Cookstove trials and tribulations: what is needed to decrease the burden of household air pollution?

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Household air pollution arising from the combustion of dirty-burning fuels in and around the home for cooking and heating (e.g., wood, crop waste, dung, coal) is estimated by WHO to cause around 4 million premature deaths a year, mainly from cardiopulmonary diseases, making it one of the commonest underlying drivers of morbidity and mortality in low- and middle-income countries (LMIC).1 Although not included in the WHO estimates, the use of kerosene for lighting contributes additional morbidity and mortality.2 Although the latest Global Burden of Disease Study 2016 estimates a smaller number of deaths attributable to household air pollution – 2.5 million – it helpfully puts these risks in the context of other risk factors amongst which air pollution is very prominent.3

The Global Alliance for Clean Cookstoves (GACC) is a UN Foundation-sponsored organization established in 2010 with the goal of fostering the distribution of 100 million clean cooking stoves by 2020 “to save lives.” When the GACC was established, however, only two clinical trials had been conducted, and neither found that cleaner cookstoves saved lives:4,5

In 2009, Romieu I et al. reported the findings of a household-level randomized controlled trial of a chimney stove vs. continued use of a traditional open fire on the respiratory health of 552 women conducted in rural Mexico over a 10-month period.4 Unfortunately, over 50% of intervention households continued to use the open fire instead of, or in addition to, the chimney stove for cooking. No statistically significant effect was seen in intention-to-treat (ITT) analyses, although a significant effect on both cough and annual rate of decline in FEV1 (31 *vs.* 62 ml) was observed for women who reporting using the chimney stove *vs.* those who did not. A later report of the child (n=668) outcomes from this study showed only an effect on upper and lower respiratory infection duration in children of the women who mainly used the chimney stove.6

In 2011, Smith KR et al. reported the findings of a household-level randomized controlled trial (RESPIRE) of a chimney stove, similar to the one used in Mexico, *vs.* continued use of an open fire on physician-diagnosed pneumonia in 518 children <19 months of age conducted in rural Guatemala.5 No statistically significant effect on the primary outcome of physician-diagnosed pneumonia was found, although an arguably clinically more important outcome, physician-diagnosed severe pneumonia (defined by the presence of hypoxemia) was significantly reduced in the intervention children. The chimney stove intervention was reported to improve respiratory symptoms in the mothers of the study children but not rate of decline in lung function in ITT analyses, although a later analysis did find that reduced carbon monoxide exposure was associated with a lower rate of decline in FEV1.7

In this context, we conducted a community-level cluster randomized controlled trial (Cooking And Pneumonia Study – CAPS) of two cleaner burning biomass-fuelled cookstoves with a solar charger *vs.* continued use of an open fire on pneumonia in 10,750 children under the age of 5 years in two rural districts of Malawi.8 A waning in exclusive use of the intervention was seen over time although most households continued to use the intervention stoves for at least one meal a day until the end of the 2-year follow-up period. There was no effect of the intervention on the primary outcome of WHO Integrated Management of Childhood Illness (IMCI)-defined pneumonia in an ITT analysis.

Several other trials of cookstove interventions have been reported in abstract or full publication:

In 2012, Hanna R et al. reported (in a working paper but not yet in the peer-reviewed literature) the findings of a household-level randomized controlled trial of a chimney stove *vs.* continued use of traditional stoves on multiple health and other outcomes in primary cooks in a rural area of India over a 4-year period (2,651 households from 44 villages participated in the study).9 The majority of intervention households continued to use the open fire for most of their cooking needs, and no effect on any health indicators measured was seen.

In 2016, Tielsch JM et al. reported in an abstract the findings of a cluster-randomized, step-wedge, community-based trial of a cleaner-burning biomass stove on acute lower respiratory tract infections (ALRI) in 5254 children under the age of 3 years in rural Nepal.10 There was no statistically significant effect on the incidence of ALRI in the intervention *vs.* control group (RR 0.87 [95% CI 0.67 to 1.13]). Potentially beneficial effects were seen in selected secondary analyses on cough, wheeze and burn injury.

In 2017, Alexander D et al. reported the findings of a household-level randomized controlled trial of an ethanol-fuelled stove *vs.* wood or kerosene-burning stoves on blood pressure in 324 pregnant women in Ibadan, Nigeria.11 There was no significant effect of the intervention on systolic blood pressure but there was an effect seen on diastolic blood pressure (DBP) of uncertain clinical relevance (mean DBP 2.8 mmHg higher in control *vs.* intervention women).

The Ghana Randomized Air Pollution and Health Study (GRAPHS) is a three-arm household-level randomized controlled trial of liquefied petroleum gas (LPG) vs a cleaner-burning biomass-fuelled cookstove *vs.* control conditions in 1415 pregnant women on birthweight and physician-diagnosed severe pneumonia in the first year of life in a rural region of Ghana (LPG=365, cleaner biomass stove=525, and control=525).12 The full trial report is awaited but birthweight and other obstetric outcomes have been reported in abstract showing no differences between trial arms.13

Many of the clinical trials discussed here have limitations including small size, limited follow-up time, variable levels of intervention adoption, lack of focus with multiple and sometimes unclear outcome definitions, protocol deviations during the trial or at the analysis stage, failure to fully follow CONSORT reporting guidelines, long delays between trial completion and full publication and a focus on reporting positive signals from secondary rather than primary ITT analyses. That said, a type of secondary analysis of particular interest regarding the assessment of efficacy is that of exposure-response; it is important to show that putatively cleaner cookstoves actually reduce exposures in the field. Taken together, the data reported to date from trials suggest that cleaner-burning cookstoves that use biomass or cleaner fuels (*e.g.*, ethanol or LPG) do not have efficacy, by themselves, for improving human health or saving lives.

We suggest that it is time to take stock, stop investing scarce resources in interventions with unproven health benefits, and instead concentrate on generating the evidence needed to inform policy-making about open fire cooking and household air pollution. It is also time to think outside the box the cookstove comes in and tackle household air pollution – or preferably all forms of air pollution - as a whole. There is increasing evidence that addressing single contributors to household air pollution in isolation does not improve health or save lives in LMIC. Possible explanations for this include household air pollution not being as harmful as previously thought and/or cleaner-burning cookstoves that use biomass or cleaner fuels not being clean enough to achieve sufficient exposure reductions. Moreover, household air pollution reduction interventions (however clean they might be) may not be sufficient in the context of other sources of air pollution (*e.g.*, ambient and tobacco smoke) to yield beneficial health effects. A more comprehensive approach involving lighting, heating, and other sources of combustion (e.g., trash burning and motor vehicles) that would provide clean air for all to breathe both inside and outside the home as its goal is likely to be needed to achieve maximal health, and accompanying environmental, benefits.

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