Chapter 6

POTENTIAL IMPACT OF COOKING AND HEATING FUEL USE ON ACUTE RESPIRATORY HEALTH OF PRESCHOOL CHILDREN IN SOUTH AFRICA

Background: Dependence on polluting fuels (wood, coal, crop residues, animal dung, paraffin) for cooking and heating exposes countless women and young children in developing countries to elevated air pollution concentration indoors. This study explored the connection between polluting fuel use for cooking and heating with childhood (<5 years) acute respiratory infections (ARI) in South Africa.

Methods: Analysis is based on data from 4 679 children living in 2 651 households collected during the 1998 South African Demographic and Health Survey. Cases were defined as those who experienced cough accompanied by short, rapid breathing during the 2 weeks prior to the survey. Logistic regression was applied to estimate the odds of suffering from ARI among children from households using high (wood or dung in combination with other fuels) and medium polluting fuels (coal or paraffin in combination with electricity or liquid petroleum gas/natural gas) relative to those from households using electricity or liquid petroleum gas/natural gas exclusively, after controlling for potentially confounding factors.

Results: Two-thirds of children lived in households using high and medium polluting fuels. Nineteen percent suffered from ARI. After adjustment, children in households using high and medium polluting fuels for cooking and heating were 26-29% more likely to have an ARI event than children from households using cleaner fuels (OR 1.26; 95% CI : 1.00-1.58 and OR 1.29; 95% CI : 1.02-1.62, respectively).

Conclusions: Although there is potential for residual confounding despite adjustment, the better documented international evidence on indoor air pollution and ARI suggests that this association may be real. As nearly half of households in South Africa still rely on polluting fuels, the attributable risk arising from this association, if confirmed, could be substantial. It is trusted that more detailed analytical intervention studies will scrutinise these results in order to develop integrated intervention programmes to reduce children's exposure to air pollution emanating from cooking and heating fuels.

6.1 Introduction

The ultimate endeavour of epidemiology is to identify modifiable determinants of disease occurrence and progression and to contribute in testing the efficacy and effectiveness of interventions on these determinants.

A study conducted in 1990 reported that acute respiratory infections (ARI)(such as pneumonia) were then the principal cause of death amongst young children in large parts of South Africa.[1] This is supported by international findings that ARI are a leading cause of childhood illness and death worldwide, accounting for an estimated 6.5% of the entire global burden of disease.[2] In addition there is no simple and rapid treatment for ARI as is the case with diarrhoeal disease and oral rehydration therapy.

Respiratory ill health is the main reason for use of the health services in the country. However, much of what must be done to prevent respiratory symptoms and diseases lies outside of the sphere of health care. Therefore interventions should be targeted at risk factors and determinants, rather than only providing medical treatment for those already affected. South Africa, a middle income country, is faced by health risk factors from a First World situation (e.g. industry, traffic, aging population) along those from a Third World situation (e.g. domestic burning of wood, animal dung, crop residues, coal and/or paraffin, poor sanitation, overcrowding). Thus intervention strategies deduced from studies conducted in developed countries are not merely applicable in this country.[3]

Wood, animal dung, coal, crop residues and paraffin (hereafter "polluting fuels") are at the bottom of the energy ladder regarding combustion efficiency and cleanliness, yet 41%, 48% and 23% of 11 million South African households used these polluting fuels for cooking, heating and lighting, respectively during 2001, even when access to electricity was available.[4,5] Smoke from fossil and biomass combustion produces numerous air pollutants that are detrimental to health, including respirable particulate matter (RSP, PM_{10}), carbon monoxide (CO), nitrogen oxides (NO_x), formaldehyde, benzene, 1,3 butadiene, polycyclic aromatic hydrocarbons (PAHs)(such as the carcinogen benzo[a]pyrene, B[a]P), and many other toxic volatile organic compounds

(VOCs). The fuels are typically burned in simple, inefficient and mostly unvented household cookstoves, which, combined with poor ventilation, generate large volumes of smoke indoors. A local study by Thomas et al reported that on average 14% of households had children (<6 years) usually or always present when their mothers were cooking.[6] This percentage increased to 18.3% of households in the lowest wealth quintile. Paraffin stoves were burning in the lower wealth quintile homes on average 4 hours per day, with the evening meal taking over half of this time to prepare. Muller et al established in a local study that people spend on average 2 hours cooking indoors during both winter and summer.[7] Consequently children and women are exposed to much higher air pollution levels indoors than from outdoor sources.

Bailie et al conducted an indoor exposure assessment study during winter in a poor urban environment in South Africa where a range of fuel types, including paraffin, was used.[5] The mean maximum hourly average was 28 $\mu g.m^{-3}$ (range 0–451 $\mu g.m^{-3}$) for NO_2, 1 414 $\mu g.m^{-3}$ (range 0-17 723 $\mu g.m^{-3}$) for SO_2 and 34 $mg.m^{-3}$ (range 0-388 $mg.m^{-3}$) for CO. The number of households where standards were exceeded by the maximum hourly averages by NO_2 and CO was six (9%) and 20 (30%) respectively (Hourly WHO standard of 200 $\mu g.m^{-3}$ and 30 $mg.m^{-3}$, respectively) and for SO_2 the number was 28 (42%) (Hourly Californian standard of 655 $\mu g.m^{-3}$)(no WHO or US EPA standard for maximum *hourly* average for SO_2 exists).[8,9] Total suspended particulates (TSP) concentrations ranged from a minimum of 7 $\mu g.m^{-3}$ to a maximum of 433 $\mu g.m^{-3}$. Comparisons of TSP concentrations with international standards have not been made, as these are now focused on PM_{10} and $PM_{2.5}$ particles. No *hourly* standards or guidelines also exist for PM_{10} and $PM_{2.5}$. Röllin et al provided scientific evidence that even in partially electrified homes in South Africa levels of RSP were significantly lower (mean 77 $\mu g.m^{-3}$, median 37.5 $\mu g.m^{-3}$) relative to their non-electrified counterparts (mean 162 $\mu g.m^{-3}$, median 107 $\mu g.m^{-3}$)(p=0.012) during summer.[10] Stationary (kitchen CO) levels in un-electrified and electrified dwellings ranged from 0.36-20.95 ppm and 0-11.8 ppm, respectively. The mean level of log (CO) in the kitchen was significantly higher in the un-electrified areas (1.25 vs. 0.69) (p=0.0004). The mean level of log (CO) for personal measurements conducted on children (<18 months) was higher in the un-electrified areas (0.83 vs. 0.34) ($p<0.0001$).

The mechanisms by which polluting fuel smoke can boost the risk of ARI is not entirely known, however exposure has been associated with diminished pulmonary immune defence mechanisms.[11-14] Tobacco smoke also has been indicated to cause poor immune system responses.[15-19] Exposure to one of the numerous pollutants in biomass smoke, PM_{10}, has been reported to provoke a systemic inflammatory response that includes stimulation of the bone marrow, which can play a role in the pathogenesis of the cardiorespiratory morbidity. [11-14] Exposure to PAH, especially B[a]P, can cause immune suppression and can raise the risk of infection and disease.[15-17] Acute and chronic exposures to NO_x can increase bronchial reactivity and susceptibility to bacterial and viral infections.[18,19] It is thus probable that persistent exposure to high levels of polluting fuel smoke can weaken the pulmonary defence mechanisms, reduce lung function and intensify children's susceptibility to ARI.

International studies have reported strong associations between exposure to polluting fuel smoke and ARI in preschool children.[20-23] However, a few studies of preschool children have failed to find a relationship between polluting fuel smoke and ARI.[24,25] Notwithstanding warnings of high levels of indoor air pollution in informal and traditional housing in South Africa, barely any comprehensive epidemiological studies have been embarked on in the country. Two local studies established a significant link with indoor air pollution indicators and respiratory health of preschool children[26,27], whilst two other local studies did not.[28,29] Wichmanna and Voyi concluded in a review that most of the local studies have dealt inadequately with confounding factors.[30] It is thus advisable to apply caution when interpreting results from local studies.

The current study will attempt to add to the current body of knowledge regarding indoor air pollution exposure and respiratory health of preschool children. The study is based on the 1998 South African Demographic and Health Survey (SADHS).[31] The 1998 SADHS is the first national health survey conducted across the entire country. Data from this survey provided the opportunity to examine the prevalence and determinants of various respiratory symptoms and diseases in a representative national population rather than a selected high risk population, as has been the case in most previous studies in developed countries.

This study examines the association between household use of fuels for cooking and heating and ARI prevalence in children (< 5 years), whilst considering a number of confounders or effect modifiers. It is trusted that more detailed analytical intervention studies will scrutinise these results in order to develop integrated intervention programmes to reduce children's exposure to air pollution emanating from cooking and heating fuels.

6.2 Materials and methods

6.2.1 Survey method

The 1998 SADHS had a cross-sectional design and was a national household survey of the population living in private households in all 9 provinces of South Africa. Detailed information on the survey design is outlined elsewhere.[31] The sampling frame for the SADHS was the list of approximately 86 000 enumeration areas (EAs) created by Central Statistics (now Statistics South Africa, SSA) for the Census conducted in October 1996. The EAs, ranged from about 100 to 250 households and were stratified by 9 provinces, urban and non-urban residence and by EA type. The number of households in the EA served as a measure of size of the EA. The first stage (proportional stratified sampling) of the two-stage sampling led to a total of 972 enumerator areas (EAs) being selected for the SADHS (690 in urban areas and 282 in non-urban areas). The second stage involved a systematic random sample of 10 and 20 houses in selected urban and rural EAs, respectively. Oversampling was conducted in some areas to enable inference to be made about differences across provinces and race – and in the Eastern Cape province, across health districts.

In addition to the main survey of households a women's health questionnaire was administered individually to women (15-49 years) in all the households selected for the main survey (Refer to Appendices 1 and 3). The SADHS questionnaires were translated into 9 of the 11 official languages of South Africa and checked by backtranslation.[31]

The questionnaires were pretested in November/December 1996 as part of a pilot study.

Interviewers were trained over several weeks. Interviews were conducted after working hours. Interviewers were instructed to return twice if a suitable respondent was not found at home. Fieldwork commenced late January 1998 and was completed in September 1998. The response rate at the household level was 97% of 12 860 households in 966 EAs. For the women's health survey, the overall response rate was 92.3%.

Ethical approval was granted by the Ethics Committee of the South African Medical Research Council to conduct the 1998 SADHS. The survey obtained informed consent from each respondent (in this case, mothers of the children included in the women's health questionnaire) before asking questions. The analysis presented in this paper is based on existing survey data with all identifying information removed.

6.2.2 Health outcome, exposure and confounder variables

For each child (<5 years), the mother was asked if the child had been ill with coughing in the 2-week period preceding the survey interview. For children who had been ill with coughing in the last 2 weeks, the mother was additionally asked if the child, when ill with coughing, breathed faster than usual with short, rapid breaths. Children who suffered from coughing accompanied by short and rapid breathing at any time during the last 2 weeks are defined as having suffered from an acute respiratory infection. This reported prevalence of ARI is the response variable in our analysis.

Exposure to cooking and heating smoke was ascertained indirectly by type of fuels used. This was the main independent variable. The survey question was, 'What does your household use for cooking and heating?' Respondents indicated all the different fuel types that were used. The households were grouped into three categories representing the extent of exposure to cooking and heating smoke—high pollution fuels (if either wood or dung was used in combination with paraffin, coal, liquid petroleum gas (LPG)/natural gas or electricity), medium pollution fuels (if either paraffin or charcoal was used with LPG/natural gas or electricity) and low pollution fuels (if LPG/natural gas or electricity was used exclusively).

Confounders pertaining to a child included: age (in months, categorised in 5 groups), sex, birth order (categorised in 4 groups) and number of children in the household. Confounders related to the biological mother of a child included: age at birth (in years, categorised in 3 groups), education (in years, categorised in 3 groups) and ethnic identity (Africa/Black, White, Coloured, Asian/Indian). Under Apartheid, South Africans were categorised into one of four socially defined groups: White (mainly European ancestry), Asian (Indian sub-continent ancestry), African or Black (descent primarily from one of a number of Bantu ethnic groups in Southern Africa) and Coloured (general grouping, including a mixture of Black, Malay, European and indigenous Khoisan ancestry). Race is very much linked to past access to resources, socio-economic status and educational status. Household standard of living index (SLI) is calculated by using the approach of Mishra by adding the following scores: 3 for a car or tractor; 2 each for a scooter/motorcycle, TV, telephone, refrigerator, piped/public tap water, flush toilet, electricity, wood/vinyl/asphalt/ceramic/cement/carpet of main floor material; 1 each for a bicycle, radio.[32] Index scores range from 0–2 for low SLI, 3–8 for medium SLI, 9–21 for high SLI.

The location of the household was categorised on an urban/rural level.

6.2.3 Data analysis

Data from the household and women's health questionnaires were merged in this analysis. The merged data file had 5 093 observations. Statistical analyses were conducted using STATA version 8. A small residual category of other fuels used for cooking and heating (n=6, 0.13% of the sample, N=5 093) was excluded from the analysis due to unknown nature of fuels in that category. All children from multiple births (n=133, 2.61% of the sample, N=5 093) were excluded from the analysis as well as all children who had passed away (n=269, 5.28% of the sample, N=5 093). Eventually 4 679 children from 2 651 households were included in the analyses. The 1998 SADHS report pointed out that the risk factors might be correlated with each other.[31] Independence among risk factors was investigated with χ^2 tests. It was observed that most of the risk factors were significantly correlated at the 95% confidence level, although very poorly with correlations coefficients varying from 0.01 to 0.40. Consequently conventional logistic regression analysis was conducted, instead of a conditional analysis. Simple descriptive statistics were used to describe the characteristics (TAB command) of the sample and in calculating the prevalence of ARI for each characteristic (SVYTAB command).

The crude odds ratio (OR) and adjusted OR along with 95% confidence intervals (CI) were derived using the SVYLOGIT procedure. A weighting factor was applied to all observations to compensate for over-sampling of certain categories of respondents in the study design. The estimation of CI accounts for design effects due to clustering at the EA, provincial and household level. The adjustments for clustering at the EA and provincial levels were done using the SVYSET command.

6.3 Results

The data presented here represent a more detailed analysis of the first national survey of the symptoms and prevalence of ARI amongst preschool children in South Africa. Table 1 lists the characteristics of the 4 679 children from 2 651 households.

Nearly 40% of children live in households that use high polluting fuels compared to 27% and 34% who live in households using medium and low pollution fuels, respectively (Table 1). Children are relatively equally distributed by sex. Children aged 0-11 months are somewhat less represented compared to the other age groups. The percentage of children in the sample decreases from birth order 1 to 3. A quarter of children are born at birth order >3. Less than half of the children live in homes with other children (43%). Approximately the same number of children is born to mothers aged 15–24 and 25-34 years. More than half (57%) of them have mothers with 3-6 years of education at the time of the survey. The majority of the children (48%) live in high standard of living households, followed by medium (36%) and low (16%) SLI homes.

Table 1 Sample distribution of South African children (<5 years) by selected characteristics, reported prevalence of acute respiratory infections (ARI) during the 2 weeks preceding the survey and crude odds ratios

Characteristic	Sample distribution (%)	ARI prevalence (%)	OR (95% CI)
South Africa	-	19.26±3*0.76	-
Cooking and heating fuel type			
Low polluting*	33.71	16.24	-
Medium polluting	26.86	19.32	1.28 (1.02-1.61)
High polluting	39.43	18.68	1.25 (1.00-1.57)
Age of child (in months)			
0-5*	10.86	18.90	-
6-11	10.84	23.08	1.24 (0.90-1.71)
12-23	20.39	22.54	1.15 (0.85-1.56)
24-35	19.81	18.02	0.89 (0.65-1.23)
36-59	38.11	13.91	0.65 (0.48-0.88)
Sex of child			
Boy*	50.37	17.82	-
Girl	49.63	18.22	1.08 (0.92-1.28)
Birth order			
1*	33.70	17.88	-
2	24.56	17.75	1.06 (0.84-1.33)
3	15.26	19.61	1.16 (0.89-1.50)
>3	25.48	17.51	0.97 (0.75-1.24)
Number of children per			
household	56.66	19.95	-
1*	43.34	15.48	0.70 (0.57-0.85)
>1			
Mother's age at childbirth			
15-24*	39.90	18.05	-
25-34	42.62	18.30	1.01 (0.83-1.22)
35-49	17.48	17.24	1.01 (0.76-1.33)
Mother's education (in years)			
<3*	24.11	20.21	-
3-6	57.47	17.78	0.96 (0.77-1.20)
>6	18.42	15.89	0.86 (0.64-1.14)
Ethnic identity			
Black/African*	80.81	17.77	-
Coloured	11.97	18.39	1.02 (0.78-1.33)
White	4.38	21.46	1.36 (0.86-2.16)
Asian/Indian	2.27	16.98	0.95 (0.49-1.84)
Household standard of living			
Low*	16.03	17.73	-
Medium	36.25	17.87	0.97 (0.70-1.34)
High	47.72	18.23	0.99 (0.73-1.34)
Residence			
Urban*	45.18	18.07	-
Rural	54.82	17.97	1.06 (0.88-1.29)
Number of children	4 679	4 679	4 679

** Reference category*

Roughly the same number of children lives in urban and rural areas. The majority of the children are classified as African/Black, followed by 12% as Coloured, 4% as White and 2% as Asian/Indian. The survey population does not quite reflect the ethnic make-up of the South African population (all ages) for Whites and Coloureds according to the 2000 Census data (Africans (77.2%), Whites (10.5%), Coloureds (8.8%) and Indians (2.5%).[4]

Nineteen per cent of children (<5 years) had an ARI event during the 2 weeks preceding the survey. The reported prevalence of ARI is somewhat higher among children living in dwellings using medium and high polluting fuels (19%) than among those living in households using low polluting fuels (16%) (Table 1). Children aged 6–23 months are somewhat more probable to have experience an ARI event than children under 6 months of age or older children.

The reported prevalence of ARI is higher for White children compared to the other ethnic groups. Children living in households with other children are less prone to have an ARI event (15% compared to 20%). Children with birth order 3 have a higher prevalence rate of ARI compared to the other groups (20% compared to 18%). Children whose mothers have less than 3 years of education at the time of the survey have more ARI events compared to the other groups. Prevalence of ARI does not fluctuate much by sex of child, mother's age at childbirth, household SLI or urban/rural setting.

Of all the variables, only cooking and heating fuel type, age of child and number of children in households are significantly associated with ARI in the unadjusted analyses (Table 1). Children living in households using medium and high polluting fuels are 25-28% more likely to have an ARI event compared to those living in households using low polluting fuels for cooking and space heating (OR 1.28; 95% CI : 1.02-1.61 and OR 1.25; 95% CI : 1.00-1.57, respectively). Children aged 36-59 months are 35% less likely to have an ARI event compared to the other age groups (OR 0.65; 95% CI : 0.48-0.88). Children living in households with other children are 30% less likely to have an ARI event (OR 0.70; 95% CI : 0.57-0.85).

In the adjusted analysis, high polluting fuel use (OR 1.29; 95% CI : 1.02-1.62), the oldest child age category (OR 0.66; 95% CI : 0.49-0.89) and having more than one child living in a household (OR 0.69; 95% CI : 0.56-0.83) are statistically associated with ARI (Table 2).

Table 2 Adjusted odds ratio estimates of cooking and heating fuel type and other risk factors on acute respiratory infection (ARI) among South African children (< 5 years)

Characteristic	OR (95% CI)
Cooking and heating fuel type	
Low polluting*	-
Medium polluting	1.26 (1.00-1.58)
High polluting	1.29 (1.02-1.62)
Age of child (in months)	
0-5*	-
6-11	1.27 (0.92-1.76)
12-23	1.15 (0.84-1.56)
24-35	0.87 (0.63-1.20)
36-59	0.66 (0.49-0.89)
Number of children in household	-
1*	0.69 (0.56-0.83)
>1	
Number of children	4 679

* *Reference category*

6.4 Discussion and conclusions

ARI has been identified as a severe problem in South Africa, particularly for children under 5 years of age.[1] There is also a strong case for acknowledging the large public health risk arising from indoor air pollution exposure due to continued reliance on polluting fuels for cooking and heating in South Africa. Results of this study suggest that exposure to cooking and heating smoke from high polluting fuels is significantly associated with ARI prevalence in young children, independent of a child's age or the number of children in a household.

The adjusted risk estimates for the type of fuel use are consistent with other South African studies that investigated the risk of indoor fuel use and ARI in children

(<5 years).[26,27,33] This study therefore provides further evidence that cooking and heating homes with especially high polluting fuels can amplify the risk of ARI in young children.

Dudley et al investigated the impact of indirect indicators of air pollution on human health.[26] Dudley et al also focused on low vitamin A levels as a risk factor for respiratory infection. [26] The results revealed differences in risk between sever and mild cases of acute respiratory infection in respect of housing conditions (OR=4.2; 95% CI=1.3-14.5) and possession of clinic report card (OR=3.4; 95% CI=1.0-11.5). Mild cases were more likely to have had a previous ARI than the controls (OR=3.2; CI:1.0-10.1). The mothers of severe cases were more likely to be under 20 years old (OR=9.9; 95% CI=1.1-228) and the sever cases were more likely to have had a hospital admission the previous 6 months (OR=5.5; 95% CI=1.2-33.4), poorer housing conditions (OR=7.9; 95% CI=2.2-29.9) and not to have electricity (OR=4.9; 95% CI=1.6-16.2).

The study performed by Von Schirnding et al was based in the major urban and peri-urban areas of the country.[27] The main aim of the project was to examine the impact of environmental risk factors associated with housing on diarrhoeal disease and acute respiratory infections (ARI). The study results were reported on a national level. The presence of more than one adult smoking in a household significantly increased the likelihood of coughing and breathing problems (OR=2.0; 95% CI=1.3-3.3). Other potential risk factors of coughing and breathing problems included: not using electricity (OR=1.7; 95% CI=1.1-2.5); using gas, paraffin, coal or wood as cooking fuels (OR=1.7; 95% CI=1.3-2.5); using gas, paraffin, coal or wood as heating fuels (OR=2.0; 95% CI=1.7-3.3); not owning a refuse bin (OR=2.4; 95% CI=1.1-5.0); not having a chimney in the home (OR=1.8; 95% CI=1.3-2.5); child younger than 2 years (OR=1.3; 95% CI=1.0-1.8), low income per household (OR=1.5; 95% CI=1.1-2.2) and low maternal school education level (OR=1.7; 95% CI=1.2-2.4).

Sanyal and Maduna determined the levels of indoor gaseous pollutants and their impact on the respiratory health of children.[33] The study established that high levels of recurring ARI among children were most prevalent in the very low and low income households using wood and coal as the main source of heating.

There are some important limitations in this study, which should be considered when interpreting the results. The SADHS had a cross-sectional design. Cross-sectional studies are weak to prove causation as they are subject to difficulties interpreting the temporal sequence of events since health status and determinants are measured simultaneously. However, the biological plausibility of exposure to smoke from medium and high polluting fuels has been addressed.[11-19]

Reliance on self-reported data does include a risk of misclassification of disease and exposure status resulting in statistical significance arising by chance. Information on ARI is based on mothers' reports and no clinical measurements were undertaken and smoke exposure was ascertained from type of fuel used for cooking and heating. Although the symptomatic definition used here is aimed to assess acute lower respiratory infections (ALRI) in children, some acute upper respiratory illness may have been integrated in the conveyed prevalence. As it is impossible to separate ALRI from these data, the term ARI is used in this study, not ALRI. In developing countries such as South Africa, where clinical data on ARI are frequently unattainable or very weak, the symptomatic definition of illness used here is assumed to present a reasonably accurate estimation of ARI in the population.

Notwithstanding the lack of measurement of air pollution exposure and ARI, the uniformity in the significance of crude and adjusted effects of polluting fuel use on childhood ARI implies a probable 'exposure–response' relationship as the adjusted odds of experiencing ARI increased from 1.26 (95% CI : 1.00-1.58) to 1.29 (95% CI : 1.02-1.62) (Table 2) when using medium polluting fuels and high pollution fuels compared to low polluting fuels, respectively.

Differential and/or nondifferential misclassification may have influenced the risk estimates. Many households in South Africa in general use a combination of cooking and heating fuels. The calculated effects may be underestimated if only considering using high polluting fuels (wood and dung) exclusively and not in combination with paraffin, coal, LPG/natural gas and/or electricity. This is also expected using medium polluting fuels (paraffin, coal) exclusively and not in combination with LPG/natural gas and/or electricity. However, none of the households under investigation used wood or dung exclusively or paraffin or coal exclusively. No quantitative exposure assessment (including duration of exposure, as reflected by frequency and duration of fuel use for heating and cooking per day) was conducted during the SADHS. It is recommended that future SADHS should separate the type of fuels use for cooking and heating in two separate questions. Exposure to smoke from polluting fuels during heating is much longer than exposure during cooking.

Given the high prevalence of ARI and relatively small number of deaths in the sample (n=269, 5.28% of the sample, N=5 093), the impact of selection bias in the sample due to ARI-related mortality on the estimated effect is likely to be little. If such bias is prominent, the risk estimates of effect of cooking and heating fuel smoke on ARI will be downwardly biased as children living in households using medium and high polluting fuels are more likely to die from ARI.

It was found that children who have received treatment for ARI are more likely to have suffered from ARI than not (64% compared to 5%). So there is little bias due from underreporting of ARI due to lack of awareness that the child had an ARI event during the 2-week reference period. This is supported by Kauchali et al who conducted a local rural study on maternal perceptions of childhood ARI (<5 years).[34] They reported that maternal recognition of respiratory distress was good (sensitivity 91.3%, 95% CI : 86.8-95.8%; specificity 95%, 95% CI : 89.5–100%), with little variation between mothers (kappa = 0.704).

Other factors that might contribute to childhood ARI, such as outdoor and indoor air pollution sources (e.g. mother's smoking status, location of household close to industry, transportation sources or waste fill sites, insecticide or fertiliser use, allergens such as pollen, dust, fungal spores from mildew and moulds) along with meteorological variables (precipitation, temperature, humidity), mother's pre-pregnancy weight, child's birthweight, mother's exposure to other pollution sources and risk factors during pregnancy as well as the current HIV/AIDS epidemic were not recorded. Excluding these risk factors from the analysis might introduce substantial bias (differential or nondifferential). Thus the direction of bias on the calculated association measures is not easy to predict. The definition of a confounder is important to remember: it must be associated with both the exposure variable of interest and the health effect. As the association between these unaccounted potential factors and polluting fuel use is not available from the literature, it is impossible to predict the direction of the potential bias on the association measure.

The most common indicators used for measurement of socioeconomic status are income level, occupation and educational level.[35] We cannot rule out that the results would have been different with another measure. However, Demographic and Health Surveys traditionally do not include questions on income and expenditure. Educational level measures one aspect of socio-economic status and we cannot rule out that the results would have been different with another measure. More than a third (35%) of the women never married, so we could not assume that the current partner's job or education remained the same during the 5 years preceding the survey. Mishra analysed the Zimbabwean DHS data and calculated a household standard of living index as a possible confounder in the association between household cooking fuel use and ARI in preschool age children (<5 years).[32] In this study a similar approach was followed.

The current HIV/AIDS epidemic along with escalating number of TB infections could also influence the association between ARI and exposure to smoke from polluting fuels. The TB prevalence rate was low amongst household members clinically diagnosed with the disease (2%) and did not indicate an association with ARI amongst preschool children (results not shown).

During the analysis it was assumed that confounding is additive and not multiplicative. If confounding is additive, then the confounding variable would produce the same additional risk of a health outcome in the exposed and unexposed; but if the health outcome is rare in unexposed, it would follow that the confounder might account for a much larger proportion of health outcome in that group. Conversely, if two exposures act multiplicatively, the proportional increase in health outcome rates due to confounding would be the same in exposed and unexposed; but if the health outcome is more prevalent in the exposed group, the absolute increase would be larger in the exposed. This issue thus has important risk assessment and public health policy implications.

The generalisibility of data is determined by the non-response rate. The response rate was larger than 90% for both the household and women's health surveys. Thus the bias that might be introduced by non-response is relatively low for the SADHS data.

Wichmann and Voyi concluded that most of the local studies on this topic are fraught with systematic and random errors, with limitations similar to this study.[30] However, this study had the advantage of controlling for more possible confounders than previous local studies. In order to improve health for the unique South African population through epidemiological studies it is imperative that these studies should attempt to minimise systematic and random errors and subsequently strengthen their validity and accuracy. It is hoped that future analytic studies will validate and improve the understanding how smoke from paraffin, coal, wood and dung detrimentally impacts on children's respiratory health in South Africa. Such research is important because a large proportion of households in South Africa and other developing countries rely on biomass fuels for household energy and ARI are a leading cause of ill health and death in young children.

However, given the fact that only 5% of the research budget is spent on health related research in South Africa, compared to 30% in developed countries, it is important that analytical studies should not merely redocument the impact of known risk factors.[36] Instead, such studies should provide a basis for designing technical or socio-behavioural interventions to minimise exposure to air pollution from cooking and heating fuels, such as the study by Smith-Sivertsen et al.[37] They conducted the very first ever published randomised control intervention trail in a poor rural community in Guatemala. South African intervention studies should include a comprehensive exposure assessment with indoor and personal measurements for SO_2, NO_2, O_3 and $PM_{2.5}$ and a detailed health assessment.

6.5 References

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