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Original Research Article

Respiratory symptoms and associated factors among women exposed to biomass fuel smoke in Sri Lanka: cross sectional study

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ABSTRACT

Background: Biomass fuel smoke is a leading cause of indoor air pollution. It is a known risk factor for respiratory diseases. This study was conducted to determine the prevalence of respiratory symptoms and associated factors among women exposed to biomass fuel smoke in Sri Lanka.
Methods: Women (n=600) were assessed using questionnaires to determine base line data, cooking fuel use, respiratory symptoms (MRC respiratory symptoms questionnaire) and diagnosed respiratory diseases. Kitchen characteristics were determined by direct observation. Sample frequencies were calculated. Logistic regression analysis was done to determine the associations.
Results: Majority (64.1%) were biomass fuel users. Their mean age was 47 years ±14 SD. Majority 99.2% were never smokers. Prevalence of cough, phlegm, cough and phlegm, wheeze, breathlessness and diagnosed asthma was 14%, 16%, 9.9%, 22%, 22.3%, and 6.3% respectively. Use of biomass fuel was related to any respiratory symptom (OR=1.9; p<0.05), cough (OR=1.9; p<0.05), phlegm (OR=2.0; p<0.05), cough and phlegm (OR=2.7; p<0.05), wheezing (OR=2.0; p<0.05) and breathlessness (OR=2.0; p<0.05). Use of biomass fuel in an outdoor kitchen was associated with cough (OR=2.8, p<0.05), phlegm (OR=4.6, p<0.05), cough and phlegm (OR=3.1, p<0.05) and breathlessness (OR=2.1, p<0.05). Use of biomass fuel in a kitchen with neither chimney nor windows was associated with phlegm (OR=2.9, p<0.05) and cough and phlegm (OR=3.0, p<0.05).
Conclusions: Use of biomass fuel for cooking in an outdoor kitchen and in a kitchen with neither chimney nor windows were positively associated with respiratory symptoms in non-pregnant women exposed to biomass fuel smoke in Sri Lanka.

Keywords: Biomass fuel, Wood, Respiratory symptoms, Chimney, Kitchen

INTRODUCTION

Biomass fuel (BMF) is a domestic source of cooking energy. Biological materials such as wood, charcoal, crop residues and animal dung are collectively called as 'biomass fuel'.[1] Nearly 3 billion people worldwide use BMF for cooking.[2] Most people using BMF live in low and middle income countries.[1] Use of BMF in Sri Lanka was 78% in 2012.[3] BMF smoke is a known leading cause of indoor air pollution.[4,5] World Health Organization estimated that indoor air pollution is responsible for about 3.8 billion annual deaths.[2] Some of the main respiratory diseases contributing to this mortality are, pneumonia 27%, chronic obstructive pulmonary disease 20% and lung cancer 8%.[2] Thus, indoor air pollution caused by BMF smoke is a substantial contributor for the global disease burden.[4] Many studies have shown an association

between the exposure to BMF smoke and health problems. Those include acute lower respiratory tract infection (ALRI) in children, chronic obstructive pulmonary disease (COPD), asthma, tuberculosis, low birth weight and infant mortality.[1,6-9-12] In Sri Lankan culture, the adult women are responsible for cooking. Thus, they are heavily affected by the exposure to BMF smoke. A study in Mangalore reported that 80% of women were aware of the ill effects of BMF smoke.[13]

The exposure to BMF smoke depends on the concentration of air pollutants and time spent in the polluted environment. In homes using biomass fuel for cooking, the mean 24 hours particulate matter concentration may reach as high as 300-3000 µm/m^3.[14] The concentration of air pollutants in the kitchen may vary based on the features of the kitchen environment. Scientific evidence from other countries such as Cameroon, Nigeria, Nepal, India, Bangladesh and Pakistan showed increased respiratory symptoms, illnesses and reduced lung functions among women exposed to BMF smoke.[5,11,15-17,18-19] However, the broad range of respiratory outcomes of exposure to biomass fuel smoke are influenced by many factors such as age, individual sensitivity, cultural practices and socioeconomic status.[20,21] Sri Lanka has its unique sociocultural features in housing, kitchen layouts, cooking stoves and cooking practices that may influence the respiratory symptoms resulting from the exposure to BMF smoke.

In the present study, we aimed to determine the prevalence of respiratory health outcomes and associated factors among women exposed to BMF smoke in Sri Lanka. We determined the association between respiratory symptoms and exposure to BMF smoke in terms of cooking fuel type, features of kitchen environment and cooking practices. Respiratory symptoms assessed were cough, phlegm, cough and phlegm, breathlessness and wheezing as defined in medical research council questionnaire for respiratory symptoms (MRCQ) and chronic respiratory diseases such asthma and COPD.

METHODS

Cross-sectional study was carried out for a period of one year (October 2017 to September 2018) on 600 women in selected Grama Niladari divisions (GNDs) of Avissawella and Padukka divisional secretariat divisions (DSDs) of Colombo district, Sri Lanka. GND is the smallest administrative unit in Sri Lanka. Two stage cluster sampling method was used to recruit participants. Twenty (20) GNDs with households using BMF >75% were selected using probability proportionate to size criteria. From each GND, thirty households (30) were selected by a household survey of systematic random sampling. The eligible females in the selected households were invited to participate in the study. The inclusion criteria were primary female cooks over 18 years of age who were the permanent residents of the selected household. Those who were currently pregnant, disabled, had recent chest injuries, chest surgeries or eye surgeries and with diagnosed heart diseases were excluded from the study. Informed written consent was obtained from all the participants. Ethical approval was granted by the Ethics Review Committee, Faculty of Medical Sciences, University of Sri Jayewardenepura.

A structured questionnaire was used to collect base line data (age, education, employment, family income), duration of cooking (hours of cooking per day and years of cooking) and possible cofounders such as smoking history and exposure to other indoor air pollutants. The characteristics of the kitchen environment were assessed using an observational check list. Those include location of the kitchen; indoor vs. outdoor, having windows and having a chimney. Based on these characteristics of the kitchens of BMF users, those were categorized in to three; category 1: kitchens with both chimney and window/s, category 2: kitchens with either a chimney or window/s, category 3: kitchens with neither chimney nor window/s. Type of biomass cooking stove; traditional three stone vs commercial clay was noted.

Respiratory symptoms were assessed using a questionnaire based on the Medical Research Council Respiratory Symptoms Questionnaire (MRCQ). The questionnaire was content validated by the subject experts and translated into Sinhalese and Tamil languages. It was pretested among 50 women who were not included in the study sample.

Respiratory symptoms assessed were cough, phlegm, cough and phlegm, breathlessness and wheezing. Breathlessness was assessed by modified Medical Research Council Dyspnoea scale (mMRC grade 0-4) and those who had mMRC dyspnoea score of ≥2 was categorized as having breathlessness.[22] Past and present history of asthma, COPD, tuberculosis, interstitial lung disease and lung cancers were assessed using medical records.

Data was analysed using software of statistical package of social sciences (SPSS version 23). Mean ±SD and frequencies were computed. Categorical variables were compared using chi-square tests and continuous variables using independent sample t-test.

Logistic regression and estimated odds ratio and 95% confidence intervals (95% CI) were used to evaluate the association between the exposure to BMF smoke and outcome variables. The associations of features of kitchen environment were assessed in separate models. Factors that were biologically meaningful or statistically significant in univariate analysis were selected as confounding variables. Those were age, family income, industrial exposures, mosquito repellent use and pet dog/cat/s at home.

RESULTS

Out of 600 women recruited, 94% (n=566) completed the study. Majority (64.1%) used BMF and remaining 35.9% (n=203) used liquid petroleum gas (LPG). Table 1 shows the participants characteristics, durations of cooking and exposure to other air pollutants. BMF users were significantly older (47 years ±14 SD) than LPG users (42 years ±13 SD) (p<0.05). They had significantly lower educational levels (59.8% ≤grade 8 vs 35% ≤grade 8) and lower mean family incomes compared to LPG users (28,817 LKR±14, 797SD vs 36,660 LKR±14, 626SD) (p<0.05). Majority of them were unemployed compared to LPG users (72.7% vs 46.3%) (p<0.05). BMF users cooked for longer hours (mean duration of cooking was 5.9 hours per day ±2.2 SD vs 4.7 hours per day ±1.7 SD) and longer periods than LPG users (mean years of cooking was 29.2 years ±14.4 SD vs 16.7 years ±11.9SD). BMF users had significantly higher industrial exposures compared to LPG users (9.4% vs. 3.4%) (p<0.05). Smoking status and other exposures to air pollutants were not significantly different among BMF and LPG users (p>0.05). The resident areas of this population had minimal motor traffic and therefore, vehicular emissions were not a major contributor to air pollution.

Table 2 shows the comparison between the prevalence, crude and adjusted odds ratios (ORs) and 95% confidence intervals (95% CI) of respiratory symptoms and diseases among BMF and LPG users. The prevalence of all respiratory symptoms was significantly higher among BMF users when compared LPG users (cough 14% vs 6.9, phlegm 16% vs 7.9%, cough and phlegm 9.9% vs 3.4%, wheezing 22% vs 10.8%, breathlessness 22.3% vs 10.8%) (p<0.05). Asthma was the commonly diagnosed respiratory illness in both groups (6.3% vs 7.4%) (p>0.05). Only one woman (0.3%) among BMF users had a past history of tuberculosis. None of the women in both groups had a diagnosis of respiratory disease. After adjusting for potential cofounders, binary logistic regression showed that using biomass fuel was significantly associated with increased risk of all respiratory symptoms (Table 2).

Table 3 shows the features of kitchen environment and cooking practices of women using BMF in Sri Lanka. All houses of BMF users had designated, enclosed kitchen areas. None of the women used open fire places. Majority of the kitchens had windows (83.7%, n=304) and chimneys (78%, n=283).

Table 1: Characteristics of respondents.

Variables	BMF n=363	LPG n=203	P value
Continuous variables	**Mean±SD**	**Mean±SD**	
Age (years)	47±14	42±13	0.00*
Monthly income (Sri Lankan Rupees)	28,817±14,797	36,660±14,627	0.00*
Hours of cooking per day	5.9±2.1	4.6±1.4	0.00*
Years of cooking	29.2±14.4	16.7±11.9	0.00*
Categorical variables	**N (%)**	**N (%)**	
Age category (in years)			0.004*
20-40	142 (39.1)	106 (52.2)	
41-60	140 (38.6)	70 (34.5)	
61-85	81 (22.3)	27 (13.3)	
Ethnicity			0.163
Sinhalese	339 (93.4)	196 (96.6)	
Other	24 (6.6)	7 (3.4)	
Education level			0.000*
≤Grade 8	217 (59.8)	71 (35)	
>Grade 8	146 (40.2)	132 (65)	
Employment status			0.000*
Employed	99 (27.3)	109 (53.7)	
Unemployed	264 (72.7)	94 (46.3)	
Smoking status			0.766
Never smoker	360 (99.2)	200 (98.5)	
Ex/current-smoker	3 (0.8)	3 (1.5)	
Having exposure to passive smoking at home	93 (25.6)	47 (23.2)	0.582
Having occupational exposures	9 (2.5)	3 (1.5)	0.625
Having industrial exposures	34 (9.4)	7 (3.4)	0.015*
Having exposure to mosquito repellents	29 (8)	27 (13.3)	0.060
Having pet dogs/cats inside homes	174 (47.9)	103 (50.7)	0.581
Living in a house by the side of main road	110 (30.3)	24 (11.8)	0.000*

Chi-square statistics; *p<0.05 is significant.

Table 2: Prevalence and odds ratios of respiratory symptoms and diagnosed asthma according to the cooking fuel type.

Respiratory symptoms and illnesses	BMF (n=363) N (%)	LPG (n=203) N (%)	Crude OR		Adjusted OR	
			OR (95% CI)	P value	OR (95% CI)	P value
Cough	51 (14)	14 (6.9)	2.2 (1.2-4.1)	0.012*	1.9 (1.0-3.6)	0.048*
Phlegm	58 (16)	16 (7.9)	2.2 (1.2-4.0)	0.007*	2.0 (1.1-3.6)	0.022*
Cough and phlegm	36 (9.9)	7 (3.4)	3.1 (1.3-7.1)	0.008*	2.7 (1.2-6.3)	0.021*
Wheezing	80 (22)	22 (10.8)	2.3 (1.4-3.9)	0.001*	2.0 (1.2-3.3)	0.012*
Breathlessness	81 (22.3)	22 (10.8)	2.4 (1.4-3.9)	0.001*	2.0 (1.2-3.3)	0.010*
Any symptom	123 (33.9)	34 (16.7)	2.5 (1.7-3.9)	0.000*	1.9 (1.2-3.0)	0.008*
Diagnosed asthma	23 (6.3)	15 (7.4)	0.8 (0.4-1.7)	0.631	0.8 (0.4-1.6)	0.489

Binary logistics regression. Adjusted for age and industrial exposures; *p<0.05 is significant.

Table 3: Respiratory symptoms of women using biomass fuel according to the features of housing and kitchen environment.

Categorical variables	BMF users with respiratory symptoms		Chi-square (df)	P value
	Yes (n=123)	No (n=240)		
	N (%)	N (%)		
Kitchen location				
Indoor	90 (73.2)	223 (92.9)	25.060 (1)	0.000*
Outdoor	33 (26.8)	17 (7.1)		
Window/s in kitchen				
Yes	100 (81.3)	204 (85)	0.568 (1)	0.451
No	23 (18.7)	36 (15)		
Chimney in kitchen				
Yes	91 (74)	192 (80)	1.380 (1)	0.240
No	32 (26)	48 (20)		
Kitchen category				
1	82	177	2.000 (2)	0.367
2	27	42		
3	14	21		
Stove type				
Traditional three stone	19 (15.4)	29 (12.1)	0.536 (1)	0.464
Commercial clay	104 (84.6)	211 (87.9)		
Using 'ottapalu'				
Yes	9 (7.3)	36 (15)	3.741 (1)	0.053
No	114 (92.7)	204 (85)		
Using blow pipe				
Yes	74 (60.2)	178 (74.2)	6.868 (1)	0.009*
No	49 (39.8)	62 (25.8)		

Chi-square statistics; *p<0.05 is significant.

As shown in Figure 1, cooking stoves were kept on concrete slabs built at approximately at the level of the waist height. No women kept cooking stoves on the ground level. Commercial clay cooking stoves (Figure 2a) were used by 86.8% (n=315) and traditional three-stone cooking stoves (Figure 2b) by remaining 13.2% (n=48). Wood, coconut shells, coconut leaves and husks were the main varieties of biomass fuel used.

Forty-five women (12.4%) burn a crop product of rubber seed ('ottapalu' in native language) with other varieties. Majority used a blow pipe (69.4%, n=252) to keep circulating air in the stove (Figure 3). Table 3 shows the respiratory symptoms of women exposed to biomass fuel smoke based on the features of kitchen environment and cooking practices. In general, kitchen location (χ^2=25, p<0.05) and use of blow pipe (χ^2=6.868, p<0.05) were significantly associated with any respiratory symptoms (Table 3).

Table 4 shows crude and adjusted odds ratios (ORs) and 95% confidence intervals (95% CI) of cough, phlegm, cough and phlegm, wheezing and breathlessness of women exposed to BMF smoke with the kitchen location and kitchen category.

Table 4: Odds ratios (ORs) and 95% CI for each respiratory symptom of women exposed biomass fuel with the characteristics of the kitchen environment.

Variables	Cough OR (95% CI)		Phlegm OR (95% CI)		Cough and Phlegm OR (95% CI)		Wheezing OR (95% CI)		Breathlessness OR (95% CI)	
	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted
Location[(a)]										
Indoor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Outdoor	2.9* (1.4-5.9)	2.8* (1.4-6.0)*	4.8 (2.5-9.3)	4.6* (2.3-9.0)	3.2 (1.5-7.1)	3.1* (1.4-6.9)	1.6 (0.8-3.2)	1.5 (0.8-2.9)	2.2* (1.2-4.2)	2.1* (1.1-4.0)
Kitchen[(b)]										
Category 1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Category 2	0.7 (0.3-1.7)	0.7 (0.3-1.7)	1.5 (0.8-3.1)	1.5 (0.7-3.1)	0.8 (0.3-2.2)	0.8 (0.3-2.2)	1.3 (0.7-2.5)	1.3 (0.7-2.5)	1.5 (0.8-2.7)	1.5 (0.8-2.7)
Category 3	2.2 (1.0-5.1)	2.2 (1.0-5.3)	3.0* (1.4-6.7)	2.9* (1.3-6.5)	3.0* (1.2-7.5)	3.0* (1.2-7.5)	1.1 (0.5-2.6)	1.0 (0.4-2.4)	1.3 (0.6-3.0)	1.2 (0.5-2.9)

Logistic regression; [a]Adjusted for age, income, use of mosquito repellents and pet dog/cats at home and [b]Adjusted for age and income; *p<0.05 is significant.

After adjusting for potential cofounders, binary logistic regression showed that having an outdoor kitchen was significantly associated with increased risk of cough (OR=2.8, p<0.05), phlegm (OR=4.6, p<0.05), cough and phlegm (OR=3.1, p<0.05) and breathlessness (OR=2.1, p<0.05). Having a kitchen of category 3 was significantly associated with increased risk of phlegm (OR=2.9, p<0.05) and cough and phlegm (OR=3.0, p<0.05).

Figure 1: Biomass fuel cooking stove in Sri Lanka placed on a concrete slab.

Figure 2: (a) Commercial clay biomass fuel cooking stove used in Sri Lanka and (b) traditional three stone biomass fuel cooking stoves used in Sri Lanka.

Figure 3: Women used a pipe to blow air into the biomass fuel cooking stove.

DISCUSSION

The present study determined the prevalence of respiratory symptoms and associated factors among women exposed to biomass fuel smoke in Sri Lanka. To the best of our knowledge, this is the first detailed study conducted in Sri Lanka to assess respiratory symptoms and associated factors among women exposed to BMF smoke using MRCQ and features of kitchen environment. Respiratory symptoms are considered as early indicators of chronic respiratory diseases. Therefore, due attention on respiratory symptoms would be an important aspect of public health facilitating preventive care and appropriate intervention.[23]

Frequency of respiratory symptoms among women exposed to BMF smoke vary from 14-22%. A previous study among 70 non-smoking BMF using women in Sri Lanka reported similar frequency for wheeze (20%) and higher frequencies for cough (30%) and breathlessness (50%).[24] In the present study, frequency of asthma was low as 6.3% whereas it was reported high as 10 out of 70 in the previous study.[24] This may be attributed due to the

larger sample size in the present study and the variations in the socioeconomic status amongst study participants. Two studies in Malawi reported lower frequencies of respiratory symptoms compared to the present study.[25,26] However, other studies in India, Nepal, Mexico, Honduran and Mayan reported higher frequencies of respiratory symptoms compared to the present study.[17,27-31] This may be due to the relatively low exposure to BMF smoke among Sri Lankan women which could be depending on the variety of BMF used, stove type and features of kitchen environment. The present study showed that all the respiratory symptoms were significantly higher in women exposed to BMF smoke compared to that of LPG users (6.9%, 7.9%, 3.4%, 10.8%, and 10.8% respectively) ($p<0.05$). However, frequency of asthma was low among BMF users compared to LPG users (7.4%). Same pattern was observed in the studies conducted elsewhere.[17-19,29]

The results showed that the use of BMF for cooking was significantly associated with increased risk of cough (OR=1.9; $p<0.05$), phlegm (OR=2.0; $p<0.05$), cough and phlegm (OR=2.7; $p<0.05$), wheezing (OR=2.0; $p<0.05$) and breathlessness (OR=2.0; $p<0.05$). The strongest association was observed for cough and phlegm (OR=2.7; $p<0.05$). A similar pattern was seen in the studies of other countries but the reported risk was much higher.[11,18] As stated earlier, possible explanation for this observation could be relatively low levels of exposure to BMF smoke. The smoke generated by wood and other varieties of BMF contains lower levels of elements, anions and particulate carbon compared to that of cow dung.[32] The use of animal dung has also shown to increase the risk of deterioration of the lung functions.[33] The present study population entirely rely on wood, coconut leaves and shells and none used animal dung. Therefore, they could have reported a less risk compared to the other communities. Burning wood in traditional cooking stoves produce high level of pollution.[32] The pollution is significantly reduced with the use of improved cooking stoves and better ventilation conditions.[35] Majority of this study population used improved clay cooking stoves (86.8%). These were introduced in 1986 under several improved cook stove development programmes.[36] Majority of study population had kitchens with both chimneys and windows. These reasons might be contributing to the low prevalence and risk of respiratory symptoms among Sri Lankan women compared to the data of other countries.

The present study, itself showed that the features of kitchen environment (having chimney and windows) was significantly associated with respiratory symptoms of women exposed to BMF smoke. Having a kitchen without a chimney and window/s was significantly associated with an increased risk of respiratory symptoms. $PM_{2.5}$ is a measure of concentration of indoor air pollutants. A study in Sri Lanka reported that median $PM_{2.5}$ concentration was low as 182.1 $\mu g/m^3$ in a kitchen with a chimney while it was 635.4 $\mu g/m^3$ in a kitchen without a chimney.[37] The excessive accumulation of higher concentration of indoor air pollutants generated by BMF smoke in poorly ventilated kitchens without chimneys and windows could lead to an increased risk of respiratory symptoms among women exposed to BMF smoke. The present study also showed, that having a kitchen outdoor was significantly associated with an increased risk of respiratory symptoms. A study on concentration of $PM_{2.5}$ across kitchen types, showed that having kitchens outdoors do not necessarily cause lower exposures.[38,39] The poor ventilation characteristics in outdoor kitchens observed in the study which were enclosed and poorly constructed cause possible excessive accumulation of BMF smoke than indoor kitchens leading to increased risk of respiratory symptoms.

Active smoking and occupational exposures are main risk factors for increased respiratory symptoms. These were negligible in this study population. The other possible risk factors such as passive smoking at home, industrial exposures around the vicinity, use of mosquito repellents, having pet dogs/cats at home and living in a house by the side of main road were not shown to be statistically significant predictors for increased respiratory symptoms of this population. Use of a pipe to blow air in to the stove was associated with increased respiratory symptoms ($\chi^2=6.868$, $p<0.05$). However, this was found to be not significant in the final adjusted model. Other than asthma, there were no other medically diagnosed patients of COPD or other respiratory diseases among this study group. Only one woman had a history of previous tuberculosis. Prevalence of tuberculosis is rural sector of Sri Lanka is low as 2.2%.[40] The strengths of the study were that the respiratory symptoms were evaluated using a validated questionnaire based on standard MRCQ in a representative sample of women and the findings were compared with a reference category. Data was captured extensively using the baseline questionnaire on the range of covariates, thereby assessment of other possible confounders were possible in the final model. Due to the descriptive study design, no longitudinal follow up assessments were possible in this study.

CONCLUSION

Using biomass fuel for cooking in an outdoor kitchen and in a kitchen with neither chimney or windows were positively associated with respiratory symptoms in non-pregnant women exposed to biomass fuel smoke in Sri Lanka. This study adds to the previous findings of increased respiratory symptoms among women exposed to biomass fuel smoke, the association of features of kitchen environment and cultural practices. Further research is needed to quantify the exposure and respiratory functions.

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