Household air pollution-related lung disease: protecting the children

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Nearly 3 billion people worldwide cook and heat their homes using biomass fuels, primarily in low and middle-income countries.[1] Smoke from biomass fuel combustion contains a combination of gases, particulate matter and volatile organic compounds that is particularly harmful to the developing lungs of children.[2] Over time, chronic exposure to household air pollution results in mucus hypersecretion, emphysema and bronchiolar fibrosis,[3] and exposure to household air pollution is a well-described risk factor for both acute and chronic respiratory disease.[4–6]

The settings in which biomass smoke exposure is most common are also settings in which there is a high prevalence of reduced lung function.[7 8] A recent study of 2000 primarily non-smokers in urban Malawi found a >40% rate of abnormal lung function (primarily reduced forced vital capacity (FVC)),[9] and the largest published spirometry study in Uganda reported that 16% of adults over age 30 years had spirometry-confirmed chronic obstructive pulmonary disease (COPD).[10] There is increasing evidence that reduced lung function begins early in life[11–15]; therefore, efforts to understand and prevent chronic respiratory disease must focus on modifiable risk factors that affect lung development in infancy and early childhood.[16 17] Several studies have previously measured lung function among children in sub-Saharan Africa,[18–21] but no prior study has reported the effect of a cookstove intervention on lung function in African children. Despite a number of cookstove intervention trials, there remains a lack of conclusive evidence regarding the benefit of cookstove interventions on lung health.[22]

In this issue of *Thorax*, Rylance *et al* report the results of a cross-sectional spirometry study of 804 children aged 6 to 8 years in rural Malawi.[23] Approximately a third of children in the study were from intervention households participating in the Cooking and Pneumonia Study (CAPS), a trial of cleaner burning biomass cookstoves; the rest were either from the control arm of the CAPS trial or from households participating in the Burden of Obstructive Lung Disease study. The investigators performed spirometry, administered standardised questionnaires regarding chronic respiratory symptoms and obtained point estimates of carbon monoxide exposure. They found that half of the children had peak carbon monoxide exposures exceeding the WHO limits, that 16.6% reported chronic respiratory symptoms and that 13.0% had abnormal spirometry. They also found that children in the intervention group of CAPS had a significantly higher FVC and lower carboxyhaemoglobin compared with children in the control group.

These findings are particularly notable in the context of a recently published spirometry study that included adults participating in the CAPS trial and adults living in the same communities but not receiving the CAPS intervention. The CAPS intervention was administered over a 2-year period, and spirometry and chronic respiratory symptoms were assessed during the intervention period. In that publication, the investigators reported a 40% rate of abnormal spirometry and 13.6% rate of chronic respiratory symptoms across all participants, but having received the CAPS cookstove intervention was not associated with a difference in chronic respiratory symptoms or spirometry endpoints. Among participants in the CAPS intervention trial, there was no significant difference between the intervention and control groups in personal $PM_{2.5}$ (67.9 vs 64 $\mu g/m^3$) or CO exposure (1.13 vs 1.28 ppm).[24] Of note, across all subjects in the study (both within the CAPS trial and the surrounding community), the median personal $PM_{2.5}$ exposure was 71.0 $\mu g/m^3$ (much higher than the daily WHO recommended limit of 25 $\mu g/m^3$). In short, the study found a high rate of lung disease in all participants but was unable to demonstrate a benefit to a cleaner biomass cookstove intervention.

Other studies of the respiratory benefits of improved cookstoves have reported similarly conflicting results, including the Randomized Exposure Study of Pollution Indoors and Respiratory Effects (RESPIRE) trial in Guatemala (negative for its primary endpoint of physician-diagnosed pneumonia but positive for hypoxaemic pneumonia),[25] a trial in Mexico (reduced duration of upper and lower respiratory infections in intervention vs controls, and mothers adherent to the cookstove intervention had a lower rate of forced expiratory volume in one second (FEV_1) decline compared with controls),[26] a study in Nepal (negative for reduction in pneumonia, but reduced persistent cough and wheeze in intervention vs control)[27] and a recently published study from Rwanda (reduced parent-reported childhood acute respiratory infection but no difference in pneumonia or $PM_{2.5}$ exposure between intervention and control).[28]

Two published studies have specifically focused on childhood lung function. An analysis of children participating in the RESPIRE trial in Uganda compared children whose families received improved cookstoves earlier in the child's life with those who received them later (ie, the latter had a greater cumulative air pollution exposure). They found that those who received the intervention earlier in life had improved lung function (peak expiratory flow) growth compared with the late-intervention controls.[29] The Ghana Randomized Air Pollution and Health Study (GRAPHS) measured the effect of prenatal exposure to household air pollution on infant lung function at 30 days of life; the investigators found an association between average prenatal carbon monoxide and infant lung function, an effect that was more pronounced among girls. Infants with greater prenatal carbon monoxide exposure had a higher baseline respiratory rate, and a higher respiratory rate was associated with a greater risk of subsequently developing pneumonia.[30]

In view of the extensive observational data supporting an association between biomass cookstoves and chronic respiratory disease, why have these studies (even among different groups from the same intervention trial) come to disparate conclusions regarding the benefit of household air pollution exposure reduction on lung health? Existing trials, including the one in the present issue of *Thorax*, have been limited in several respects.

First, the interventions tested have not sufficiently reduced air pollution exposure. Thus far, published reports have primarily used improved biomass stoves, which still have significant pollution emissions. In many cases, children are exposed to additional sources of air pollution, including trash burning, lighting and ambient air

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pollution. Reducing the cookstove exposure alone is not sufficient for reaching the WHO recommended safe levels. Second, measuring long-term personal exposure to air pollution is difficult. While the investigators of the present study did not find an association between 24-hour personal CO exposure and either chronic respiratory symptoms or spirometry parameters (which were both measured after the end of the CAPS intervention study), the wide daily and seasonal variability in exposure may limit the study's ability to demonstrate an association between a point estimate of exposure and a long-term effect on lung function. Third, the studies have suffered from challenges in selecting an appropriate endpoint. Several studies have measured the incidence of WHO/Integrated Management of Childhood Illness (IMCI) pneumonia, which is known to have poor sensitivity and specificity[31]; other studies have measured the effect of cookstove interventions on spirometry, which is unlikely to reflect the short-term benefits of air pollution reduction. Studies measuring lung function among children (whose lung size and mechanics are changing rapidly during growth) may be more likely to demonstrate a benefit compared with studies measuring lung function in adults.

Further research, including the ongoing Household Air Pollution Intervention Network (HAPIN) trial (NCT02944682), will be needed to address these limitations. Future studies will need to adopt a more aggressive and holistic approach to exposure reduction, employ improved techniques for assessing personal air pollution exposure over time and consider alternative biomarkers of lung health. Given the global burden of household air pollution exposure and chronic respiratory disease, the stakes for determining the optimal strategy for preventing household air pollution-related lung disease could not be higher.

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