The effect of housing characteristics and occupant activities on the respiratory health of women and children in Lao PDR

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Abstract

The paper presents the results of a study conducted into the relationship between dwelling characteristics and occupant activities with the respiratory health of resident women and children in Lao People's Democratic Republic (PDR). Lao is one of the least developed countries in south-east Asia with poor life expectancies and mortality rates. The study, commissioned by the World Health Organisation, included questionnaires delivered to residents of 356 dwellings in nine districts in Lao PDR over a five month period (December 2005-April 2006), with the aim of identifying the association between respiratory health and indoor air pollution, in particular exposures related to indoor biomass burning. Adjusted odds ratios were calculated for each health outcome separately using binary logistic regression. After adjusting for age, a wide range of symptoms of respiratory illness in women and children aged 1-4 years were positively associated with a range of indoor exposures related to indoor cooking, including exposure to a fire and location of the cooking place. Among women, "dust always inside the house" and smoking were also identified as strong risk factors for respiratory illness. Other strong risk factors for children, after adjusting for age and gender, included dust and drying clothes inside. This analysis confirms the role of indoor air pollution in the burden of disease among women and children in Lao PDR.

Keywords: Developing countries, respiratory health outcome, pulmonary disease, indoor air pollution.

1. Introduction

The association between air pollution and adverse health outcomes in developed and developing countries is now well established (WHO, 2005; WHO, 2002; Schwartz et al., 1994). Because people spend the majority of their time indoors where dispersion of pollutants may be poor, indoor air pollution may pose many hundreds of times greater exposure than outdoor air pollution (Bruce et al., 2000). Indoor air pollution is of particular concern in developing countries (Bruce et al., 2000; Smith & Metha, 2003; Ezzati, 2005), where up to 90% of rural households cook and heat using unprocessed biomass such as dung, crop residues, wood and charcoal (Bruce et al., 2000). This activity has been established as a major contributor to indoor air pollutants (Zhang & Smith, 1999; Wornat et al., 2001; Oanh et al., 1999; Daisey et al., 1989) and has been linked to respiratory and cardiac illness and cancer (Desai et al., 2004; Smith et al., 2005; Kara et al., 2003; Ozbay et al., 2001). Indeed, the household use of solid fuels has been claimed as the largest single environmental cause of ill health (Smith et al., 2005).

Epidemiological studies undertaken in a number of developing countries have consistently confirmed the association between health and indoor air, particularly for adverse respiratory illnesses and for vulnerable groups such as women and children (Shrestha and Shrestha, 2005; Wang et al, 1997; Mestl et al., 2007; Park and Lee, 2003; Mestl et al., 2006; Zhang and Smith, 2007; Mumford et al., 1989; Diaz et al., 2007; Bruce et al., 2008; Sharma et al., 1998; Lanata et al., 2004). In their review, Bruce et al. (2000) found ‘consistent evidence’ that indoor air pollution increases the risk of acute respiratory

infections (ARI) in childhood, ‘the most important cause of death in children under 5 years of age in developing countries’ (Bruce et al., 2000; Ezzati and Kammen, 2001). This is a global phenomenon: in a review of thirteen studies from nine developing countries, Smith et al (2003) reported up to twelve-fold increases in risk of acute lower respiratory infection associated with exposure to biomass smoke and acute lower respiratory infection for children under 5 years of age.

This paper reports on a study aimed at assessing the association between indoor air pollution, in particular related to biomass burning and cooking activities, and respiratory health in Lao People’s Democratic Republic (PDR). The study, conducted in collaboration with the Government of Lao PDR and the World Health Organisation, is the first of this nature conducted in the country. This paper focuses on the relationship between the dwelling type and occupant activities and respiratory health of resident adult women and children aged 1-4 years.

The Lao population is distinguished by a number of factors that impact substantially on this association and differentiate it from countries in which similar studies have been conducted. Lao PDR is the most rural country and one of the least developed in South-east Asia, with an average life expectancy of 62 years in 2008 (WHO, 2010). Wood is almost universally used for cooking, with both open and closed stove types typically located inside the main dwellings or in separate buildings (NHS, 2000). Respiratory infection is the third largest cause of death in the entire population of Lao (19%, NHS, 2000).

2. Methods

2.1. Study Design

The study was designed in close collaboration with thirteen representatives of the Lao Ministry of Health, the Lao National Statistics Centre and the Lao Science, Technology and Environmental Agency (STEA). Participants in the study were chosen according to a cluster sampling design comprising two Provinces, nine Districts within these Provinces, and 20 hospitals or health centres within the Districts. Six Districts from Vientiane Province (Phonhong, Mad, Feuang, Thoulakhom, Kasy and Vangvieng) and three from Bolikhamxay Province (Bolikhanh, Khamkeut and Pakkading) were chosen to meet the prerequisites of wide representation of ethnic groups, wide range of housing characteristics, high prevalence of respiratory illness, accessibility and adequate staff resources.

A list of hospitals, health centres, villages and village population within each District was obtained from the National Statistics Centre. A random sample of 20 health centres was selected, with 12 from Vientiane Province (Thoulakhom (3), Phonhong (1), Kasy (1), Vangvieng (3), Feuang (3), Mad (1)) and 8 from Bolikhamxay Province (Bolikhanh (2), Pakkading (2), Khamkeut (4)). For each health centre, four children aged 1-4 years admitted for ARI sequentially from 1st October 2005 were enrolled in the study. No more than two such children were enrolled from any one village. A total of 80 children were enrolled, in order to meet an *a priori* statistical power of 0.80 to estimate an effect size

for respiratory illness associated with a binary outcome of indoor air exposure of the magnitude reported by Bruce et al (2000). For each child, 1-2 children who had not been admitted for ARI was randomly selected from the same village in a different house, matched by age, ethnic group and location of kitchen.

In each of these villages, a list of households was used to select two further households. Where possible, households were chosen so that one had a stove inside the living area and the other had a separate kitchen. A total of 356 households were included in the study. For each household member of the survey study, questionnaire information related to indoor air factors, exposure and respiratory and cardiovascular health were gathered.

The study was conducted throughout the cool season (December 2005 – April 2006), during which indoor exposure and respiratory illness are potentially at their highest.

2.2. Questionnaire

A questionnaire was delivered to a representative of each household enrolled in the cross-sectional study. The questionnaire was based on the American Thoracic Society Questionnaire (Ferris, 1978), the World Health Survey (WHO, 2010), World Bank approach, ISAAC questionnaire (ISAAC 2011) and Western Australia Heart Survey, and critically evaluated by two international experts. Separate questions were developed for children and adults and were tailored to local conditions by the 13-member local team, many of whom have medical degrees and are professionals in public health and

environmental practice. The questionnaire was piloted in Pong Song and translated into Lao.

A small team of local health experts, who participated in the questionnaire development, a pre-study training workshop and the pilot exercise, were selected to administer the questionnaire to all households in the study. The questionnaire comprised six parts: interviewer information, completed by the chief interviewer; a health questionnaire for each child (completed by a parent or primary carer) and adult (completed by the adults themselves where possible or by a close relative or head of the household) in the household (which focused on symptoms, medical diagnoses and hospitalisation associated with acute respiratory infections in the past two weeks, the past month and in the past year) ; a household characteristics questionnaire (which focused on indoor combustion sources, ventilation and other exposures such as smoking and dust) completed by the head of the household; and a town/village questionnaire, completed for each community by the community head, community health worker or the head of the household.

Direct and indirect indoor, outdoor and occupational exposures to pollutants were also solicited. Participants were also asked about the type of cooking fuel, but since more than 99% of respondents reported using wood, this was not included as an explanatory variable in the analysis.

2.3. Statistical analysis

For women, the questionnaire comprised 14 health outcomes (Table 1) and 15 potential explanatory variables (Table 2). For children, the questionnaire comprised ten health outcomes (Table 3) and 15 potential explanatory variables (Table 4).

The statistical analysis comprised three main stages: exploratory analysis, primary regression models, and supplementary regression models. The primary models included all available explanatory variables (Tables 2 and 4), and the supplementary models included a subset of variables considered to be most epidemiologically relevant based on published literature.

In the first stage, exploratory statistical analyses of the association between household characteristics, exposure and health outcomes among women and children aged 1-4 years comprised summary statistics and plots, correlations and associated chi-squared tests, and analyses of variance.

In the second stage, each health outcome was expressed as a binary response and fitted in a logistic regression model. For children, all explanatory variables except age were included in the primary model as binary factors, due to sample size, and the model was fit to all children in the study group, to males and females separately, and to children aged 1-2 years. Forward, backward and stepwise selection approaches were considered to identify a set of statistically significant variables.

In the third stage, the explanatory variables for women were also collapsed to binary factors and three additional models were fit: (i) the same model as in the primary analysis, with all 15 variables; (ii) a reduced model focusing on six indoor activities; (iii) a baseline model focusing on activities directly related to cooking. See Table 2 for details. Three supplementary models were also considered for analysis of the data for children. The first was similar to the primary analysis but re-categorised two of the explanatory variables: time spent close to the fire and cooking place as indicated in Table 4. The second was a regression using only gender and age, where age was expanded to all 4 categories (ages 1 – 4). The third was fit using all levels of explanatory factors and comprised age, gender and five factors directly related to indoor pollutants; see Table 4 for details.

All statistical analyses were conducted using Microsoft Excel, SPSS 15.0 and SAS 9.2. A significance level of 0.10 was adopted as a reporting threshold and as the exclusion criterion in model selection. This choice of significance level was based on consideration of the study conditions and on the fact that the study aimed to identify potential associations which can then be further investigated in subsequent studies. As with all analyses of this nature, it is acknowledged that different model choice and model selection criteria could reveal other sets of variables could describe the outcomes equally well.

3. Results

3.1 Demographics

Good adherence to the study design was achieved with 356 households investigated in total. The study interviewers reported an almost 100% response rate. The analysis is based on a total of 388 women and 480 children aged 1-4 years from these households.

The demographic characteristics of the women in the study group are summarised in Table 2. Almost half of the women were aged 20-29 years and although almost all were never smokers, 71% of them were exposed to smoke inside. Almost half of the cooking places were in a separate room and 30% were in a separate building. Almost half of the women spent between 1 and 3 hours in the cooking place whilst almost a quarter of them spent more than six hours in this location. Most of the houses had wooden floors with wood and bamboo walls and over half of the women reported a lot of dust inside. More than 70% of women reported drying clothes inside the dwelling.

A summary of the demographic characteristics of the children aged 1-4 years in the study group is shown in Table 4. Overall, they comprised 48% females and 52% males, with 56% children in the 1-2 year age group. Over half of the children spent more than 16 hours inside the dwelling including sleeping time, and more than 8 hours excluding sleeping. Twenty two percent of the group spent more than 5 hours in the cooking place, although cooking was not always taking place: only 16% reportedly spent more than 5 hours close to a fire. Almost half (43%) of the corresponding households had a cooking place outdoors or in a separate building, while for 16% of children the cooking area was inside the living/sleeping room. Over half (52%) of children lived in households with

always a lot of dust inside and most were exposed to indoor tobacco smoke (70%) and drying clothes inside (71%).

3.2 Results for women

Primary model: The analysis of respiratory outcomes among women in the last 12 months yielded the following results (see also Table 5). Five of the 14 health outcomes (chest whistling with no physical movement, asthma, bronchitis, tuberculosis, lung cancer) were experienced by less than 10% of women. The results of these analyses should be treated with caution.

Time spent close to a fire was positively associated with shortness of breath (p=0.02) and dry cough not due to colds (p=0.07). Compared to women with less than one hour of exposure daily, more than six hours of exposure per day had odds ratios of 2.10 (95% CI 0.58-7.57) for shortness of breath and 2.92 (0.73-11.67) for dry cough. An odds ratio less than 1.0 was observed for tuberculosis associated with time spent close to a fire (OR=0.17, 95% CI 0.005-5.797); however only 14 out of 388 women were diagnosed with tuberculosis.

Personal smoking was significantly positively associated with chest whistling with no physical movement not due to colds (p=0.08), waking in the night with cough or wheeze (p=0.07) and asthma diagnosis (p=0.08). Current smokers had odds ratios of 5.18 (1.24-21.67), 3.13 (1.12-8.73) and 5.73 (1.27–25.9) for these respective outcomes.

Passive smoking, as measured by reported smoking (by anyone) inside the dwelling, was positively associated with tightness in the chest (OR=1.70, 95% CI 0.92-3.16), itchy eyes, itchy rash or eczema (OR=2.22, 95% CI 1.02-4.83), bronchitis diagnosis (OR=3.78, 95% CI 1.13-12.60) and lung cancer diagnosis (OR=0.04, 95% CI 0.00-1.42). The association with lung cancer is based on small numbers of diagnosed cases (n=8). In addition, the majority of women in the cohort were under age 30, which is probably too young for lung cancer to be advanced enough to be clinically detected and diagnosed. Increased odds ratios were also observed for shortness of breath (1.21), morning phlegm (1.14) and chest whistling with physical movements (1.27), although these were not significant at the 10% level.

Dust inside the dwelling was the most consistent risk factor associated with adverse health. Compared to women who reported little or no dust, women who reported dust always inside the dwelling had elevated odds ratios of 3.00 (0.59-15.28) for tightness in the chest, 1.10 (0.26-4.68) for morning cough, 6.03 (1.19-30.54) for shortness of breath, 1.84 (0.41-8.35) for morning phlegm, 15.1 (1.38 - 165) for chest whistling due to physical movement, 2.15 (0.13-35.5) for chest whistling with no physical movement not due to cold and 2.04 (0.32-13.03) for itchy eyes, itchy rash or eczema.

Household characteristics were also significantly associated with health outcomes. Women in dwellings with thatch roofs or wood or bamboo internal walls were at significantly higher risk of tightness in chest, morning cough, morning phlegm, chest whistling with physical movements, dry cough not due to colds and itchy eyes, itchy rash

or eczema. A dirt floor was a risk factor for itchy eyes, itchy rash or eczema but an odds ratio of less than 1.0 was observed for tightness in the chest and dry cough not due to colds. (Since less than 4% women reported living in dwellings with dirt floors, these last analyses were based on small numbers so odds ratios are not reported for these results.)

Supplementary models: Analyses based on the supplementary models supported the above results. The binary logistic regression with all fifteen (binary) explanatory variables strongly confirmed the role of house characteristics. A thatch roof or wood/bamboo internal walls were found to be associated with poorer respiratory health, but wood/bamboo external walls were associated with less adverse health outcomes.

3.3 Results for children

Primary model: Analyses of respiratory outcomes in the last month yielded the following results. Due to the number of outcomes and the complexity of the results, these are described rather than tabulated.

Time spent close to a fire was a significant risk factor for adverse health outcomes. Boys who spent more than one hour a day close to a fire were more likely to suffer illness with a cold (OR=2.22, 95% CI 1.32-3.74) and itchy rash or eczema (OR=3.03, 95% 1.31-6.99), and girls were more likely to suffer illness with a cold (OR=1.98, 95% 1.01-3.89), fever (OR=2.081, 95% CI 1.196-3.879)), cough (OR=2.23, 95% 1.10-4.49) and wake in the night (OR=2.44, 95% 1.17-5.09).

The location of the cooking area was a significant factor for fever, cough, watery eyes with no pus, watery eyes without pus, itchy rash or eczema and diagnosis of pneumonia in the last 12 months in the whole study cohort of children. This was most apparent in boys, girls only experienced watering eyes without pus watering eyes with pus and diagnosis of pneumonia in the last 12 months. Interestingly, the analyses consistently showed that these risks were lower for households in which the cooking place was located in a separate room or inside the living/sleeping room, compared to a separate building. As a consequence, the estimated odds ratios are not reported. In addition, for almost all analyses, odds ratios of less than 1.0 were computed for time spent in the cooking place.

Dust inside the home was found to be a significant risk factor for adverse health outcomes. Compared with households that reported no dust or dust sometimes, children in households with dust always inside suffered an increased risk in illness with a fever (OR=1.98, 95% CI 0.89-4.41), cough (OR=1.97, 95% CI 0.90-4.34), watering eye with pus (OR=5.19, 95% CI 1.06-25.4) and itchy rash or eczema (OR=3.95, 1.29-12.2). Among 1-2 year olds, time spent in the cooking place and dust were the most consistent risk factors for all health outcomes. Increased but not statistically significant risks for dust were observed for wake in night with wheeze or cough (OR=2.62, 95% CI 0.89-7.72), runny nose not due to cold (OR=2.96, 95% CI 0.91-9.68); a significantly increased risk was reported for itchy rash or eczema (OR=4.34, 95% CI 1.00-18.8).

Roof material did not appear as a significant factor in the analysis of the whole cohort, but was identified in the gender-specific analyses. Lower risks of bronchitis and watery eyes with pus were observed for children in households with thatch roofs and non-dirt floors. This may be due to improved ventilation and less dust in these households.

Dirt floor material was significantly positive for cold at any time, illness with a cough, wake in the night with wheeze or cough, runny nose not due to colds, stinging or watering eyes with and without pus, itchy rash or eczema, ever diagnosed with bronchitis and pneumonia diagnosed in the last 12 months.

Supplementary models: Under the supplementary models, time spent in the cooking place was found to be associated with reported cold at any time (p=0.052), illness with a fever (p=0.039) and stinging or watering eyes without pus not due to colds (p=0.054). Compared with children with less than one hour of such exposure per day, children who spent more than 8 hours in the cooking place had an increased odds ratio of 1.67 (p=0.096) for illness with a cough.

The location of the cooking place was also found to be associated with illness with a cough (p=0.039), difficulty breathing at any time (p=0.004), stinging or watering eyes with and without pus (p=0.040 and 0.019, respectively). However, no clear or consistent pattern was apparent between the locations (separate building, separate room, inside living/sleeping room, outdoors) and the health outcomes.

Drying clothes inside was associated with illness with a cough (p=0.046), runny nose not due to colds (p=0.001), stinging or watering eyes with and without pus not due to colds (p=0.052 and 0.065, respectively) and itchy rash or eczema (p=0.001). Compared with children in households that never dried clothes inside, large odds ratios for children in households that always dried clothes inside were observed for all of these health outcomes: illness with a cough (OR=1.70, p>0.10), waking in the night with wheezing or cough not due to colds (OR=1.97, p=0.049), runny nose not due to colds (OR=3.14, p=0.001), stinging or watering eyes with and without pus not due to colds (OR=2.80, p=0.053; OR=2.38, p=0.047, respectively) and itchy rash or eczema (OR=2.95, p=0.006).

Dust inside the house was associated with most health outcomes: illness with a fever (p=0.053), cough (p=0.081), waking in the night with wheezing or cough not due to colds (p=0.042), runny nose not due to colds (p=0.015), stinging and watering eyes with and without pus (p=0.016 and 0.058, respectively), itchy rash or eczema (p=0.001), diagnosis with bronchitis by a doctor or other health care worker (p=0.062) and diagnosis with pneumonia in the last 12 months (p=0.003). Compared with children in houses with never a lot of dust inside, the largest odds ratio for children in houses with always a lot of dust was observed for illness with a cough (OR=1.72, p=0.049).

4. Discussion

The present study assesses the role of indoor air pollution in the burden of respiratory disease among two of the most vulnerable cohorts, women and pre-school children (aged 1-4 years).

Among women and children, after adjusting for age and gender, a wide range of symptoms of respiratory illnesses was positively associated with a range of indoor exposures, including cooking, fire, dust, smoke and drying clothes. Dust always inside the house was identified as the risk factor associated with the widest range of health outcomes among women and a significant risk factor for a range of respiratory illnesses among children. Among women, passive smoking was a strong risk factor for some illnesses.

Among activities related to cooking and biomass burning, increased time spent close to a fire was significantly associated with increased risk of many of the respiratory health outcomes studied among children. Exposure to a fire was also found to be a risk factor for women; compared to women with less than one hour of exposure daily, more than six hours of exposure per day had elevated risks of experiencing shortness of breath and dry cough.

Time spent in the cooking place was not significantly positively associated with any of the health outcomes investigated among women. Among children, however, the location of the cooking place was identified as a risk factor, with higher risks observed for children in households with the cooking place in a separate building. This is not

unexpected, since dispersal of pollutants in these separate buildings may be poorer than in the main residence.

House characteristics were found to play a major role in the risk of respiratory health of women in this study. These variables dominated the supplementary analyses, revealing poorer health outcomes for women in houses with thatch roof or wood/bamboo internal walls, but not for women in houses with wood/bamboo external walls. This may be due to the ventilation that such houses provide. After accounting for these characteristics, only a few indoor activities were identified as risk factors for any of the health outcomes in women; these included cooking place in a separate building, personal smoking, smoky job and dust always in the house. Among children, floor, external and internal wall materials were also associated with respiratory health outcomes in the supplementary model.

The results of this study demonstrated that exposure to indoor biomass burning increased the risk of ARI in children and women in Lao PDR, which is consistent with previous studies (Bruce et al., 2000). Most odds ratios for incidence were elevated by a magnitude of 2-6 times comparable to published literature (Morris et al., 1990; Armstrong and Campbell, 1991; Cerqueiro et al., 1990), while the odds ratios for time spent in the cooking place were less than 1.0 among children. This is perhaps not unexpected, given that the questionnaire and the statistical analysis did not identify the circumstances of the time spent in the cooking place, for example, ill children may have spent less time in the

cooking place. Moreover, it is consistent with the earlier observation of better health outcomes for children in households with the cooking place inside the living area.

The limitations of this study are acknowledged. We discuss here five such issues. First, appropriate adjustment for confounding factors in epidemiological studies such as the one reported here is acknowledged to be problematic (Bruce et al., 2000). Although controlling for age and gender are almost universally agreed, the inclusion of other factors such as ventilation and competing risks in a multivariate model can substantially change the observed risks associated with particular exposures. Bruce et al. (1998) showed that the prevalence of reported cough and phlegm was significantly higher among women using open fires in highland Guatemala, but they observed a number of confounding variables, including household and socioeconomic indicators such as floor type or possession of a radio and television. They suggest that methodologies used in earlier studies mean that other variables, which were not measured, could have equally been responsible for the associations with respiratory problems.

The implication of this problem for the present study is that all reported estimates of odds ratios must be considered in light of the other variables in the model. This motivated the consideration of a range of statistical models for both women and children, including an expanded model comprising all explanatory variables and reduced models comprising subsets of these variables related to indoor activities and activities related directly to cooking. This allows for a greater understanding of the complex aetiology of respiratory disease in Lao PDR.

A second limitation of the study is that diagnosis of diseases such as bronchitis and asthma may vary significantly from country to country. This was addressed by careful discussion of the relevant questions in the questionnaire carefully with selected medical professionals. The questions were worded as carefully as possible and matched those asked in other similar international questionnaires. Moreover, the survey staff were themselves trained medical professionals who were aware of the definitions of these terms.

Thirdly, the moderate size of some of the observed risks (as indicated by the magnitude and significance of the corresponding odds ratios) and the variability of the observed exposure-response relationships are also acknowledged, but it is noted that these in line with the published literature. Bruce et al. (2000) identified fifteen studies that provided quantitative estimates of the association between acute lower respiratory infection and exposure associated with the use of biomass fuel. Even among this selected group of studies, direct comparison of the odds ratios was difficult because of differences in study locations, populations, age groups, study designs, type of fuel and definition of health outcomes. Moreover, as in our study, the measurement of exposure almost universally relied on proxies, including type of stove (eight studies) and reported hours near the stove (two studies). While nine of the studies reported significantly increased odds ratios in the range 2-5 for incidence or death, the other six studies reported no significant associations.

Fourthly, the results of this study are based on self-reported questionnaires. The use of questionnaires as a vehicle for obtaining information about health outcomes and exposure

is common (Smith and Metha, 2003; Mestl et al., 2007) but acknowledged to be prone to recall bias through misclassification of both outcomes and exposures. Reasonable efforts were made to reduce this bias through the use of multiple time frames (last week, last month, anytime), in-person interviews by trained local staff (many of whom had medical degrees), concomitant measurement of air pollutants (described separately), and a careful pilot study and analysis.

A final acknowledged limitation of the analyses reported here is the lack of quantitative exposure data and assessment. This was not feasible in the present study. Moreover, other important questions are outside the scope of the available information. As one example, it would be interesting to examine whether the observed associations of respiratory health with house characteristics are due to social factors. It is hoped that the results that have been observed and reported here will provide motivation for further investigation and quantification which may more clearly reveal associative and causal factors.

5. Conclusion

The WHO Child Health Epidemiology Reference Group has provided methodological guidelines for the design, conduct and reporting of epidemiological studies of acute lower respiratory infections in under-5s in developing countries (Bruce et al., 1998). The strength of the present study is that it has access to almost all of the study setting characteristics and has adhered to almost all of the study design considerations that were

listed by the Reference Group as determinants of study quality. Whilst it suffers from drawbacks common to all studies of this type, this study's contribution to the accumulation of evidence will provide more reliable estimates of risk and a more informed basis for decision-making by concerned governments and communities.

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Tables

Table 1. Respiratory health outcomes in women [*#]

Question	Response	Number
Tightness in the chest	No	283(73.7%)
	Yes	101(26.3%)
Morning cough	No	254(65.8%)
	Yes	132(34.2%)
Shortness of breath	No	272(71.0 %)
	Yes	111(29.0%)
Morning phlegm	No	269(69.9%)
	Yes	116(30.1%)
Chest whistling due to physical movements	No	335(89.1%)
	Yes	41(10.9%)
Chest whistling or wheezing with no physical movement, not	No	344(92.5%)

due to colds	Yes	28(7.5%)
Waking in the night from wheezing or coughing, not due to colds	No	313(81.5%)
	Yes	71(18.5%)
Dry cough not due to colds	No	325(84.4%)
	Yes	60(15.6%)
Runny nose not due to colds	No	346(89.9%)
	Yes	39(10.1%)
Itchy eyes, itchy rash or eczema	No	327(84.7%)
	Yes	59(15.3%)
Have you ever been diagnosed with asthma by a doctor or other health worker?	No	354(93.7%)
	Yes	24(6.3%)
Have you ever been diagnosed with bronchitis by a doctor or other health worker?	No	351(92.6%)
	Yes	28(7.4%)
Have you ever been diagnosed with tuberculosis?	No	374(96.4%)
	Yes	14(3.6%)

Have you ever been diagnosed with lung cancer?	No	350(97.8%)
	Yes	8(2.2%)

* Respiratory symptoms reported in the last 12 months, except for the last 4 items .

Each dependent variable includes three categories, “No”, “Yes” and “Don’t remember”. Those cases with “Don’t remember” were not included in the respective analysis.

1 **Table 2**. Potential explanatory variables for women

2

Factor	***Category***	***Expanded Code***	***Binary Code***	***N***	***Percent***
Sex[@]	Female	-		388	57.5%
	Male	-		287	42.5%
Age	50+	1	1	48	12.4%
	40-49	2	1	40	10.3%
	30-39	3	1	72	18.5%
	20-29	4	1	185	47.7%
	15-19	0	0	43	11.1%
Time spent in cooking place[*#]	More than 6 hours	1	1	94	24.2%
	4-6 hours	2	1	71	18.3%
	1-3 hours	3	1	182	46.9%
	Less than 1 hour	0	0	41	10.6%

Time spent close to a fire[#]	More than 6 hours	1	1	57	14.7%
	4-6 hours	2	1	58	14.9%
	1-3 hours	3	1	202	52.1%
	Less than 1 hour	0	0	71	18.3%
Dusty job	Yes	1	1	39	10.1%
	No	0	0	349	89.9%
Smoky job	Yes	1	1	10	2.6%
	No	0	0	378	97.4%
Smoker[*]	Yes, current smoker	1	1	28	7.2%
	Quit more than a year ago	2	1	5	1.3%
	No, never smoked	0	0	355	91.5%
Roof material	Other[$]	1	1	37	9.6%
	Tile	2	1	85	22.1%
	Zinc	3	1	177	46.1%
	Thatch	0	0	85	22.1%

Floor material	Dirt	1	1	14	3.7%
	Wood	2	1	247	64.3%
	Bamboo	3	1	59	15.4%
	Concrete[$]	0	0	64	16.7%
External wall material	Wood	1	1	146	38.0%
	Bamboo	2	1	185	48.2%
	Brick & Concrete[$]	0	0	53	13.8%
Internal wall material	Wood	1	1	140	36.5%
	Bamboo	2	1	188	49.0%
	Brick & Concrete[$]	0	0	56	14.6%
Cooking place[*#]	Outdoors	1	1	55	14.3%
	Inside living/sleeping room	2	1	50	13.0%
	Separate room	3	1	162	42.2%
	Separate building	0	0	117	30.5%
Dust outside dwelling	Always a lot	1	1	198	51.6%

	Sometimes a lot	2	1	138	35.9%
	Never a lot	0	0	48	12.5%
Dust inside dwelling*	Always a lot	1	1	185	48.2%
	Sometimes a lot	2	1	143	37.2%
	Never a lot	0	0	56	14.6%
Smoke inside dwelling*	Yes	1	1	272	70.8%
	No	0	0	112	29.2%
Dry clothes inside*	All the time	1	1	36	9.4%
	In the rainy season	2	1	121	31.5%
	Sometimes	3	1	120	31.3%
	Never	0	0	107	27.9%

1 (0) Reference category; (*) Factors used for reduced model; (#) Factors used for baseline model.

2 (@) Sex variable was not included in the models, since this paper focuses on women only.

3 ($) "*Other*" includes 2 cement cases; "*Concrete*" included 1 carpet cases; "*Brick & Concrete*" includes 2

4 soil cases and 5 other cases respectively.

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1 **Table 3**. Respiratory health outcomes in children aged 1-4 years *[#]

2

Question	Response	Number
Cold	No	219(47.2%)
	Yes	245(52.8%)
Fever	No	252(52.7%)
	Yes	226(47.3%)
Illness with a cough	No	206(43.9%)
	Yes	263(26.1%)
Waking in the night from wheezing or coughing, not due to colds	No	274(60.5%)
	Yes	179(39.5%)
Runny nose not due to colds	No	330(70.5%)
	Yes	138(29.5%)
Stinging or watering eyes, no pus	No	412(87.7%)
	Yes	61(12.9%)

Stinging or watering eyes, with pus	No	438(92.4%)
	Yes	36(7.6%)
Itchy rash or eczema	No	397(83.6%)
	Yes	78(16.4%)
Have you ever been diagnosed with bronchitis by a doctor or other health worker?	No	286(61.2%)
	Yes	181(38.8%)
Have you been diagnosed with pneumonia in the last 12 months	No	306(65.4%)
	Yes	162(34.6%)

1 * Respiratory symptoms reported in the last month, except for bronchitis and pneumonia.

2 # Each dependent variable includes three categories, “No”, “Yes” and “Don’t remember”. Those cases with

3 “Don’t remember” were not included in the respective analysis.

4

1 **Table 4**. Potential explanatory variables for children

2 .

Factor	***Category***	***Binary Model***	***Expanded Model***	***Frequency***[a]
Sex[*,#]	Male	1	1	248 (51.7%)
	Female	0	0	232 (48.3%)
Age[*,#]	1 year old	1	1	135 (28.1%)
	2 year old	2	2	133 (27.7%)
	3 year old	3	3	127 (26.5%)
	4 year old	0	0	85 (17.7%)
Time spent inside dwelling (including sleeping)	Less than 6 hours	0	0	34 (7.1%)
	6-8 hours	0	1	21 (4.4%)
	9-12 hours	0	2	64 (13.3%)
	12-16 hours	1	3	95 (19.8%)
	More than 16 hours	1	4	266 (55.4%)

Time spent inside dwelling (excluding sleeping)	Less than 2 hours	0	0	33 (6.9%)
	2-4 hours	0	1	108 (22.5%)
	5-8 hours	1	2	99 (20.6%)
	More than 8 hours	1	3	240 (50.0%)
Time spent in cooking place*	Less than 1 hour	0	0	105 (21.9%)
	1-2 hours	0	1	176 (36.7%)
	3-5 hours	1	2	92 (19.2%)
	5-8 hours	1	3	47 (9.8%)
	More than 8 hours	1	4	60 (12.5%)
Time spent close to a fire	Less than 1 hour	0	0	151 (31.5%)
	1-2 hours	1^	1	181 (37.7%)
	3-5 hours	1	2	70 (14.6%)
	5-8 hours	1	3	36 (7.5%)
	More than 8 hours	1	4	42 (8.8%)
Roof material	Thatch	0	0	113 (23.8%)

	Zinc	1	1	197 (41.5%)
	Tile	1	2	98 (20.6%)
	Others[c]	1	3	67 (14.1%)
Floor material[b]	Dirt	0	1	35 (7.4%)
	Wood	0	2	275 (57.9%)
	Bamboo	1	3	80 (16.8%)
	Concrete[c]	1	0	85 (17.9%)
External wall material	Wood	0	1	159 (33.1%)
	Bamboo	0	2	258 (53.8%)
	Brick & Concrete[c]	1	0	58 (13.1%)
Internal wall material	Wood	0	1	147 (31.0%)
	Bamboo	0	2	258 (54.3%)
	Brick & Concrete[c]	1	0	70 (14.7%)
Location of the cooking	Separate building	0	0	135 (28.4%)
	Separate room	1	1	196 (41.3%)

place*	Inside living/sleeping room	1	2	74 (15.6%)
	Outdoors [c]	1^	3	70 (14.7%)
Dust outside	Always a lot	1	1	263 (55.4%)
	Sometimes a lot	0	2	157 (33.1%)
	Never a lot	0	0	55 (11.6%)
Dust inside*	Always a lot	1	1	246 (51.8%)
	Sometimes a lot	0	2	158 (33.3%)
	Never a lot	0	0	71 (15.0%)
Smoke inside*	Yes	1	1	335 (70.5%)
	No	0	0	140 (29.5%)
Dry clothes inside*	All the time	1	1	60 (12.6%)
	In the rainy season	1	2	138 (29.1%)
	Sometimes	0	3	140 (29.5%)
	Never	0	0	137 (28.8%)

(0) Reference category; ([*]) Factors used for reduced model; ([#]) Factors used for baseline model.

([a]) Those cases with a response of "Don't remember" were not counted;

([b]) Dirt floor includes soil and concrete, Non-dirt floor includes wood, bamboo and carpet;

([c]) "*Other*" includes 2 cement cases; "*Concrete*" included 2 carpet cases; "*Brick & Concrete*" includes 2 soil cases and 2 other cases, respectively, *"Outdoors"* includes one case of other.

^Supplementary model 1 – include this category as part of reference group.

Table 5. Odds ratios significant at the 10% level and corresponding 95% confidence intervals for respiratory outcomes in women – primary model

Exposure	***Outcome***	***OR (95% CI)***
Time spent close to a fire: 6 hrs/day vs. <1 hr/day	Shortness of breath	2.10 (0.58-7.57)
	Dry cough not due to colds	2.92 (0.73-11.67)
	Tuberculosis	0.17 (0.005-5.80)
Personal smoking: Yes vs. No	Chest whistling with no physical movement not due to colds	5.18 (1.24-21.7)
	Waking in the night from wheezing or coughing, not due to colds	3.13 (1.12-8.73)
	Asthma diagnosis	5.73 (1.27-25.9)
Passive smoking: Yes vs. No	Tightness in the chest	1.70 (0.92-3.16)
	Itchy eyes, itchy rash or eczema	2.22 (1.02-4.83)

	Bronchitis	3.78 (1.13-12.60)
	Lung cancer	0.04 (0.00-1.42)
Dust inside the dwelling: Always vs. Little or none	Tightness in the chest	3.00 (0.59-15.28)
	Morning cough	1.10 (0.26-4.68)
	Shortness of breath	6.03 (1.19-30.54)
	Morning phlegm	1.84 (0.41-8.35)
	Chest whistling due to physical movement	15.1 (1.38-165)
	Chest whistling with no physical movement not due to cold	2.15 (0.35-35.5)
	Itchy eyes, itchy rash or eczema	2.04 (0.32-13.03)

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