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Sustained use of biogas fuel and blood pressure among women in rural Nepal

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ABSTRACT

Background: More than two fifths of the world's population cook with solid fuels and are exposed to household air pollution (HAP). As of now, no studies have assessed whether switching to alternative fuels like biogas could impact cardiovascular health among cooks previously exposed to solid fuel use.
Methods: We conducted a propensity score matched cross-sectional study to explore if the sustained use of biogas fuel for at least ten years impacts blood pressure among adult female cooks of rural Nepal. We recruited one primary cook ≥ 30 years of age from each biogas (219 cooks) and firewood (300 cooks) using household and measured their systolic (SBP) and diastolic blood pressure (DBP). Household characteristics, kitchen ventilation and 24-h kitchen carbon monoxide were assessed. We matched cooks by age, body mass index and socio-economic status score using propensity scores and investigated the effect of biogas use through multivariate regression models in two age groups, 30–50 years and >50 years to account for any post-menopausal changes.
Results: We found substantially reduced 24-h kitchen carbon monoxide levels among biogas-using households. After matching and adjustment for smoking, kitchen characteristics, ventilation status and additional fuel use, the use of biogas was associated with 9.8 mmHg lower SBP [95% confidence interval (CI), −20.4 to 0.8] and 6.5 mmHg lower DBP (95% CI, −12.2 to −0.8) compared to firewood users among women >50 years of age. In this age group, biogas use was also associated with 68% reduced odds [Odds ratio 0.32 (95% CI, 0.14 to 0.71)] of developing hypertension. These effects, however, were not identified in younger women aged 30–50 years.
Conclusions: Sustained use of biogas for cooking may protect against cardiovascular disease by lowering the risk of high blood pressure, especially DBP, among older female cooks. These findings need to be confirmed in longitudinal or experimental studies.
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1. Introduction

More than two fifths of the world's population cooks with solid fuels, mostly in poor households of low- and middle-income countries (Bonjour et al., 2013). These fuels are often burnt in inefficient stoves inside poorly ventilated houses producing high levels of several health-damaging pollutants, in particular fine particles of a diameter of up to 2.5 μm (PM2.5) and mixture of other pollutants (Rehfuess, 2006, Naeher et al., 2007). In 2012, 4.3 million deaths were attributed to household air pollution (HAP) caused by such pollutants globally (WHO, 2014). Sixty percent of these deaths were due to cardiovascular complications-ischemic heart disease (IHD) and stroke (WHO, 2014), which are also the top two leading causes of global deaths (Lozano et al., 2012). The remaining 40% were due to adverse effects on respiratory health-mainly lower respiratory tract infections among children, and chronic obstructive pulmonary disease and lung cancer among adults (WHO, 2014). The overall disease burden due to HAP is much greater among women, as they tend to be primarily responsible for cooking and therefore receive higher exposures than other family members. Estimates using data from India show that reductions in HAP to WHO guideline limits would,

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for example, eliminate sixty percent more IHDs among women than among men (Smith et al., 2014).

Evidence linking HAP to cardiovascular disease (CVD) is recent, indeed there are no epidemiological studies that directly examine how HAP exposure increases the risk of IHD or stroke, although two studies have linked HAP exposure to the risk of high blood pressure (Mccracken et al., 2007, Baumgartner et al., 2011), which is a leading risk factor for global disease burden (Lim et al., 2012). Instead, the recent burden of disease estimates provided by the Global Burden of Disease 2010 project (Lim et al., 2012) and WHO (2014) are based on a novel integrated exposure-response analysis across multiple sources of particulate matter air pollution, ranging from active and passive smoking via HAP to ambient air pollution (Burnett et al., 2014). PM2.5 from ambient air pollution and active or passive smoking is a well-recognized risk factor for cardiovascular disease (Brook et al., 2010, Pope et al., 2009). The likely effect of HAP on CVD is inferential and based on similar physical characteristics of the particulates and HAP particulate matter exposures that are located in between active smoking and passive smoking/ ambient air pollution (Smith et al., 2014).

Likewise, no epidemiological studies have assessed whether switching to cleaner fuels could potentially translate into cardiovascular health gains in cooks previously exposed to high levels of HAP for a long period. A randomized trial in Guatemala produced evidence that reduced pollutant exposure after switching from an open fire to an improved stove could lower blood pressure in adult females (Mccracken et al., 2007) but this study could not measure the associated risk of hypertension due to its before-and-after intervention study design.

In rural Nepal, more than 85% of households are reliant on biomass fuels burnt using traditional stoves (CBS, 2012). Women in these households, who for cultural reasons start cooking from an early age, are exposed to very high levels of HAP. Peak concentrations of respirable particles inside kitchens at times are as high as 60,000 $\mu g/m^3$ (Devakumar et al., 2014) while 24- h kitchen concentrations average several hundred $\mu g/m^3$ (Kurmi et al., 2013, Singh et al., 2012).

There is limited evidence on the effectiveness of currently available improved stoves in reducing HAP exposure (Albalak et al., 2001, Riojas–Rodríguez et al., 2001). Therefore, a switch to clean fuels up to the next rung of the energy ladder appears to be the only way to meet WHO Air Quality Guidelines for PM10/PM2.5. Among rural Nepalese households, who depend on subsistence farming and animal rearing, the national Biogas Support Program (BSP) has been promoting an alternative source of household fuel for the last two decades. Biogas plants rely on anaerobic digestion of organic human and animal waste inside locally built underground digesters and produce gas rich in methane. This is easily piped to the kitchen and burnt for cooking and heating purposes. Around 300,000 such biogas plants have been adopted by rural households throughout the country (AEPC, 2013). However, to date neither the impact of this program on pollutants nor its impact on health have been examined in Nepal or globally.

We therefore conducted a propensity score matched cross-sectional study to explore if the adoption and sustained use of biogas plants by households impacts pollution levels and cardio-respiratory health compared to households that have continued to use traditional wood stoves. Specifically, we hypothesized that the sustained use of biogas for at least ten years would be associated with lower systolic and diastolic blood pressure and a reduced risk of hypertension among adult female cooks. The ten years lag time of biogas use was based on the hypothesis that the chronic effects of prior HAP exposure on the respiratory and cardiovascular system could take as long as a decade to normalize after switching to cleaner fuels.

2. Materials and methods

The protocol of this study was reviewed and approved by the Ethical Review Boards of the Nepal Health Research Council (Kathmandu, Nepal) and the Oxford Tropical Research Ethics Committee (University of Oxford, UK) prior to any contact with study participants. The Ludwig-Maximilians-Universitaet Ethical Commission (Munich, Germany) granted an ethical waiver for the study after having reviewed the two granted ethical clearances.

2.1. Study site

This study was carried out in Gorkha, a hilly district of Nepal, located 140 km west of the capital Kathmandu. To avoid the unwanted effect of traffic emissions, this district was purposively selected as it had the lowest road density network among the 19 districts with the highest rate of biogas adoption. Household recruitment was undertaken in four villages (Palungtar, Chyangli, Dhuwakot and Chhoprak), home to agricultural indigenous populations and located far away from industries, asphalted roads and mechanized traffic. All these villages were below 1000 m elevation from sea level and households used a combination of fuels: wood, biogas, liquefied petroleum gas (LPG), charcoal and small amounts of crop residues depending on season. Night time temperatures even in the winter never fell below freezing so families did not use space heating.

2.2. Sampling

Although we aimed for random sampling, the hilly terrain of the four villages, which were only accessible by foot, made it impractical to conduct a rapid census and determine a reliable sampling frame for biogas as well as wood users. Instead, we did a complete enumeration of all households who met the eligibility criteria and were within a radius of two hours of walking distance from the designated center of the villages.

2.3. Sample size

This study was primarily designed to evaluate the impact of sustained biogas use on the respiratory health of female cooks and was statistically powered to detect differences in FEV1 (forced expiratory volume in one second). As a secondary outcome we assessed cardiovascular health of the cooks and was powered to detect at least 5 mmHg differences in both the systolic as well as diastolic blood pressure between the two groups.

2.4. Study population and duration

All households of the selected villages with adult female cooks of 30 years or more with at least one cattle and having primarily cooked during the last ten years or longer with either biogas or traditional wood stoves were eligible. All recruitments were done during the summer months, 20 March–12 May, 2012 and 18 April–10 May, 2013.

2.5. Blood pressure measurement

In addition to the weight and standing height, we measured brachial blood pressure of participants at their homes. An automatic blood pressure monitor (Omron SEM-1; Omron Corp, Tokyo, Japan) was used to measure systolic and diastolic blood pressure. Participants were asked to rest in a chair or an improvised chair for 5 min with their feet flat on the ground and arms uncrossed at their side. The device automatically inflated and deflated and produced SBP, DBP and heart rate. Participants were kept at ease

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