the past two (2) decades in Low and Middle Income Countries (LMICs) across the globe. However, there remains uncertainty regarding the effects of these interventions on household air pollution concentrations, personal exposure concentrations and health outcomes.

*Objectives:* The primary objective was to determine if household air pollution (HAP) interventions were associated with improved indoor air quality (IAQ) in households in LMICs. Given the potential impact of HAP interventions on health, a secondary objective was to evaluate the effectiveness of HAP interventions to improve health in populations receiving these interventions.

*Data sources:* OVID Medline, Ovid Embase, SCOPUS and PubMED were searched from their inception until December 2015 with no restrictions on study design. The WHO Global database of household air pollution measurements and Members' archives were also reviewed together with the reference lists of identified reviews and relevant articles.

*Study eligibility criteria, participants and intervention:* We considered randomized controlled trials, or non-randomized control trials, or before-and-after studies; original studies; studies conducted in a LMIC (based on the United Nations Human Development Report released in March 2013 (World Bank, 2013); interventions that were explicitly aimed at improving IAQ and/or health from solid fuel use; studies published in a peer-reviewed journal or student theses or reports; studies that reported on outcomes which was indicative of IAQ or/and health. There was no restriction on the type of comparator (e.g. household receiving *plancha* vs. household using traditional cookstove) used in the intervention study.

*Study appraisal and synthesis methods:* Five review authors independently used pre-designed data collection forms to extract information from the original studies and assessed risk of bias using the Effective Public Health Practice Project (EPHPP). We computed standardized weighted mean difference (SMD) using random-effects models. Heterogeneity was computed using the Q and I2-statistics. We examined the influence of various characteristics on the study-specific effect estimates by stratifying the analysis by population type, study design, intervention type, and duration of exposure monitoring. The trim and fill method was used to assess the potential impact of missing studies.

*Results*: Fifty-five studies met our a priori inclusion criteria and were included in the systematic review. Fifteen studies provided 43 effect estimates for our meta-analysis. The largest improvement in HAP was observed for average particulate matter (PM) (SMD = 1.57) concentrations in household kitchens (1.03), followed by daily personal average concentrations of PM (1.18), and carbon monoxide (CO) concentrations in kitchens. With respect to personal PM, significant improvement was observed in studies of children (1.26) and studies monitoring PM for  $\ge$ 24 h (1.32). This observation was also noted in terms of studies of kitchen concentrations of CO. A significant improvement was also observed for kitchen levels of PM in both adult populations (1.56) and in RCT/cohort designs (1.59) involving

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replacing cookstoves without chimneys. Our findings on health outcomes were inconclusive.

*Limitations, conclusions and implications of key findings:* We observed high statistical between study variability in the study-specific estimate. Thus, care should be taken in concluding that HAP interventions - as currently designed and implemented - support reductions in the average kitchen and personal levels of PM and CO. Further, there is limited evidence that current stand-alone HAP interventions yield any health benefits. Post-intervention levels of pollutants were generally still greatly in excess of the relevant WHO guideline and thus a need to promote cleaner fuels in LMICs to reduce HAP levels below the WHO guidelines.

*Systematic review registration number:* The review has been registered with PROSPERO (registration number CRD42014009768).

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## 1. Introduction

Nearly one-third of the world's population use solid fuels such as wood, animal dung, and crop residues as their primary source of domestic energy use (e.g. Bonjour et al., 2013; Balakrishnan et al., 2013; Chafe et al., 2014). Cooking and heating with solid fuel on open fires or traditional stoves emits a complex mixture of organic compounds and gases, which include carbon monoxide (CO), oxides of nitrogen (NOx) and sulphur (SOx), aldehydes, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), chlorinated dioxins, fine particulate matter (PM), and free radicals (Albalak et al., 2001; Mishra, 2003). Health problems associated with household air pollution (HAP) from solid fuel/biomass fuel use includes, but is not limited to, respiratory tract infection (Mishra, 2003) exacerbation of inflammatory lung conditions (Gordon et al., 2014), cardiac events (Bruce et al., 2015), asthma (Bruce et al., 2015; Gordon et al., 2014), chronic obstructive pulmonary disease (COPD) (Assad et al., 2015; Bruce et al., 2015; Gordon et al., 2014), low birth weight (Amegah et al., 2014) and tuberculosis (Kurmi et al., 2014).

Cookstove intervention programs have been implemented and studied extensively in Low and Middle Income Countries (LMICs). However, there remains significant uncertainty regarding the effectiveness of these interventions. Rehfuess et al. (2004) and Thomas et al. (2015) recently reported reviews on this subject. Rehfuess et al. (2004) conducted a systematic review and meta-analysis covering the period between 1998 and July 2012. The authors identified 38 studies published in LMICs and ICs and noted reduction in average daily concentrations of the two most commonly measured pollutants: PM and CO. Thomas et al. (2015) conducted a systematic review of studies published up to April 2014. These authors captured almost the same studies previously reviewed by Rehfuess et al. (2004) but the findings from these two reviews were contradictory. The household air pollution field is changing rapidly and new evidence has accumulated since the last review (Thomas et al., 2015). In such a rapidly evolving field there is the need to confirm or refute previous findings. Also timely evaluation of methods and results of studies can help inform public health policy and future studies. It is from these perspectives that we are conducting this systematic review to determine if HAP interventions are associated with improved IAQ in households in LMICs. A secondary objective is to evaluate the effectiveness of HAP interventions to improve health in populations living in LMICs.

## 2. Methods

## 2.1. Search strategy

This systematic review was carried out according to established methods (Mukhopadhyay et al., 2012; IRIS, 2014) and reported according to recommendations from the Preferred Reporting Items for

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