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A panel study of the acute effects of personal exposure to household air pollution on ambulatory blood pressure in rural Indian women

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ABSTRACT

Background: Almost half the world's population is exposed to household air pollution from biomass and coal combustion. The acute effects of household air pollution on the cardiovascular system are poorly characterized. We conducted a panel study of rural Indian women to assess whether personal exposures to black carbon during cooking were associated with acute changes in blood pressure.

Methods: We enrolled 45 women (ages 25–66 years) who cooked with biomass fuels. During cooking sessions in winter and summer, we simultaneously measured their personal real-time exposure to black carbon and conducted ambulatory blood pressure measurements every 10 min. We recorded ambient temperature and participants' activities while cooking. We assessed body mass index, socioeconomic status, and salt intake. Multivariate mixed effects regression models with random intercepts were used to estimate the associations between blood pressure and black carbon exposure, e.g., average exposure in the minutes preceding blood pressure measurement, and average exposure over an entire cooking session.

Results: Women's geometric mean (GM) exposure to black carbon during cooking sessions was lower in winter (GM: 40 μg/m^3; 95% CI: 30, 53) than in summer (GM: 56 μg/m^3; 95% CI: 42, 76). Interquartile range increases in black carbon were associated with changes in systolic blood pressure from −0.4 mm Hg (95% CI: −2.3, 1.5) to 1.9 mm Hg (95% CI: −0.8, 4.7), with associations increasing in magnitude as black carbon values were assessed over greater time periods preceding blood pressure measurement. Interquartile range increases in black carbon were associated with small decreases in diastolic blood pressure from −0.9 mm Hg (95% CI: −1.7, −0.1) to −0.4 mm Hg (95% CI: −1.6, 0.8). Associations of a similar magnitude were estimated for cooking session-averaged values.

Conclusions: We found some evidence of an association between exposure to black carbon and acute increases in systolic blood pressure in Indian women cooking with biomass fuels, which may have implications for the development of cardiovascular diseases.

1. Introduction

Household air pollution from combustion of biomass (wood, crop residues, dung) and coal for cooking are leading contributors to the global burden of disease, responsible for an estimated 3.5 million annual premature deaths (Lim et al., 2012). Over 2.8 billion people globally and 75% of Indians cook by burning biomass fuels in traditional stoves (Bonjour et al., 2013; Prasad et al., 2012; World Health Organization, 2014b). Incomplete combustion of biomass emits high concentrations of potentially toxic pollutants including particulate matter (PM), carbon monoxide, and organic compounds (e.g., formaldehyde, benzo[*a*]pyrene) (Naeher et al., 2007). In homes where biomass is used regularly for cooking, daily concentrations of indoor air pollutants can be 2–6 times higher (e.g., ranging from ~50 to 200 μg/m^3) than the World Health Organization's interim household air pollution

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guideline of 35 μg/m^3 (Clark et al., 2013b; World Health Organization, 2014a), although exposures below the guideline may still adversely affect health (Wellenius et al., 2012).

Exposure to household air pollution has well-documented adverse effects on the respiratory systems of children and adults (Smith et al., 2004). Of interest to the present study is that cross-sectional studies in adults have shown associations with a higher prevalence of carotid atherosclerotic plaque (Painschab et al., 2013), coronary heart disease, and stroke (Lee et al., 2012) in long-term users of biomass fuels as compared with users of gaseous fuels. A small number of studies by others and us suggested an association between exposure to household air pollution and higher blood pressure (Alexander et al., 2014; Baumgartner et al., 2011; Clark et al., 2013a; McCracken et al., 2007; Shan et al., 2014). Those studies were either cross-sectional or were pre-post-studies over a period of several months. Together, those studies suggested that exposure to household air pollution may contribute to the development of hypertension and cardiovascular diseases (McCracken et al., 2012), which are the leading causes of death and disease globally and in developing countries including India (Lim et al., 2012).

To our knowledge, the acute impacts of household air pollution on blood pressure have not been investigated in longitudinal or panel studies. Many of the constituents of ambient air pollution are also found in household air pollution, and experimental studies have shown that exposure to ambient air pollution was associated with increased blood pressure within hours of exposure (Kubesch et al., 2014; Langrish et al., 2009; Urch et al., 2005). Acute changes in blood pressure may increase an individual's risk of developing adverse cardiovascular events by destabilizing pre-existing atherosclerotic plaques, or by limiting normal blood flow to the heart (Brook et al., 2009). The objective of the present study was to determine whether personal exposures to black carbon, a pollutant marker of incomplete combustion from biomass, were associated with rapid changes in blood pressure among rural Indian women cooking with biomass fuels.

2. Methods

We conducted a panel study among rural Indian women in which we measured their personal, real-time (1-min resolution) exposures to black carbon and assessed simultaneously their ambulatory blood pressure every 10 min during cooking sessions in winter and summer.

2.1. Study site and population

This study was conducted in Hire Waddarkal, a village in the northern Koppal district of Karnataka, India (N 15°37′, E 76°18′). The region has a semi-arid climate and receives <600 mm of rainfall annually. Most homes in this region use biomass for cooking (Government of India Ministry of Home Affairs, 2010), and space heating is uncommon in this temperate region where winter temperatures are generally above 16 °C and summer temperatures often exceed 40 °C (Central Ground Water Board MoWR, Government of India, 2008).

At the time of our study, the village had approximately 350 homes, with an average household comprising six family members. A typical home had 1–2 rooms such that sleeping, eating, and cooking often occurred in the same room. Most houses were constructed from a combination of natural materials including mud, dung, wood, and vegetation, and processed materials including slate, cement, concrete, and bricks. Of the working population, 75% of people were agricultural labourers, 8% participated solely in other manual labour (e.g., fishing, carpentry), and 21% worked as both agricultural and manual labourers. Villagers reported working for about 47 h per week in addition to the 12–14 h per week spent collecting and preparing fuel wood for cooking and boiling water.

2.2. Recruitment of participants

The study was conducted during the post-monsoon winter season of 2011 (October 1–November 28) and in the summer and early monsoon season of 2012 (March 28–July 12). We recruited a random selection of women from a total of 187 women who were enrolled in an ongoing cookstove evaluation study (see Supplementary material). In the larger evaluation study, women were eligible to participate if they cooked and used biomass as their main cooking fuel, used a traditional cookstove, lived in a home with 10 or fewer occupants, and were willing to pay 200 rupees (~US $3) for a new cookstove. Women were excluded from the study if they were previous or current smokers, pregnant at enrolment, or younger than 25 years of age. If a household had more than one eligible woman, the woman who reported that she would be cooking on the measurement day was enrolled into this study.

Trained field staff introduced the study to eligible women and other household occupants. Women interested in participating were read the consent form and they provided oral informed consent. Of the 50 eligible women approached to participate in the study, five women declined to participate because they did not want to wear the air pollution monitoring devices. This study received ethical approval from St. Johns Medical College in Bangalore (#103/2011), the University of Minnesota (#1104S97992), and McGill University (#A11-M119-14B).

2.3. Energy use practices

Participants cooked on vented or unvented traditional stoves (*chulas*) made of cement and mud, and sometimes cooked over an open fire (Supplementary material, Fig. S1). Some women (~40%) also used a rocket stove (Chulika) obtained through enrolment in the cookstove evaluation study. All participants in our study used wood for cooking, with one home supplementing with agricultural residues and another supplementing with liquefied petroleum gas.

Cooking was typically done twice daily, with the timing and duration of cooking varying among households. Cooking in the morning started as early as 4:15 am in some households and finished around 10:00 am in others. Cooking in the evenings typically began after 4 pm and ended as late as 9 pm. In most homes, two stoves were used simultaneously to prepare a variety of foods including curries, flatbreads (e.g., roti), rice, and sambar. Additional information about participant selection, the study site, and household energy use behaviours can be found in the Supplementary material.

2.4. Data collection

2.4.1. Questionnaires

We administered household and individual questionnaires to elicit information on demographics, energy use behaviours, assets and incomes, exposure to environmental tobacco smoke, and individual health status (e.g., self-reported health, medication use). Field staff read the questions to participants in Kannada, the local language, and recorded their responses directly on the questionnaire. The questionnaire was developed in English from questions used in previous studies of household air pollution and health (Baumgartner et al., 2011), translated into Kannada, and then back-translated into English. After back-translation, the questionnaire was pilot-tested with English-Kannada speaking