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Use of cleaner-burning biomass stoves and airway macrophage black carbon in Malawian women

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HIGHLIGHTS

- Sputum induction to assess airway macrophage black carbon is feasible in the field.
- Airway macrophage black carbon represents a way to assess internal dose of particulate matter exposure.
- Cleaner burning biomass-fuelled cookstoves reduce inhaled PM dose.

GRAPHICAL ABSTRACT

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ABSTRACT

Exposure to particulate matter (PM) from burning of biomass for cooking is associated with adverse health effects. It is unknown whether or not cleaner burning biomass-fuelled cookstoves reduce the amount of PM inhaled by women compared with traditional open fires.

We sought to assess whether airway macrophage black carbon (AMBC) - a marker of inhaled dose of carbonaceous PM from biomass and fossil fuel combustion - is lower in Malawian women using a cleaner burning biomass-fuelled cookstove compared with those using open fires for cooking. AMBC was assessed in induced sputum samples using image analysis and personal exposure to carbon monoxide (CO) and PM were measured using Aprovecho Indoor Air Pollution meters. A fossil-fuel exposed group of UK women was also studied.

Induced sputum samples were obtained from 57 women from which AMBC was determined in 31. Median AMBC was 6.87 μm^2 (IQR 4.47–18.5) and 4.37 μm^2 (IQR 2.57–7.38) in the open fire ($n = 11$) and cleaner burning cookstove groups ($n = 20$), respectively ($p = 0.028$). There was no difference in personal exposure to CO and PM between the two groups. UK women ($n = 5$) had lower AMBC (median 0.89 μm^2, IQR 0.56–1.13) compared with both Malawi women using traditional cookstoves ($p < 0.001$) and those using cleaner cookstoves ($p = 0.022$).

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We conclude that use of a cleaner burning biomass-fuelled cookstove reduces inhaled PM dose in a way that is not necessarily reflected by personal exposure monitoring.

1. Introduction

Exposure to carbonaceous particulate matter (PM) from the burning of biomass fuels is associated with a range of adverse health effects, including chronic obstructive pulmonary disease (COPD) in adults (Kelly and Fussell, 2011), and increased risk of pneumonia in infants and young children (Goldizen et al., 2015). Despite robust data from epidemiological studies, interventions aimed at reducing exposure to household air pollution (HAP) have not produced the expected benefits to health. First, in a randomised controlled trial in Guatemala (Randomised Exposure Study of Pollution Indoors and Respiratory Effects, RESPIRE), the provision of a woodstove with a chimney did not reduce physician-diagnosed pneumonia in young children compared with open fire using controls (Smith et al., 2011), albeit severe physician-diagnosed pneumonia was reduced in a secondary analysis. Second, in an recent open cluster randomised study in Malawi (Children and Pneumonia Study, CAPS), we found no difference in rates of pneumonia in young children from households in community clusters assigned to cleaner burning biomass-fuelled cookstoves (Philips HD4012LS; Philips South Africa, Johannesburg, South Africa) compared with continuation of open fire cooking (Mortimer et al., 2017). Possible explanations for this finding include exposure to smoke from other sources including burning of rubbish, tobacco, and income generation activities and exposure from neighbours' cooking fires since cleaner cookstoves were issued only to households that had a resident child younger than 5 years (Mortimer et al., 2017).

An important outstanding question is whether or not use of cleaner burning biomass-fuelled cookstoves reduces inhaled dose of PM in the group most exposed to HAP; i.e. women who do the family cooking. Although measuring long-term personal exposure to PM in adults by portable monitoring is not yet practical, we previously developed a method for assessing inhaled dose of carbonaceous PM by measuring the amount of carbon in airway macrophages (AMBC) obtained using sputum induction. In previous studies, we have found that AMBC is increased in biomass-exposed women in Gondar (Ethiopia) compared to UK women (Kulkarni et al., 2005), and in UK children, found that higher AMBC is associated with impaired lung function (Kulkarni et al., 2006). Although the kinetics of AMBC have not been fully defined, since AM are long-lived cells, AMBC is thought to reflect longer-term exposures (Bai et al., 2014). Since the cookstove used in the CAPS trial reduces PM emissions by about 75% compared to open fires in field tests (Wathore et al., 2017), we hypothesised that AMBC would be reduced in women randomised to the intervention arm of the CAPS trial. We therefore sought to compare AMBC in women using the cleaner cookstove with those using a traditional open fire. We recruited these two groups from women nearing end of the CAPS trial (i.e. after 20–-24 months) who were also recruited into the Malawi Adult Lung Health Study (ALHS). In order to give comparison with a non-biomass exposed population a small group of British women were also recruited.

2. Methods

This cross-sectional study recruited women from Chikwawa, one of the two sites in rural Malawi used for the CAPS trial. Chikwawa is a district in southern Malawi with a surrounding population of approximately 360,000 people, the majority of whom cook over open fires. We approached women from households included in the CAPS trial who were part of a sub-study called the Adult Lung Health Study (ALHS). ALHS was designed to address the prevalence and determinants of COPD in adults in rural Malawi and the extent to which exposure to HAP explains the rate of decline in lung function (Mortimer, 2017).

Recruitment of women to the study was carried out over 10 days. Before the study, the communication team from the Malawi Liverpool Wellcome Trust's Clinical Research Programme (MLW) visited potential participants to explain sputum induction to identify potential participants at the village level. Twenty villages closest to the Chikhwawa District Hospital that were broadly representative in structure and income of the wider CAPS trial were included. Those that expressed a wish to take part were transported to the Malawi Liverpool Wellcome Research Centre at Chilwawa District Hospital. On arrival, they were provided with group and personal level information, prior to obtaining written consent. Women underwent spirometry (Forced expiratory volume in 1 second, FEV_1, Forced Vital Capacity, FVC) and sputum induction in accordance with the American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines (Pizzichini et al., 2002). Women were excluded if they were; i) receiving treatment for active pulmonary tuberculosis, or ii) HIV positive.

The Malawi College of Medicine Research Ethics Committee (Ref P.11/12/1308) and the Liverpool School of Tropical Medicine Research Ethics Committee (Ref (Nwokoro et al., 2012).40) approved the protocol which was peer reviewed and published by The Lancet and is available in open access at www.capstudy.org. Trial registration ISRCTN 59448623 (Mortimer, 2017).

To compare AMBC in Malawian women with women exposed only to fossil fuel PM, we recruited a small group of healthy British women living in London and working at Queen Mary University of London. They were approached by the research team with written information and completed sputum inductions after written consent was obtained. The same team who did the sampling in Malawi carried out the sputum induction and processing in the UK. Ethical approval for UK controls was granted by HRA NRES Centre Manchester REC committee 13/LO/0440.

Sputum induction was done using a standardised technique using nebulised hypertonic saline (3.5% for a maximum of 20 min) (Pizzichini et al., 2002). Induced sputum samples were placed on ice, and transported to the University of Malawi, College of Medicine, Blantyre, for processing within 4 hours. In the UK sputum induction was done onsite at the Royal London Hospital and samples were placed on ice and processed within 4 hours. Specimens from Malawi and the UK were processed identically. Briefly, mucolysis was first carried out by vortexing in the presence of 0.1% Dithiothreitol, then cells are cytospun as previously described (Kulkarni et al., 2006). Slides were imaged by light microscopy at ×100 magnification in oil (Moticam1000 camera, Motic Europe or Mazurek Optical Services microscope and camera), digital images transferred to ImageJ software, and analysed for AMBC as previously described. Briefly, digital images of 50 randomly selected AM were analysed for AMBC and data expressed as mean area per AMBC per subject (μm^2) (Kulkarni et al., 2006; Brugha et al., 2015; Nwokoro et al., 2012).

Personal exposures of Malawian women to CO in mean ppm and fine particulate matter ($PM_{2.5}$) in $\mu g/m^3$ were measured over a 48-h period as part of the ALHS study using Aprovecho Indoor Air Pollution meters (Aprovecho Research Centre, OR, USA). Monitoring of CO and $PM_{2.5}$ was done once the intervention cookstoves were in place and at least one year before assessment of AMBC and are indicative of average exposures over the study time-period.

3. Study power and statistical analysis

From our previous AMBC data (Kulkarni et al., 2005), recruitment of 18 subjects in the traditional cookstove and 18 intervention cookstove