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Home environment and indoor air pollution exposure in an African birth cohort study

Aneesa Vanker [a,*], Whitney Barnett [a], Polite M. Nduru [b], Robert P. Gie [c], Peter D. Sly [d], Heather J. Zar [a]

[a] Department of Paediatrics and Child Health, Red Cross War Memorial Children's Hospital and MRC Unit on Child & Adolescent Health, University of Cape Town, Klipfontein Road, Rondebosch 7700, South Africa

[b] Centre for Infectious Disease Epidemiology and Research, Room 5.48, Level 5, Falmouth building, UCT Medical School, University of Cape Town, 7700, South Africa

[c] Department of Paediatrics and Child Health, Tygerberg Children's Hospital, Stellenbosch University, Francie van Zijl Avenue, Tygerberg 7505, South Africa

[d] Queensland Children's Medical Research Institute, and Children's Health and Environment Program, The University of Queensland, Level 4, Foundation Building, Royal Children's Hospital, Herston, Brisbane, Queensland 4029, Australia

HIGHLIGHTS

- Assessing antenatal environmental and indoor air pollution exposures
- Measuring indoor air pollution in a resource limited setting
- Association between fossil fuel use and increased pollutant levels measured
- Poor home environment and socioeconomic status
- African birth cohort study with potential impact on child health

GRAPHICAL ABSTRACT

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ABSTRACT

Background: Household indoor air pollution (IAP) is a global health problem and a risk factor for childhood respiratory disease; the leading cause of mortality in African children. This study aimed to describe the home environment and measure IAP in the Drakenstein Child Health Study (DCHS), an African birth cohort.
Methods: An antenatal home visit to assess the home environment and measure IAP (particulate matter, sulphur dioxide, nitrogen dioxide, carbon monoxide and volatile organic compounds (VOCs)) was done on pregnant women enrolled to the DCHS, in a low-socioeconomic, peri-urban South African community. Urine cotinine measured maternal tobacco smoking and exposure. Dwellings were categorised according to 6 household dimensions. Univariate and multivariate analysis explored associations between home environment, seasons and IAP levels measured.
Results: 633 home visits were completed, with IAP measured in 90% of homes. Almost a third of participants were of the lowest socio-economic status and the majority of homes (65%) lacked 2 or more of the dwelling category dimensions. Most households had electricity (92%), however, fossil fuels were still used for cooking (19%) and heating (15%) in homes. Antenatal maternal smoking prevalence was 31%; 44% had passive smoke exposure.

* Corresponding author at: Department of Paediatrics and Child Health, Red Cross War Memorial Children's Hospital, University of Cape Town, South Africa.
E-mail addresses: Aneesa.vanker@uct.ac.za (A. Vanker), Barnett.whitney@gmail.com (W. Barnett), pm.nduru@uct.ac.za (P.M. Nduru), rpg1@sun.ac.za (R.P. Gie), p.sly@uq.edu.au (P.D. Sly), heather.zar@uct.ac.za (H.J. Zar).

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Of IAP measured, benzene (VOC) was significantly above ambient standards with median 5.6 μg/m^3 (IQR 2.6–17.1). There were significant associations between the use of fossil fuels for cooking and increased benzene [OR 3.4 (95% CI 2.1–5.4)], carbon monoxide [OR 2.9 (95% CI 1.7–5.0)] and nitrogen dioxide [OR 18.6 (95% CI 3.9–88.9)] levels. A significant seasonal association was found with higher IAP levels in winter.

Conclusion: In this low-socioeconomic African community, multiple environmental factors and pollutants, with the potential to affect child health, were identified. Measurement of IAP in a resource-limited setting is feasible. Recognising and quantifying these risk factors is important in effecting public health policy changes.

1. Introduction

Household indoor air pollution (IAP) is a leading cause of morbidity and mortality globally (Gordon et al., 2014) and a major risk factor for childhood respiratory disease and for severe disease (Smith et al., 2000; Mishra, 2003; Campbell, 1997). Childhood respiratory disease, particularly pneumonia, remains the leading cause of under-5 mortality and morbidity in low- and middle-income countries (LMICs) including South Africa (Zar and Ferkol, 2014; Ferkol and Schraufnagel, 2014; le Roux et al., 2015).

The risk of exposure to IAP is particularly prevalent in LMICs where alternative fuels remain the main source of fuel for cooking and heating. Alternative fuel sources include solid fuels such as coal, biomass fuel such as wood, dung and crop residues and non-solid fuels like paraffin, liquefied petroleum and gas. Combustion of these products produces numerous by-products which contribute to household IAP (Torres-Duque et al., 2008). The risk of developing childhood pneumonia is almost doubled following exposure to indoor biomass fuels, as is the long-term risk of developing chronic lung disease in adulthood (Dherani et al., 2008; Grigg, 2009).

In South Africa, despite increased electrification of areas, up to 40% of the population still use alternative fuel sources for household activities (Barnes et al., 2009; Wichmann and Voyi, 2006). In rural areas, up to 90% of households use biomass fuels as an energy source (Barnes et al., 2009; Po et al., 2011). Home environmental factors such as crowding, type of cook stove, ventilation and duration of exposure are also important contributors to exposure levels (Gordon et al., 2014; Barnes et al., 2009). The contribution of IAP exposure to the incidence and severity of childhood respiratory disease has not been well studied in an African setting. Quantifying indoor air pollution is difficult and there are few studies that measure IAP in individual homes on a large scale in this context (Gordon et al., 2014; Dherani et al., 2008; Barnes et al., 2009).

The aim of this study was to describe the home environments and measure IAP in the Drakenstein Child Health Study (DCHS), an African birth cohort study (Zar et al., 2015). Further, we aimed to investigate the feasibility of intensive sampling in individual homes in a LMIC setting and to explore associations between home environmental factors and pollutant exposure.

2. Methods

The DCHS is located in the Drakenstein sub-district of the Western Cape, South Africa, a peri-urban area 60 km outside Cape Town (Zar et al., 2015). A prospective study to assess the home environment and household IAP exposure in participants was done from March 2011 until May 2014.

2.1. Study population and participants

This low socio-economic community accessed health care mainly in the public sector. Pregnant women were recruited from two primary health care clinics: Mbekweni (serving a predominately black African population) and Newman (serving a predominately mixed race population). Consenting pregnant women were enrolled between 20–28 weeks' gestation. Mothers completed study questionnaires and provided urine for analysis of urine cotinine as a measure of smoking and smoke exposure. Urine cotinine was measured using the IMMULITE® 1000 Nicotine Metabolite Kit (Siemens Medical Solutions Diagnostics®, Glyn Rhonwy, United Kingdom). This provides a quantitative test using a competitive chemiluminescent immunoassay, which contained solid-phase beads coated with polyclonal rabbit anti-cotinine antibody (Siemens, 2009). Urine cotinine levels were classified as <10 ng/ml (non-smoker), 10–499 ng/ml (passive smoker), or ≥ 500 ng/ml (active smoker).

2.2. Assessment of home environment and indoor air pollution (IAP) exposures

Self-reported questionnaires were administered at enrolment by trained staff. A self-reported assessment of socioeconomic status (SES) adapted from the South African Stress and Health Study (SASH) was done (Stein et al., 2007). A composite SES score was developed based on current employment status and standardised scores of educational level, household income and a composite asset index made up of access to household resources, amenities and market access categorising participants as being lowest SES, low-moderate SES, moderate-high SES or high SES.

Home visits for assessment of the home environment and measurement of IAP were done antenatally within 4 weeks of enrolment. Both primary health care clinics, Mbekweni and Newman, had a dedicated team of two environmental fieldworkers trained to undertake home visits, administer questionnaires and set up equipment for IAP measurement. Field worker training was completed under the supervision of an accredited environmental laboratory (SGS Environmental Services®). Each participant received an information leaflet reviewing the reasons for the home visit and the measures being conducted. Data were gathered on type of home, its position and size, number of inhabitants, access to basic amenities, fuels used for cooking and heating, ventilation within homes and pesticides/cleaning materials used based on validated questionnaires (Moraes et al., 2015; Ribas-Fitó et al., 2006; Chen et al., 2011; Asher et al., 1995; Levine et al., 2012). An implementation of the Alkire-Foster method, a flexible technique used to incorporate a number of dimensions of poverty or well-being, that can complement poverty assessment (Alkire and Foster, 2011a; Alkire and Foster, 2011b) was applied to the dwelling characteristics. Six dwelling factors were used; type of home (formal versus informal), primary building material (brick or cement versus other materials), water supply (piped into dwelling or yard), toilet facilities (non communal flush), kitchen type (separate room in house) and ventilation in the kitchen area (pipe or duct to exterior). Dwellings were then categorised according to the number of dimensions lacking. This method defines a dwelling as a “poor structure” if it lacks one-third or more of the factors considered. Size of the kitchen and main living room were measured using an ultrasonic measuring tool. The position of the home in relation to the road and passing traffic was also estimated.

The most common IAP was measured (Table 1). All measurements were done in the communal/main living room, away from windows and doors, approximately 1.5 m from the ground. Devices were left in the home for 24 h to 2 weeks depending on the measurement (Table 1).