Impact of Exposure to Biomass Fuel on Pulmonary Function and Lung Age in Rural Women

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ABSTRACT

BACKGROUND

Around half a million of people still rely on biomass fuels for cooking, which is a major source of household air pollution, associated with increased morbidity and mortality. Biomass smoke exposure is associated with airway obstruction and decreased ventilatory function. Though various studies are available in relation to biomass exposure and pulmonary function, literature is limited on lung age. Hence, the current study was undertaken to evaluate the effect of biomass fuel on pulmonary function and lung age in rural women and correlate biomass exposure index with the spirometry parameters and lung age.

METHODS

A cross sectional study was conducted in rural areas of Tamilnadu. Around 350 women were screened and 100 women aged > 18 years with biomass exposure for at least five years and able to perform spirometry were selected for inclusion in the study. After obtaining consent, the subjects were evaluated further with detailed history and spirometry to record the lung function parameters and lung age. Biomass exposure index was calculated from hours spent in cooking per day multiplied with the years of cooking.

RESULTS

Mean age of the participants was 49.88 ± 10.76 years. 68 % had indoor kitchen with inadequate ventilation in 57 % of households. Majority of the women were housewives and belonged to the middle- and low-income groups. Around 19 % were symptomatic with cough and expectoration being predominant symptoms. Spirometry was abnormal in 83 % of the women and showed obstruction in majority. Mean forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV1), forced expiratory flow 25 - 75 % (FEF) and peak expiratory flow (PEF) were reduced in the study population. A significant negative correlation was observed between the biomass exposure index (BEI) hour-years and FEV1 and FEF 25 % - 75 %. A significant positive correlation was observed between BEI hours-year and lung age.

CONCLUSIONS

Majority of the women exposed to biomass fuel smoke, though asymptomatic, had abnormal lung function with increased lung age. Intensity of exposure as measured by biomass exposure index correlated significantly with FEV1, FEF 25 - 75 % and lung age. Hence, regular surveillance of the women using biomass fuel for cooking should be done for early identification of respiratory impairment.

KEY WORDS

Biomass Exposure, Biomass Fuel, Pulmonary Function, Lung Age, Biomass Exposure Index

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BACKGROUND

Cooking is an essential part of the day-to-day activities and almost one half of the world's population relies on biomass fuel as the primary source of domestic energy. Biomass fuel consists of firewood, dung cakes, agricultural crop residues (such as shrubs, grass and straw), charcoal and kerosene.¹ Globally, around 2.8 billion people are still using solid fuels (such as wood, crop wastes, charcoal, coal and dung) for cooking.² In India, 55.5 % (54.8 – 56.2) and in Tamilnadu 20.0 – 31.9 % of population are using solid biomass fuels.³

Incomplete combustion of biomass fuels emits toxic fumes like particulate matter, carbon monoxide, sulphur dioxide, nitrogen dioxide, benzene and formaldehyde contributing enormously to the indoor pollution.⁴ Exposure to these toxic fumes causes significant morbidity and mortality in humans, especially females. Household air pollution (HAP) from burning of solid fuel has emerged as one of the top ten global threats to public health as it accounts for 5 % of the global burden of disease.² HAP causes various diseases such as chronic obstructive pulmonary disease (COPD), pneumonia, lung cancer, ischaemic heart disease and stroke.⁵ HAP is also associated with 2.4 of 5.6 m cases of cataract among adult Indian women, and 0.02 of 0.15m stillbirths across India.⁶ According to the latest Global Burden of Disease Study 2017, 1.6 million pre-mature deaths each year were attributable to household air pollution.⁷ In India, the number of deaths attributed to illness due to HAP were reported as 481,738 in 2017.³

The level of exposure to the toxic fumes from a biomass smoke varies widely with the type of fuel, house architecture and ventilation. In rural areas, especially in developing countries, 90 % of the women involved in cooking expose themselves to high pollution levels because of enclosed kitchens with lack of chimney and poor ventilation. Women who get exposed to high levels of smoke indoor are more than twice as likely to suffer from chronic obstructive pulmonary disease. Risk of COPD was about three times higher in populations exposed to solid-fuel smoke; of which, exposure to wood smoke have greater impact compared to animal dung / crop residues and coal / charcoal.⁸

Effect of biomass fuel smoke decreases pulmonary function resulting in abnormal findings on spirometry. Pattern of pulmonary function abnormality is usually obstructive, but can be restrictive or mixed.^{9,10,11} Biomass smoke often involves small airways leading to their obstruction.¹² Intensity of biomass exposure can be measured using BEI; by multiplying cooking duration in years and hours / day, can be used to assess exposure to biomass fuel, similar to smoking index used to assess exposure to tobacco smoke.¹³ Minimum threshold of BEI of 60 is associated with significant risk of developing chronic bronchitis.¹⁴

Though studies are available in the Indian literature on the effects of biomass fuel on spirometric parameters, studies on lung age are limited. Hence, the current study was undertaken to evaluate the effect of biomass fuel on pulmonary function and lung age in rural women and to correlate the biomass exposure index with the spirometry parameters and lung age.

METHODS

This was a cross-sectional study conducted from January to July 2020 in rural places of Tamilnadu within 5 – 10 km radius around Chettinad Hospital and Research Institute, to evaluate the pulmonary function and lung age in women exposed to biomass fuel by spirometry. The ethical approval was obtained from the institutional human ethics committee and a detailed informed consent was obtained from all the participants.

Inclusion Criteria

- Females exposed to biomass.
- Age >18 years.
- Exposure to biomass fuel for a minimum period of 5 years.

Exclusion Criteria

- Acute respiratory infections.
- Active pulmonary tuberculosis.
- Acute / recent cardiac events.
- Hemodynamic instability.
- Pre-existing respiratory diseases.
- Subjects unable to perform or with contraindications to spirometry.

Around 350 women were screened and 100 women who had met the criteria were included in the study. Demographic details including age, height, weight, body mass index and socioeconomic status were noted. Clinical history for prior respiratory illness, occupation and personal (active / passive smoking) history for any confounding factors was recorded. Detailed history of biomass exposure including housing conditions, duration of biomass exposure, type of fuel, hours spent in cooking and years of exposure has been collected. All the vitals were recorded.

Spirometry was performed by using NDD EasyOne Air ultrasonic portable spirometer in accordance with the American Thoracic Society (ATS) guidelines. Spirometric measurements included FVC, FEV1 and the ratio of FEV1 to FVC (FEV1 / FVC), expressed as percentage, FEF 25 % - 75 % and PEF. The values were interpreted as per ATS / ERS guidelines.

Lung Age

Lung age values were noted from spirometry reports.

Biomass Exposure Index (BEI)

Biomass exposure index can be calculated by multiplying number of hours of exposure to biomass smoke per day * years of exposure.

Grading of BEI¹⁵

- < 30 hours years - mild exposure
- 30 - 60 hours years – moderate exposure
- > 60 hours years – heavy exposure

Statistical Analysis

Data was analysed using SPSS statistical package for social science (version 23.0 SPSS Inc: Chicago). Study variables were expressed as mean, standard deviation and frequency using descriptive statistics. Analysis of variance (ANOVA) was used to compare the spirometry parameters among different groups of BEI. Pearson coefficient was used to assess the correlation between BEI and spirometry indices and lung age. P-value < 0.05 was considered significant.

RESULTS

A total of 100 women with biomass exposure were evaluated. The mean age (years) and BMI (Kg / m²) of the study participants was 49.88 ± 10.76 and 24.99 ± 5.26 respectively.

Factors Affecting Biomass Exposure	N	%
Type of biomass fuel	Wood	43
	Coal	28
	Cow dung	22
	Combined wood and kerosene	7
Kitchen type	Indoor	68
	Outdoor	32
Ventilation	Adequate	43
	Inadequate	57
Over crowding	Yes	54
	No	46
Smoking	Active	0
	Passive	18
	Non-smoker	82
Biomass exposure index	< 30	16
	30 - 60	25
	> 60	59

Table 1. Factors Related to the Household Air Pollution (N = 100)

Majority of the women were homemakers (52 %) while, 24 % were farmers, 10 % were cooks and 14 % were construction labourers. Among the socioeconomic status, all the subjects belonged to the middle (54 %) and low (46 %) income groups with majority of the women having indoor kitchen (68 %) and inadequate ventilation (57 %). More than half of them (54 %) live in overcrowded house. Type of biomass fuel used by the subjects was as follows: wood (43 %), coal (28 %), cow dung (22 %) and mixed (wood and kerosene - 7 %) (Table 1)

82 % of the women were non-smokers and the rest 18 % were exposed to passive cigarette smoking from the family members. Majority of the participants had heavy biomass exposure (52 %) with BEI of > 60. (Table 1)

Pattern	Total (N = 100)	Symptomatic (N = 19)	Asymptomatic (N = 81)
Obstructive	43 (43 %)	4 (21.05 %)	39 (48.15 %)
Restrictive	32 (32 %)	4 (21.05 %)	28 (34.57 %)
Mixed	8 (8 %)	3 (15.79 %)	5 (6.17 %)
Normal	17 (17 %)	8 (42.10 %)	9 (11.11 %)

Table 2. Spirometry Pattern among the Study Population (N = 100)

Around 19 % were symptomatic with cough in 17 %, expectoration in 15 % and exertional dyspnoea in 9 %. Overall, pulmonary function by spirometry was abnormal in 83 % of the women exposed to biomass. Of the asymptomatic (N = 81), 89 % of the subjects had impaired lung function.

Pattern of spirometry was obstructive type in majority (43 %) followed by restriction (32 %) and mixed (8 %). (Table 2)

	Mean ± S.D.	Percentage Predicted (Mean ± S.D.)
FVC (L)	1.83 ± 0.53	73.51 ± 12.31
FEV1 (L)	1.53 ± 0.52	71.87 ± 15.33
FEV1 / FVC	77.24 ± 12.87	-
FEF (25 - 75 %) (L)	1.99 ± 1.25	62.83 ± 25.21
PEF (L / sec)	3.54 ± 1.66	67.26 ± 18.38

Table 3. Mean PFT Parameters among the Study Populations (N = 100)

FVC - Forced Vital Capacity, FEV1 - Forced Expiratory Volume in One Second, Forced Expiratory Flow 25 - 75 % and PEF - Peak Expiratory Flow.

Mean FVC, FEV1, FEF 25 - 75 % and PEF were reduced and lung age (84.36 ± 17.89 years) was increased in the study population. (Table 3) (N = 100)

Variable	BEI			F-Value P-Value	
	Mild (< 30)	Moderate (30 - 60)	Heavy (> 60)		
FVC	82.06 ± 7.34	69.77 ± 12.04	72.71 ± 12.61	6.47	0.002*
FEV1	84.39 ± 11.05	70.90 ± 13.99	68.10 ± 15.29	8.84	< 0.001*
FEV1 / FVC	80.83 ± 9.50	78.33 ± 15.07	75.36 ± 9.47	1.72	0.184
FEF 25 % - 75 %	82.72 ± 25.61	68.73 ± 26.78	52.54 ± 18.42	13.46	< 0.001*
PEF	77.50 ± 16.46	66.27 ± 20.55	64.29 ± 16.69	3.71	0.02*
Lung age	67.69 ± 12.87	80.24 ± 12.89	90.62 ± 17.63	14.23	< 0.001*

Table 4. Mean Spirometry Parameters and Lung Age Based on the Intensity of Exposure

*P < 0.05 - statistically significant, ANOVA test was used, BEI - biomass exposure index, FVC - forced vital capacity, FEV1 - forced expiratory volume in one second, forced expiratory flow 25 - 75 % and PEF - peak expiratory flow

The mean of spirometry parameters and lung age stratified according to BEI is shown in Table 4. As the exposure increased, there was a significant decrease in FVC, FEV1, FEF 25 - 75 % and PEF and increase in lung age. BEI of > 30 was associated with increased lung age and decreased spirometry parameters.

Parameters	P-Value		
	Mild vs. Moderate	Mild vs. Heavy	Moderate vs. Heavy
FVC	0.002*	0.012*	0.517
FEV1	0.006*	0.000*	0.668
FEV1 / FVC	0.743	0.193	0.498
FEF 25 % - 75 %	0.099	0.000*	0.006*
PEF	0.094	0.022*	0.880
Lung age	0.040*	0.000*	0.020*

Table 5. Comparison of Spirometry Variables and Lung Age According to BEI by Tukey Post-Hoc Test

*P < 0.05 - statistically significant

BEI - Biomass Exposure Index, FVC - Forced Vital Capacity, FEV1 - Forced Expiratory Volume in One Second, Forced Expiratory Flow 25 - 75 % and PEF - Peak Expiratory Flow.

When the spirometry parameters and lung age were compared among the different groups of intensity of biomass exposure, there was a statistically significant difference in all the parameters except FEV1 / FVC ratio between the mild and heavy exposure groups. Whereas, the difference was significant with only FVC, FEV1 and lung age when the mild and moderate groups were compared and with FEF 25 - 75 % and lung age when moderate and heavy groups were compared.

	Variable	R-Value	P-Value
BEI	FVC	- 0.003	0.97
	FEV1	- 0.21	0.03*
	FEV1 / FVC	- 0.139	0.166
	FEF25 % - 75 %	- 0.31	0.002*
	PEF	- 0.16	0.09
	Lung age	0.355	< 0.001*
Table 6. Pearson Correlation between BEI and Spirometry Variables and Lung Age			
P < 0.05 – statistically significant			
BEI - Biomass Exposure Index, FVC - Forced Vital Capacity, FEV1 - Forced Expiratory Volume in one second, forced expiratory flow 25 - 75 % and PEF - Peak Expiratory Flow.			

We observed negative correlation between the BEI hour-years and all the spirometry parameters, however, correlation was significant with FEV1, ($r = -0.21$, $P < 0.05$) and FEF 25 % - 75 % ($r = -0.31$, $P < 0.05$). A Significant positive correlation was observed between BEI hours-year and lung age. ($r = 0.355$, $P < 0.001$) (Table 5)

DISCUSSION

During the lifetime, an average Indian woman can be exposed to the biomass fuel smoke for 30 - 40 years with an average of six hours per day, equivalent to 60,000 hours of exposure.¹³ Household air pollution due to incomplete combustion of solid fuels is a major risk factor for development of chronic respiratory diseases among the women, elderly and children who stay at home most of the time. HAP contributes to the increased rate of premature deaths and disability adjusted life years (DALY's). Though the rate of usage of solid fuel has decreased over the years, still a greater proportion of population are still using biomass fuels for cooking in developing nations. A study conducted in Tamilnadu among 5000 households reported 90 % used biomass fuel for cooking.³ HAP contributes to 19625 deaths and 709 per 100 000 populations DALY's per year in Tamilnadu according to Global Burden of Diseases 2017.⁷

Effect of exposure depends on type of the biomass fuel, intensity of exposure, and ventilation.^{6,16} Average 24-hr. exposure to respirable particulate matter was reported to be high in a combined and enclosed kitchen compared to a separate and outdoor kitchen.³ Usage of chullah and solid fuels was associated with significant decline in pulmonary function, as compared to liquid petroleum gas (LPG).^{16,17,18} Of the solid fuels, wood and animal dung releases more pollutants leading to pulmonary function impairment.¹⁹ Majority of the women in our study have indoor kitchen with inadequate ventilation. About half of them live in overcrowded place. All these factors can contribute to the amount of exposure to biomass smoke, leading to development of COPD, chronic bronchitis or chronic airway diseases. Reddy et al. observed that biomass fuel has no significant effect on pulmonary function if used in kitchens with good ventilation.²⁰

Cooking with biomass fuel contributes to high levels of indoor pollution with release of several pollutants including soot particles that can penetrate deep into the lung.⁶ The solid particulate matter (PM₁₀ and PM_{2.5}) and toxic gases emitted during biomass combustion can cause airway inflammation and impaired ventilatory function. Chronic

exposure to these indoor pollutants is associated with increased prevalence of respiratory symptoms^{17,21} and chronic obstructive pulmonary disease in non-smoking women.²² Prevalence of COPD among women using biomass fuel in Tamilnadu was reported as 2.5 %.²³ Pathophysiology of biomass smoke related COPD is different from tobacco smoking COPD and chronic bronchitis phenotype is seen more commonly in biomass-COPD.²⁴

In our study, cough (17 %) and sputum production (15 %) were the predominant symptoms reported similar to the study by Regalado et al.²¹ Bindu et al.¹⁵ reported cough and dyspnoea as the major symptoms associated with biomass exposure. In the present study, 83 % were found to have an abnormal spirometry with decline in FVC, FEV1 and PEF. Spirometry pattern was obstructive (43 %) in majority, followed by restrictive (32 %), and mixed type (8 %). This is similar to the study by Mangat et al. who reported decreased lung function and a high risk of obstructive type of lung disorder. However, Balcan et al.¹¹ observed both obstructive (19 %) and restrictive pattern (17 %). Restrictive pattern was reported by Behera et al.¹⁰ with reduced FVC and normal FEV1, FEV1 / FVC and PEF values, whereas, Agarwal et al. reported reduction of all spirometry parameters with reduction in FVC more than the FEV1.¹⁸

The severity of exposure to biomass fuel smoke can be measured by "Biomass Exposure Index", first described by Behera et al.¹³ BEI is a simple tool to assess the risk of developing the respiratory diseases, and similar to pack years or smoking index in tobacco smoking. Studies showed significant reduction in lung function in women with biomass exposure of > 60 years.^{15,19} In our study, 52 % had high exposure, 32 % had moderate exposure and 18 % had mild exposure. All the spirometry parameters except FEV1 / FVC were reduced significantly in moderate and high exposure groups as compared to mild group. Significant negative correlation was observed between the BEI hour-years and FEV1 ($P < 0.05$) and FEF 25 % - 75 % ($P < 0.05$) which was similar to the study findings reported by Behera et al.¹⁰ In another study by Priya et al. biomass exposure index was high with an average of 85.68 ± 3.69 hour-years in women cooking on biomass with significant deterioration in pulmonary function.²⁵

Lung age is an estimate derived from spirometric variable (usually FEV1) to calculate the approximate age of a person being tested.²⁶ Lung age helps the patients understand the condition of their pulmonary function. Reduction in lung function is associated with increase in lung age. It can be calculated from FEV1 and height using formulas as suggested by Morris et al. or spirometry will generate the report.²⁷ Factors such as obesity and air pollution can accelerate ageing of the lung.^{28,29} The present study showed that the 80 % of participant's lung age was abnormal to their current age, with average of 84.36 ± 17.89 years. Lung age showed significant positive correlation with BEI in our study population.

CONCLUSIONS

Majority of the women exposed to biomass fuel smoke, though asymptomatic, had abnormal lung function with increased lung age. Intensity of exposure as measured by

biomass exposure index correlated significantly with FEV1, FEF 25 - 75 % and lung age. Hence, regular surveillance of clinical symptoms and lung function for early identification of respiratory impairment is necessary to raise awareness and provide education regarding regular use of alternate safe fuels. This would help to reduce the morbidity and mortality associated with chronic respiratory diseases secondary to the biomass fuel exposure.

Limitations

Passive smoking and occupational exposure were possible confounders, and they were not adjusted.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.

Financial or other competing interests: None.

Disclosure forms provided by the authors are available with the full text of this article at jemds.com.

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