Environment Conservation Journal 17 (3) 57-65, 2016
ISSN 0972-3099 (Print) 2278-5124 (Online)
Abstracted and Indexed

Respiratory signs and symptoms of a rural subpopulation in India: What do they tell us?

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Received: 28.08.2016 **Accepted: 12.11.2016**

Abstract

The study estimated the prevalence of chronic respiratory conditions among the cooks exposed to the burning of solid biomass cooking fuel. Questionnaire-based survey and lung function tests were administered to capture the self-reported respiratory health symptoms and lung health respectively. The estimated prevalence of chronic bronchitis was 3.14%, 4.84%, 7.09%, 10.91% for 26–35, 36–45, 46–55, 56–65 years age group respectively. Obstructive lung disease was observed in 5.4%, 4.6%, 7.1%, and 13.5% of respondents for age groups 26–35, 36–45, 46–55, 56–65 year respectively and 6% over all ages (p value < 0.05 for trend). Immediate actions are needed to reduce the pollution exposure of the rural populations by providing the clean cooking energy.

Keywords:* *Biomass cooking; COPD; FEV1; FVC; Pulmonary function test

Introduction

Earlier studies on Indian population have established that women chronically exposed to smoke from biomass burning during household cooking suffer from many health conditions like chronic bronchitis, secondary inflammatory changes in the airways, tuberculosis, and cataract (Jindal *et al*., 2012; Lakshmi *et al*., 2012; Zodpey and Ughade, 1999). Analysis of National Family Health Survey-3 data reveals that women cooking with biomass fuels are more likely to have experienced stillbirth, cataract, and tuberculosis than those who cook with cleaner fuels (Mishra *et al*., 1999, 2005). A meta-analysis of Indian studies illustrates that chronic bronchitis was nearly two times more common among women exposed to biomass cooking fuel (OR=2.37, 95% CI: 1.59, 3.54). About 53% (PAF=0.53, 95% CI: 0.33, 0.68) cases in rural and 20% (PAF=0.20, 95% CI: 0.10, 0.32) cases of such diseases in urban areas could be attributed to biomass cooking fuel, resulting in close to 2.4 million (95% CI: 1.4, 3.2) out of 5.6 million cases in India (Sehgal *et al*., 2014).Studies conducted on women extensively exposed to smoke from biomass combustion have reported, increased lung volume or diffuse emphysema, thickening of interlobular septae, focal emphysematous areas, increased cardiothoracic ratio, and increased broncho-vascular arborisation (Ozbay *et al*., 2001). The chest roentgenograms of workers exposed to wood smoke for a long term display a diffuse, bilateral, reticulo nodular pattern, combined with normalized or hyper inflated lungs, as well as indirect signs of pulmonary arterial hypertension (PAH), fibrous and inflammatory focal thickening of the alveolar septa as well as diffuse parenchymal anthracotic deposits, which are the most prominent pathologic findings from the studies conducted (Sandoval *et al*., 1993).This study was designed to estimate prevalence of chronic bronchitis and obstructive disease among women constantly exposed to air pollution from the use of biomass-based traditional cookstoves and to understand how the rate of prevalence in rural area is compared with the rates in urban areas. The secondary objective was to assess if the length of exposure had any significant association with the lung function measures.

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Study design

This cross-sectional survey was conducted in eight villages in Bishnupur-I, and Bishnupur-II blocks (administrative unit within a district) of coastal district of South 24 Parganas, West Bengal. A sample of around 1,200 participants was estimated for a cross-sectional study using StatCalc software (EpiInfo) for chronic bronchitis prevalence of 3.27% (Jindal *et al.*, 2012) at alpha error of 5% and 1% absolute precision.The health workers, after an extensive field study, prepared a social map of the community, which aided in selection of the households. Systematic random sample of every sixth house in the community with a total number of 8000 households was carried out for the study. Primary cook from these houses were approached to participate and wherever the household member was not available for participation or if the primary cook declined to participate, the appropriate resident in the house to the left of the sentinel house was asked to participate. All study participants provided written and informed consent before participating in the health assessment. The study was duly approved by institute's ethics committee.Interviews were administered to capture the self-reported health symptoms and known risk factors. A validated questionnaire developed for INSEARCH study (Jindal *et al.*, 2012) was used to assess respiratory health symptoms and chronic bronchitis. Risk factors included in the questionnaire were fuel used at home for cooking and lighting, personal habits (smoking, etc.), duration of exposure to traditional cookstove, occupational and neighbourhood air pollution exposure, ventilation (health worker observed), exposure to allergens such as cockroach, dust mites, animal dander, incense stick, mosquito coil, and socio-economic variables. The investigators were trained by environment and air quality monitoring experts to grade houses for ventilation and mould status. The training included field based observations and placard were provided to help classify houses for ventilation status as good, average or poor and also for the presence of mould and moisture.

Lung function parameters recorded and case definitions

Pulmonary function test using Vitalograph Spirometer was performed to measure Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), and Peak Expiratory Flow (PEF)of each participant. A minimum of three forced expiratory manoeuvres were performed and the best of the three values was selected for statistical analysis (if a participant had difficulty understanding the processes, then a total of eight chances were given to perform the test). The parameters were expressed either in litres or as a percentage of the reference (Asian) predictive values. Chronic obstructive pulmonary disease (COPD) was defined as the ratio of FEV1/FVC<0.70, and those responding in affirmative to being affected by phlegm in the morning for at least three consecutive months during the year were defined to have chronic bronchitis as also used by Jindal *et al.*(2012).

Statistical analysis

Tukey's pair wise test of comparison of multiple means was undertaken to determine differences in lung function parameters across age categories. Linear regression analysis was performed for FEV1and FVC as continuous variables, and logistic regression analysis for dichotomous variables for chronic bronchitis. Exposure (independent) variables deployed in the model were length of household level air pollution exposure to biomass-based traditional cookstove and kerosene stove. Biomass cooking exposure index was calculated by obtaining a product of years of exposure (age of respondent minus 15years assumed to be the start of exposure based on formative research), self-reported duration of cooking in a day (in hours), and number of cooking sessions in a day. Kerosene exposure index was calculated similarly. The regression models were adjusted for a variety of self-reported air pollution exposures related to occupational exposure, lifestyle, and neighbourhood.

Results and Discussion

A total of 1,005 women, aged 26–65 years were interviewed and lung function measurements were conducted on all participants. Analysis of socio-demographic variables showed that a total of 81% respondents were homemakers, followed by 16% engaged either in farming or were self-employed. About 99% respondents described the location of

their houses as rural, a total of 79% respondents had flush toilets, and 85% had cell phones at home.
Cooking fuel related exposure revealed that nearly all respondents (94%) used traditional biomass based cookstoves, 45% had separate cooking area while 26% respondents had outdoor cooking which was not covered (Table1). Out of those who had indoor kitchen, ventilation was average in the cooking area for a large percent (82%) of households as recorded by the observations of the field investigators, with 67% households having at least one window in the kitchen. Nearly one third (35%) respondents had smokers living in their home and 3.63% of respondents were occasional smokers. Large percentage of households (70%) used incense sticks in their houses, and mosquito coils (77%), and 59% residence were categorised as mouldy/moist. About 87% of the respondents did not cook animal fodder. Neighbourhood air pollution exposure as determined by neighbourhood characteristics showed that 94% of the respondents did not live in the vicinity of factories and 83% did not have garbage burning nearby (Table 1).A total of 77% respondents considered themselves healthy at present, 14% reported diseases requiring long treatment, while 37% respondents were on some medication. As presented in Table 2, 16.9% experienced shortness of breath after exercise, 7.8% respondents reported wheezing, 9.6% reported having to get up at night because of cough, 4.8% were affected by phlegm in the morning at least for three consecutive months during the year, and 3.11% reported shortness of breath when not doing strenuous work during last 12 months. Doctor diagnosed asthma was reported in1.28% respondents and inhalers was used by less than 1% of the respondent population.As shown in Table 3, FEV1 and FVC were normally distributed. The FEV1 levels(litres) assessed for the study population were 1.87 (0.41, 1.76), 1.78 (0.45,2.93), 1.65 (0.03,2.56), 1.54 (0.54,2.63) for 26–35, 36–45, 46–55, 56–65 years respectively with lower FEV1 measurements associated with age. The FVC levels(litres) assessed for the study population were 2.11 (0.76, 3.68), 2.02 (0.45, 3.18), 1.88 (0.5,2.91), 1.78 (0.98, 3.34) for 26–35, 36–45, 46–55, 56–65 years respectively with lower FVC measurements associated with increasing age. Tukey's multiple comparison of means test showed that mean value for FEV1 and FVC were higher in lower age category (Table 3) and the pair wise differences were significant between all age groups other than 45–55 compared with 56–65 year for mean FEV1.For mean FVC the pair wise differences were significant between all age groups other than 26–35 compared with 36–45, 46–55 compared with 56-65 year. The mean values of FEV1 measurement did not differ significantly by different ventilation parameters related to cooking area, or location of kitchen.The mean percent of predicted (compared with reference Asian population)FVC and FEV1 were analysed across age categories. Mean of percentage of predictive values for FEV1was 89%, 88%, 90%, 91% and for FVC it was 85%, 85%, 87%, and 88% respectively for 26–35, 36–45, 46–55, 56–65 year (Table 3).The mean percentage of predictive values was not significantly different across age groups. A ratio of FEV1/FVC was created as this ratio indicates chronic obstruction in the respiratory pathway i.e. high ratio means lower risk. Overall, out of the 739 participants, 6.36% showed less than 70% ratio. Ratio less than 70% was observed for 5.4%, 4.6%, 7.1%, and 13.5% of respondents respectively for age groups 26–35, 36–45, 46–55, 56–65year. Thus, larger percentage of COPD (<70% ratio of FEV1/FVC) was observed among higher age groups.The calculated biomass cooking exposure index ranged from 0 to 116,800 hour and kerosene exposure index ranged from 0 to 52,560 hours (Table 4). Further, multivariate regression analysis was carried out to study the association for the health endpoints namely, FEV1, FVC, and two dichotomous variables—complaints of phlegm (1=Yes, 2=No), and ratio of FEV1/FVC (1=less than 70% FEV1/ FVC and 2=more than or equal to 70% FEV1/FVC) (Table 5). The independent (explanatory) variables were age (categorical), traditional/kerosene cookstove exposure index(continuous) and use of kerosene lamp, the model was adjusted for other air pollution exposures, including current smoking status and exposure to second hand smoke, use of incense stick, and mosquito coil in their homes, burning of garbage near their residence. Exposure to air pollutants because of other neighbourhood characteristics (factories) was largely non-existent or similar (vehicular), therefore, these were not

Table 1 Self-reported sources of air pollution exposure and cooking exposure (n = 1005, because of missing responses the frequency may not add upto 1005)

Parameter	Response	Frequency	Percentage
Primarily traditional cookstove users	Yes	805	94.15
Current smoker	Sometimes	31	3.63
	Never	732	85.48
Current source of lighting	Kerosene lamp	659	78
Only kerosene stove users	Yes	16	1.87
Number of meals in a day using biomass cookstove	1	233	23.30
	2	693	69.30
	3	67	6.70
Number of meals in a day using kerosene cookstove	Not using	878	88.06
	1	114	11.43
	2	5	0.50
Number of meals in a day using LPG cookstove	Not using	927	97.07
	1	25	2.62
	2	2	0.21
	3	1	0.10
Cook animal fodder	Yes	113	11.29
Burn garbage in or near the house	Yes	159	15.88
Any current smoker at home	Yes	351	35.06
Number of household members smoking at home	0	661	66.03
	1	289	28.87
	2	42	4.20
	3	8	0.80
	4	1	0.10
Average number of cigarettes smoked at home	0	690	68.93
	1-5	168	16.78
	6 – 10	106	11.29
	> 10	37	3.0
Number of meals cooked using solid biomass	0	7	0.70
	1	233	23.30
	2	693	69.30
	3	67	6.70
Duration of biomass use for cooking meals (hour)	0	12	1.20
	>=1-2	158	15.81
	>=2-3	702	70.27
	>=3-4	122	12.21
	>=4	5	0.50
Number of meals prepared using kerosene cookstove	0	878	88.06
	1	114	11.43
	2	5	0.50
Duration of kerosene cookstove used for cooking meals (hours)	0	879	90.15385
	>0-1	79	8.102564
	>1-2	15	1.538462
	>=3	2	0.205128

Table 2 Distribution of self-reported respiratory health status (n =1005)

Question	Number	Percentage
Ever had wheezing or whistling sound from chest during last 12 months	66	7.8
Woken up in the morning with a feeling of tightness in chest	43	5.1
Ever felt shortness of breath after finishing exercise	143	16.9
Ever felt shortness of breath when not doing strenuous work in the last 12 months	26	3.1
Ever had to get up at night because of cough during the last 12 months	81	9.6
Cough first thing in the morning	45	5.4
Bring up phlegm first thing in the morning	64	7.6
Bring up phlegm from chest most of the morning for at least three consecutive months during the year	40	4.8

Table 3 Distribution of lung function by age category

Age category (year)	N	FEV1 (Litres)		FVC (Litres)		<70% FEV1/ FVC % (N)
		Mean (95% CI)	% of Predicted*	Mean (95% CI)	% of Predicted*	
26–35	295	1.87 (0.41,1.76)	89.4	2.1 (10.76,3.68)	85.8	5.4 (16)
36–45	261	1.78 (0.45,2.93)	88.3	2.02 (0.45,3.18)	85.0	4.6 (12)
46–55	154	1.65 (0.03,2.56)	90.4	1.88 (0.5,2.91)	87.1	7.1(11)
56–65	59	1.54 (0.54,2.63)	91.0	1.78 (0.98, 3.34)	89.0	13.5(8)

* **predicted values are percentage of the reference values for Asian population**

Table 4 Cooking exposure index based on self-reported air pollution exposure

Source of pollution exposure	Frequency (N)	Percentage
Solid biomass exposure index (hours)		
>0 -18250	109	14.83
>18250 -36500	337	45.85
>36500-54750	190	25.85
>54750 -73000	72	9.8
>73000 -91250	18	2.45
>91250 -109500	7	0.95
>109500 -127750	2	0.27
Kerosene exposure index (hours)		
0	657	90.37
>0 -5000	16	2.20
>5000 -10000	32	4.40
>10000 -15000	14	1.93
>15000	8	1.10

included in the regression analysis. The multivariate regression model explains 8.1% of the variance in FEV1 and 6.3% of variance in FVC. The analysis showed that increase in the age variable was associated with significantly lowering FEV1 (coefficient-0.1128, p value<.0001) and FVC (coefficient -0.1035, p value<.0001) after adjusting for air pollution exposure related variables—biomass-based cooking of animal fodder, garbage burning in or near the home, exposure to second-hand smoke, and incense sticks/ mosquito coil at home (Table 5).

Table 5 Regression analysis for respiratory parameter FEV1 and FVC among women aged >=26 to <= 65 years

Outcome		**FEV1**		**FVC**	
Parameter	**Levels**	**Estimate**	**P value**	**Estimate**	**P value**
Adjusted r square**		0.0714	<.0001	0.0613	<.0001
Biomass cooking exposure index (hour)	product of hours per day*((age-15)*365)	2.511314E-7	0.8133	-1.2312E-7	0.9123
Kerosene cooking exposure index (hour)	product of hours per day*((age-15)*365)	-0.00000996	0.0057*	-0.00000942	0.0127*
Age categorical variable (year)	26-35	-0.11280	<.0001*	-0.10351	<.0001*
	36-45				
	46-55				
	56-65				

***p value <0.05**
****Adjusted for air pollution exposure to biomass cooking of animal fodder, garbage burning in or near home, second hand smoke, lighting incense sticks, and mosquito coil at home**

Increase in kerosene exposure index was significantly associated with decrease of FEV1 and FVC. Biomass cook stove index as predictor was significantly correlated with age.Univariate analysis showed that participants with <=70% FEV1/FVC ratio were significantly higher in mean age and kerosene stove cooking exposure, but had similar score for biomass cookstove exposure index (Table S1). Participants reporting phlegm in the morning at least for three consecutive months during the year were significantly higher in mean age, but had lower biomass and kerosene cook stove exposure index.Logistic regression analysis for chronic bronchitis and COPD (<=70% FEV1/FVC) as outcome and explanatory exposure variables showed that chronic bronchitis was significantly associated with increase in categorical variable age after adjusting for air pollution exposure to biomass cooking of animal fodder, garbage burning in or near home, second-hand smoke, and use of incense sticks/mosquito coil at home (Table 6). The adjusted odds ratio (95% CI OR) for 56–65 age category when compared with 26–35 was 4.41 (1.13, 17.27) for chronic bronchitis and 5.80 (1.87, 18.0) for COPD (Table 6).Removing occasional smokers from the analysis did not alter the results.

The association of lung function indices with age category could be an effect of aging as is also noted by other researchers (Mangat *et al.*, 2014; Rinne *et al.*, 2006). However, age is significantly correlated with cooking exposure. The univariate analysis presented in Table 5 is of particular interest as it shows that the biomass cookstove exposure index is similar in both the groups <0.70 and >= 0.70 FEV1/FVC ratio. The chronic bronchitis prevalence rates were compared with rates reported by the study conducted by Jindal *et al.* (2012) among 169,575 individuals at 12 centres across the country with a sample drawn from urban and rural population, aged 15–65 years. The study defined chronic bronchitis as presence of cough with expectoration for >= three months in a year for two or more consecutive years.

Table 6 Logistic regression analysis for ratio FEV1/FVC (<70% FEV1/FVC) and chronic bronchitis (phlegm for more than three months) among women aged >=26 to <= 65 years

Outcome		<70% FEV1/FVC			phlegm for more than 3 months		
Parameter	**Levels**	**Estimate**	**P value**	**Odds Ratio (95% CI)**	**Estimate**	**P value**	**Odds Ratio (95% CI)**
R square**		0.0141			0.0381		
Biomass cooking exposure index (hour)	product of hours per day*((age-15)*365)	-0.000020	0.1038	**1**	-8.16E-7	0.9455	**1**
Kerosene cooking exposure index (hour)	product of hours per day*((age-15)*365)	0.000039	0.1039	1	-0.1661	0.7696	0.85 (0.27,2.57)
Age categorical variable	26-35	**Reference**			**Reference**		
	36-45	0.093	0.8218	1.098 (0.49, 2.47)	0.3284	0.4902	1.39 (0.55, 3.53)
	46-55	0.773	0.0923	2.17 (0.88, 5.33)	0.8735	0.1133	2.40 (0.81, 7.06)
	56-65	1.758	0.0023*	5.80 (1.87, 18.0)	1.4837	0.0332*	4.41 (1.13, 17.27)

***p value <0.05**
****Adjusted for air pollution exposure to biomass cooking of animal fodder, garbage burning in or near home, second hand smoke, lighting incense sticks, and mosquito coil at home**

Table S1 Univariate analysis of continuous variables for respiratory health effects (Supplemental Material)

Health Effect	**Level**	**Independent Variable**	**N**	**Mean**	**P value**
ratio <70% FEV1/FVC	Yes	age (years)	47	45	0.015*
	No		724	42	
ratio < 70% FEV1/FVC	Yes	cooking exposure index(hours)	47	35889	0.817
	No		698	36522	
ratio < 70% FEV1/FVC	Yes	kerosene exposure index(hours)	46	2274	0.035*
	No		680	928	
Phlegm complain for three months in last one year	Yes	age (years)	37	46	0.005*
	No		696	42	
Phlegm complain for three months in last one year	Yes	cooking exposure index(hours)	37	3908	0.374
	No		694	36393	
Phlegm complain for three months in last one year	Yes	kerosene exposure index(hours)	35	607	0.573
	No		678	1017	

***p value <0.05**

Physician evaluation was not used to establish the diagnosis. The study showed overall chronic bronchitis in 4.07% of rural and 2.5% of urban population, 3.49% cases of chronic bronchitis in mixed population from rural and urban, while overall prevalence observed in our study was five per cent. For Kolkata centre (geographically close and demographically similar to our study population in South 24 Parganas), Jindal *et al.* (2012) reported 1.3%, 2.5%, 3.4% chronic bronchitis prevalence for the respondents aged 35–44, 45–54, 55–65 years respectively in general population, which is nearly half of the level present in our study population at 3.14%, 4.84%, 7.09% prevalence. This closely reflects the expected trend if we take into account the adjusted pooled odds ratio (OR=2.37, 95% CI: 1.59, 3.54) as reported by Sehgal *et al.* (2014). However, the high prevalence of adverse effects across age groups, in comparison to urban prevalence rate from Jindal *et al.* (2012) may indicate that the adverse effects could initiate after a short exposure period from biomass based rural household pollution and be less influenced by the length of exposure. The plausible biological mechanism for higher prevalence rate could be related to cooking fuel soot or particulate matter which cause inflammatory reaction in the mucus lining of the respiratory tract causing luminal narrowing by excess mucus, edema, cellular infiltration, and smooth muscle hypertrophy leading to small airway obstruction (Ware and Matthay, 2000).Another study also reported that the absolute values of the measured lung function parameters were lowest in the biomass and mixed fuel using non-smoking rural Indian women (Behera *et al.*, 1994).

Conclusion

The analysis of this field-based cross sectional study illustrates that the community presents nearly five percent women with chronic bronchitis; and six percent showed COPD. Lower respiratory indices significantly deteriorated with age; however age is closely correlated with increasing length of air pollution exposure and difficult to segregate through this study design. Based on the results of previous studies and the present study, the authors recommend need for interventions to reduce air pollution exposure and burden of public health diseases. Particularly because lung functions indices are strong and independent predictors of all-cause mortality.In view of the growing levels of air pollution in urban areas and high exposures in rural areas and because of its association with health, particularly, respiratory morbidity, it would be appropriate to capture the prevalence and trend of respiratory disease in India through periodic national level representative surveys, such as National Statistical Survey (NSS)or District Level Household and Facility Surveys (DLHFS).

Acknowledgements

The authors sincerely thank The Energy and Resources India (TERI, New Delhi, India) for financially assist the present study. We are thankful to the health workers of Child In Need Institute (CINI, India) for all their support. Hard work and commitment of TERI's field staff namely Mr Mahesh and Mr Surinder is appreciated. We express our sincere gratitude towards the villagers for their support in successful completion of our project work. Finally, the authors acknowledge the anonymous reviewers for their valuable time and inputs. The authors declare they have no actual or potential competing financial interests.

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