Environmental Research 166 (2018) 658–667

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Effect on blood pressure and eye health symptoms in a climate-financed randomized cookstove intervention study in rural India

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ARTICLE INFO

Keywords:
Biomass fuel
Black carbon
Cardiovascular health
Climate financed
Particulate matter

ABSTRACT

Background: Air pollution from cooking with solid fuels is a potentially modifiable risk factor for increased blood pressure and may lead to eye irritation.
Objectives: To evaluate whether a climate motivated cookstove intervention reduced blood pressure and eye irritation symptoms in Indian women.
Methods: Households using traditional stoves were randomized to receive a rocket stove or continue using traditional stoves. Systolic (SBP) and diastolic blood pressure (DBP), and self-reported eye symptoms were measured twice, pre-intervention and at least 124 days post-intervention in women > 25 years old in control (N = 111) and intervention (N = 111) groups in rural Karnataka, India. Daily (24-h) fine particle ($PM_{2.5}$) mass and absorbance (Abs) were measured in cooking areas at each visit. Mixed-effect models were used to estimate before-and-after differences in SBP, DBP and eye symptoms.
Results: We observed a lower SBP (−2.0 (−4.5, 0.5) mmHg) and DBP (−1.1 (−2.9, 0.6) mmHg) among exclusive users of intervention stove, although confidence intervals included zero. Stacking or mixed use of intervention and traditional stoves contributed to a small increase in SBP 2.6 (−0.4, 5.7) mmHg) and DBP (1.2 (−0.9, 3.3) mmHg). Exclusive and mixed stove users experienced higher post-intervention reductions, on average, in self-reported eye irritation symptoms for burning sensation in eyes, and eyes look red often compared to control. Median air pollutant concentrations increased post-intervention in all stove groups, with the lowest median $PM_{2.5}$ increase in the exclusive intervention stove group.
Conclusions: Health benefits were limited due to stacking and lower-than-predicted efficiency of the intervention stove in the field. Stove adoption and use behavior, in addition to stove technology, affects achievement of health co-benefits. Carbon-financing schemes need to align with international guidelines that have been set based on health outcomes to maximize health co-benefits from cookstove interventions.

1. Introduction

High blood pressure (BP) is the leading global risk factor for premature deaths and disease burden (Forouzanfar et al., 2015). High BP is a recognized risk factor for chronic kidney (Jha et al., 2013) and cardiovascular diseases (CVD) including stroke and ischemic heart disease (Sesso et al., 2003; Glynn et al., 2002), which are among the leading causes of death and disease burden worldwide (Feigin et al., 2015; Roth et al., 2015).

High BP has many contributing risk factors, including diet, tobacco use, physical inactivity, excess body weight or body mass index (BMI), genetics, family history, stress, and alcohol (Chobanian et al., 2003; Shanthirani et al., 2003; Whelton et al., 2002). In addition, a 2010 review found moderate epidemiological evidence of an effect of short-

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https://doi.org/10.1016/j.envres.2018.06.044
Received 1 August 2017; Received in revised form 14 June 2018; Accepted 21 June 2018
0013-9351/

term (~ days) exposure to ambient fine particulate matter ($PM_{2.5}$) and increased BP (Brook et al., 2010). Both short- and long-term exposure to ambient $PM_{2.5}$ is associated with adverse fatal and non-fatal cardiovascular events (Miller et al., 2007; Mustafic et al., 2012; Shah et al., 2015, 2013).

Whereas associations between air pollution and cardiovascular events are well-established, the majority of this evidence comes from urban and traffic-related air pollution exposures. A substantial segment of the world's population (2.7 billion, mainly in rural areas) is exposed to household biomass combustion from burning of wood, cow dung, and crop residues in inefficient traditional stoves (International Energy Agency, 2011; World Energy Outlook/International Energy Agency, 2015). Exposures in these indoor settings are typically substantially higher (Bruce et al., 2006) and differing in particle chemical composition (Naeher et al., 2007) compared with urban exposures to outdoor air pollution (Brauer et al., 2012).

Several cross-sectional studies in Asia, Latin America, and Africa suggest associations between biomass derived or household air pollution (HAP) and BP (Baumgartner et al., 2011; Burroughs Peña et al., 2015; Clark et al., 2011; Neupane et al., 2015; Painschab et al., 2013), and CVD related biomarkers (Clark et al., 2009; Quinn et al., 2016; Ruiz-Vera et al., 2015; Shan et al., 2014). Only a limited number of longitudinal studies have examined effects of air pollution or cookstove interventions on BP (Alexander et al., 2017, 2015; Clark et al., 2013a; Hanna et al., 2012; McCracken et al., 2007) and indicated mixed findings with regards to the effect of PM reductions on BP with only two of these studies including a randomized population with a control group (Alexander et al., 2017; McCracken et al., 2007). A review concluded that additional evidence from longitudinal studies was needed to confirm the role of HAP on BP (Giorgini et al., 2015).

Eye irritation is a frequently reported symptom amongst traditional cookstove users. Systematic reviews indicate an association between HAP exposure and cataracts (Smith et al., 2014) and links to other measures of eye health have also been suggested (West et al., 2013). Cross-sectional studies found reduced reporting of eye irritation symptoms among users of natural gas (compared to wood fuel) and chimney clay stoves (compared to traditional stoves) (Khushk et al., 2005; Siddiqui et al., 2005). A longitudinal study in Guatemala assessed the effectiveness of a chimney wood stove intervention on eye irritation symptoms and found reduced odds of reporting sore eyes in the intervention group that corresponded with lowered blood carbon monoxide in exhaled breath (Díaz et al., 2007).

In this study, we evaluated whether a climate motivated cookstove intervention implemented by a local non-governmental organization (NGO) in rural India resulted in blood pressure and eye health benefits for women. The intervention is approved under the Clean Development Mechanism, a carbon financing scheme established under the United Nations Framework Convention on Climate Change (Chiquet, 2015). This allows greenhouse gas (GHG) emission reductions from use of higher efficiency cookstoves to be sold as carbon credits to investors to offset existing GHG emissions. Carbon financed cookstove interventions are increasing worldwide (Ecosystem Marketplace and Global Alliance for Clean Cookstoves, 2014; Lambe et al., 2015; Putti et al., 2015), and while their overarching aim is to reduce GHG emissions (Sanford and Burney, 2015), they have the potential to provide public health benefits. However, the extent of the health benefits from climate financed cookstove intervention has not been previously investigated.

Our aim was to evaluate the potential health benefits of a stove intervention that was not primarily motivated by health considerations and which was already underway (Aung et al., 2016). India is an important setting to evaluate the potential for health co-benefits as it has the largest population in the world using biomass fuels (841 million) (International Energy Agency, 2015). Hypertension and HAP are the first and fourth-highest-ranking health risk factors for mortality in India (Forouzanfar et al., 2015). Results of this study could guide intervention programs to address these two major modifiable risk factors for CVD, a leading cause of mortality and morbidity in India, and in low- and middle-income countries (Feigin et al., 2015; Institute for Health Metrics and Evaluation (IHME), 2016).

2. Methods

2.1. Setting

A carbon-financed cookstove intervention was initiated by an Indian NGO in northern Karnataka, India as part of an approved United Nations' CDM cookstove program. Details of the program are described elsewhere (Aung et al., 2016). Briefly, the NGO planned to distribute 40,000 biomass “rocket-style” cookstoves across 110 rural villages (21,500 households). As a CDM-approved program, the intervention was intended to generate saleable carbon credits attributed to carbon emission reductions; the calculated quantity of carbon emission reduction attributed to stove use was derived from laboratory-based fuel consumption measurements (where the intervention cookstoves must demonstrate reduced fuelwood use) and available estimates of the proportion of biomass burned that would have been harvested non-renewably. Sale of the carbon credits subsidized the cost of the intervention stoves.

Prior to the launch of the full CDM program across Karnataka, the partner NGO planned a pilot intervention in Hire Waddarkal (HW) Village in Koppal District, Karnataka. Of the 300 households in the HW Village, 202 met the CDM eligibility criteria (Aung et al., 2016) to participate in the intervention program.

2.2. Study design

We partnered with the local NGO prior to the start of the pilot intervention in HW Village. This allowed us to randomize distribution of the intervention cookstoves to the CDM eligible households. Of the 202 CDM eligible households, 187 homes were eligible to participate in the study (Aung et al., 2016) and were randomly assigned to either the control (n = 91) or intervention (n = 96) groups.

Baseline (pre-intervention) measurements were collected over a period of 3 months from end September to December 2011 (post-monsoon to winter season). Intervention homes received two “rocket-style” cookstoves after baseline measurements. Identical follow-up measurements were conducted in control and intervention groups over a period of 4 months from end of March to July 2012 (summer to pre-monsoon season) with a minimum of 124 days (average of 194 days) between pre- and post-intervention measurements. Control households were given the option to receive the intervention stoves at the end of the one-year study period.

2.3. Study population

Participation of eligible participants was restricted to women above age 25 years who were non-smokers and not pregnant at time of enrollment. From the 187 households, total of 247 women were eligible to participate. Upon obtaining oral informed consent, we recruited 222 women into the study who were randomized to control (n = 111) and intervention (n = 111) groups.

2.4. Intervention

Intervention stoves were single-pot “rocket-style” biomass cookstoves, with an elbow-shape insulated combustion chamber made of lightweight ceramic (See Supplemental material, Fig. S1). The stoves used the same locally available fuelwood as traditional cookstoves. Laboratory tests indicated that the intervention stoves had thermal efficiency of 30.8% – three times more than a traditional stove – and reduced fuelwood consumption by 67% relative to a traditional stove (The Gold Standard, 2011). Each household received two intervention