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Research Article

Effect of chronic exposure to biomass fuel smoke on pulmonary function test parameters

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ABSTRACT

Background: Life in a typical Indian household revolves around the cooking area, and Indian women spend much of their time there. Cooking stoves in most households are nothing more than a pit, a *chulha* (a U-shaped construction made from mud), or three pieces of brick. Cooking under these conditions entails high levels of exposure to cooking smoke. Aim of this study was to evaluate the effect of Chronic Exposure to Biomass Fuel Smoke on Pulmonary Function Test Parameters.
Methods: 60 non-smoking women without any history of any major chronic illness in the past were selected for this study. The study group comprised of 30 rural female subjects who were chronically exposed to biomass fuel smoke combustion and 30 age matched urban female subjects exposed chronically to clean fuel combustion (Liquified Petroleum Gas–LPG) in Haryana (India). All the subjects were evaluated for pulmonary function tests by RMS Medspiror.
Results: Biomass exposure index came out to be 85.68±3.69 for women cooking on biomass and LPG index was 64.17±6.97 for women cooking on LPG. This implies significant chronic exposure of women to biomass fuel smoke. The lung function parameters were significantly lesser in biomass exposed rural women [FEV_1 ($p<0.01$), FVC ($p<0.01$), FEF_{25-75} ($p<0.01$), FEV_1/FVC ratio ($p<0.01$), PEFR ($p<0.01$), MVV ($p<0.01$)] than the LPG exposed urban women. The evaluation of PFT suggested obstructive type of pulmonary disease.
Conclusion: The derangement in pulmonary function parameters in women exposed to biomass smoke pollutants could be due to chronic significant exposure as suggested by high Biomass exposure Index. Inadequate ventilation in cooking area without chimney/vent also contributed to pulmonary function derangement and COPD.

Keywords: Biomass fuel, Clean fuel (LPG), COPD, Biomass exposure index, Pulmonary function tests, Spirometry

INTRODUCTION

Air pollution has been commonly perceived as an urban problem associated with motor vehicles and industries. However in developing countries air pollution tends to be highest indoors where biomass fuels are burned by many households for cooking and space heating.[1,2] Nearly 50% of the world's population[2] and 75% of Indian households use solid fuels (primarily firewood and cow dung). This prevalence of solid fuel use in India is as high as 90% in rural areas.[3]

It is now recognized that the health burden due to exposure from pollutants released during the incomplete combustion of solid fuels in rural indoors equals or even exceeds the burden contributed by urban outdoor exposures.[3]

Indoor air pollution due to biomass fuels is ranked 10th amongst most preventable risk factors for global disease burden and ranked 4th when only developing countries are considered.[4] World Health Organization states that more than 1.6 million deaths per year and 38.5 million disability-adjusted-life years are due to indoor biomass fuel smoke exposure and it predominantly affects women and children.[5] In India there is a yearly death toll of 662,000 due to biomass fuel exposure, and with these alarming figures India tops the list of fuel-related deaths in the South Asian region.[6]

Chronic obstructive pulmonary disease (COPD) is a major cause of chronic morbidity and mortality throughout world. It is the fourth leading cause of death in the world.[7,8] In industrialized countries, tobacco smoking is responsible for more than 80% of the incidence of COPD.[9] COPD is also observed in rural areas of developing countries, affecting mainly non-smoking women with exposure to biomass smoke during cooking. About 3 billion people worldwide are exposed to smoke from biomass fuel compared with 1·01 billion people who smoke tobacco, suggesting that exposure to biomass smoke might be the most important global risk factor for chronic obstructive pulmonary disease(COPD). In developing countries nearly 50% of deaths from COPD are attributable to biomass smoke, of which about 75% are of women.[10]

There are wide variations between rural and urban households regarding the specific type of biomass fuel used. In rural India, 62% of households use firewood and 14% cook with dung cakes while 13% use straw, shrubs, grass and agricultural crop residues. In urban India, 22% use firewood, 8% use kerosene, and the rest uses cleaner fuels like liquefied petroleum gas (LPG) or natural gas.[11] Seventy-five percent of rural households reported firewood as their primary cooking fuel as compared to only 22% of urban households.[12]

Moreover a majority of households in poor rural communities burn solid fuels in inefficient devices, often in kitchens that are poorly ventilated, resulting in very high exposure to multiple toxic products of incomplete combustion.[3]

Biomass materials are considered low-efficiency fuels because they emit many pollutant products and they take longer time to cook the food. The production and the use of biomass fuels are done under suboptimal conditions which contributes enormously to indoor air pollution and to greenhouse gas (GHG) burden.[4]

'Liquefied petroleum gas' (LPG) is commonly used as an indicator of a 'clean fuel using household'. The use of LPG (or other gaseous fuels), which is known to result in the lowest pollution levels within households, remains a nonfeasible proposition for bulk of India's population as a result of prices, limited supply, and access.[3]

Along with number of hours of exposure of individuals to biomass fuel smoke, ventilation factors also play an important role in determining the total exposure. These further depend on characteristics of stove such as presence of chimney/vent and characteristics of kitchen such as location of kitchen in relation to living room, building material etc. It has been seen that the overall prevalence of chronic obstructive pulmonary disease (COPD) was higher in biomass fuel users than the clean fuel users and it was two times higher (3%) in women who spend >2 hours/day in the kitchen involved in cooking.[13]

It is estimated that an average woman in India may be subjected to 60,000 h of exposure to smoke due to combustion of biomass fuels in her life time.[14] Exposure includes both the concentration of the pollutants and the time spent by the person in that environment (person-time). Assessment of biomass fuel exposures is done by measuring indoor concentrations of various pollutants including particulate matter (SPM 10 and SPM 2.5), personal exposures and breath levels of different pollutants but these methods are difficult to apply in everyday clinical practice.[4] A simple, easily applicable method is 'biomass exposure index' which can be calculated by multiplying the average hours spent on cooking per day and the number of years of cooking as developed by Behera *et al*.[14] A minimum threshold of biomass exposure index of 60 is necessary to have a significant risk of developing chronic bronchitis in women.[15]

The constituents of biomass smoke are particulate matter of less than 10 µm in aerodynamic diameter (PM10), carbon monoxide, nitrogen dioxide, sulphur dioxide, formaldehyde, and polycyclic organic matter, including carcinogens (e.g., benzopyrene).[16] Particles with a diameter smaller than 10 µm (PM10), and particularly those with a diameter smaller than 2.5 µm (PM2.5), can penetrate deeply into the lungs and appear to have the greatest potential for damaging health.[17] PAH, azo and amino compounds have also been found to be potentially carcinogenic. Formaldehyde affects respiratory system causing reduction in vital capacity and chronic bronchitis.[17] Toxic inorganic chemicals are known to cause asphyxiation, stillbirth, infant death, heart disease, and severe acute and chronic lung disease and their mechanisms of cell injury are still unexplained.[17]

Respiratory diseases occurring in adults primarily in rural women exposed to biomass combustion are interstitial lung disease, COPD, tuberculosis and lung cancer.[18] Studies both in India and other countries have confirmed a decline in lung function parameters[14,19-26] and high morbidity and mortality in biomass fuel users.[4,27]

Many studies have been conducted depicting adverse effects of biomass fuel smoke on respiratory system but only a few studies have taken into account the concept of Biomass exposure index which is very important factor for considering significant chronic exposure to Biomass fuel smoke. Moreover no such study has been conducted in Haryana. So this study was performed to evaluate the effect of biomass fuel combustion on pulmonary function in biomass exposed women keeping in view the importance of biomass exposure index and thereby highlighting the effect of chronic exposure of biomass smoke pollutants.

METHODS

This study was carried out in Physiology Department of Pt. B.D. Sharma PGIMS, Rohtak, Haryana (India).

Study Group

Sample size of 60 subjects was taken. The study cases were non-smoking women between the ages of 30-45 years using biomass fuel (cowdung, wood etc.) for cooking in rural areas of Haryana. The controls were age matched non smoking women using LPG for cooking and belonging to urban areas of Haryana. Both were cooking for a minimum period of 10-15 years and minimum duration of 2-4 hours/day. Female subjects with history of any major chronic illness in the past (pulmonary disease, cardiovascular disorder, any endocrine or metabolic disorder, psychiatric disorder) were excluded from the study. Subjects using mixed fuels were also excluded. Ethical justification was taken from the institutional committee.

Consent was taken from every subject to undergo the whole procedure. The whole procedure was explained in detail to each subject in her own language to allay any apprehension or fear. All the experiments were conducted from 10 AM to 1 PM to avoid diurnal variation. The basic parameters like age, weight, height, heart rate and respiratory rate were recorded. Relevant history like occupation, house type, kitchen type, fuel type, cooking duration in hrs/day and cooking duration in years were also recorded. The procedure for performing various tests was explained to the subjects in detail and they were made familiar with the devices used to perform the tests. The effect of age, weight and height was adjusted to avoid confounding error. The study is blinded as at the time of performing PFT we were unaware to which group the subject belonged.

Pulmonary Function Tests

The pulmonary functions were evaluated using RMS Medspiror. The subject's age (years), height measured in standing position without shoes in cms and weight measured in Kg were fed into the machine and the machine automatically gave the normal values corresponding to that age, weight and height thereby removing these confounding factors.

The subjects were instructed to apply mouth piece closely to the lips and close their nose with the nose clip/with her own fingers so as to prevent any leakage of air. The procedure was explained in detail and demonstrated to the subject prior to the commencement of each test and maximum effort on behalf of the subject was emphasized.

The parameters recorded were Forced vital capacity [FVC in litres], Forced expiratory volume in first second [FEV_1 in litres], FEV_1/FVC%, Forced expiratory flow rate 25-75% [MEFR litres/second], Maximum voluntary ventilation [MVV litres/minute] and Peak expiratory flow rate[PEFR litres/minute]. Every test was repeated thrice and spirometric indices were calculated using best out of 3 technically satisfactory performances as per recommendations of American Thoracic Society.[28]

Procedure for recording of FEV_1, FVC, MEFR 25-75%, PEFR

For recording of FVC, FEV_1, MEFR 25-75%, PEFR the subjects were asked to breathe in and out normally into the mouth piece. Then the subject was asked to take deep breath to fill lungs to maximum possible and then exhale into the mouth piece as quickly as possible. All the subjects made three such attempts and the best of them was selected.

Procedure for recording of MVV

For recording of MVV subjects were asked to inhale and exhale as deeply and quickly as possible for 15 seconds. Then MVV was calculated in litres/minute. The subjects were also instructed to stop if they feel any discomfort.

Group formation

For interpretation of the result, the data were divided into two groups: Group I- data of rural female subjects exposed to biomass fuel smoke.

Group II- data of urban female subjects exposed to clean fuel smoke.

Statistical Analysis

Statistical analysis was done by using a commercially available software package Microsoft Excel® 2007 and SPSS software. Statistical significance between group I and group II was determined by using Student's unpaired t test for symmetrical data and Mann Whitney U test for skewed data. A p value of <0.05 was considered statistically significant.

RESULTS

The house type, kitchen type and fuel type distribution of biomass group and control group is shown in Table 1, 2 and 3.

Table 1: House Type Distribution.

House Type	Group I(n=30) Rural Female	Group II(n=30) Urban Female
Kutcha	12 (40%)	(0%)
Pakka	13 (43.33%)	26 (86.67%)
Mixed	5 (16.67%)	4 (13.33%)
Total	30 (100%)	30 (100%)

Table 2: Kitchen Type Distribution.

Kitchen Type	Group I(n=30) Rural Female	Group II(n=30) Urban Female
Open Non Separate	10 (33.33%)	(0%)
Kutcha Separate	11 (36.67%)	(0%)
Pakka Separate	9 (30%)	30 (100%)
Total	30 (100%)	30 (100%)

Table 3: Fuel Type Distribution.

Fuel Type	Group I (n=30) Rural Female	Group II (n=30) Urban Female
Wood (WD)	10 (33.33%)	(0%)
Cow dung (CD)	5 (16.67%)	(0%)
Wood/Cow dung (WD/CD)	15 (50%)	(0%)
LPG	(0%)	30 (100%)
Total	30 (100%)	30 (100%)

The age distribution, cooking duration in hours/day and cooking duration in years of biomass group and control group is shown in Table 4, 5 and 6.

Table 4: Age distribution of groups.

Age Group (yrs.)	Group I (n=30)	Group II (n=30)
30-34	8 (26.67%)	14 (46.67%)
35-39	9 (30%)	5 (16.67%)
40-45	13 (43.33%)	11 (36.67%)
Total	30 (100%)	30 (100%)
Mean age in years ±SD	38.03±5.50	36.87±6.25

Table 5: Cooking Duration in hours/day.

C.D (Hours/Day)	Group I (n=30)	Group II (n=30)
2.5	-	9
3	7	10
3.5	1	-
4	13	8
4.5	2	-
5	5	1
6	2	1
8	-	1
Total	30	30
Mean Hours ±S.D	4.08±0.84	3.45±1.21

The anthropometric profile of both the groups is shown in Table 7.

Table 6: Cooking Duration in years.

Cooking Duration (Years)	Group I (n=30) Rural Women	Group II (n=30) Urban Women
10-15	4	13
16-20	10	8
21-25	11	5
26-30	5	4
Total	30	30
Mean ±S.D	21±4.39	18.6±5.76

Anthropometric Parameters

Table 7: Weight, Height and BMI distribution.

Parameters	Group I Rural Females (Mean ±S.D)	Group II Urban Females (Mean ±S.D)	p value
Weight (Kg)	49.13±8.44	54±12.01	p>0.05 (NS)
Height (cm)	152.33±5.25	155.43±4.71	p<0.05 (S)
BMI (Kg/m²)	21.24±3.80	22.24±4.17	p>0.05 (NS)

Table 8: PFT Parameters (% Predicted values).

Parameter	Group I (Mean ±S.D)	Group II (Mean ±S.D)	Group I Vs. Group II (p value)
FEV1-% of predicted	61.03±21.1	92.8±11.47	p<0.01 (S)
FVC-%of predicted	72.1±11.96	92.4±10.24	p<0.01 (S)
FEF 25-75%-% predicted	65.5±19.96	95.87±5.75	p<0.01 (S)
PEFR-% predicted	63.7±20.13	91.33±5.2	p<0.01 (S)
MVV-% predicted	61.27±20.56	92.97±6.56	p<0.01 (S)

Overall inadequate ventilation status was found in Group I Biomass fuel users as estimated by House type and Kitchen type. Biomass exposure index was calculated by multiplying cooking duration in years and in hours/day. It came out to be 85.68±3.69 for Group I biomass users. On taking history the cases (Group I) had complaints of lacrimation, running nose at the time of start of combustion and respiratory symptoms like breathlessness on exertion, cough with expectoration. But the patients did not come to hospital as they were ill-literate and unaware of the fact that these symptoms could be due to biomass fuel combustion. The LPG group did not complain of any such symptoms. The pulmonary function test (spirometric) parameters were compared as shown in Table 8 and the values were found to be significantly reduced in Group I biomass exposed rural women.

Table 9: PFT Parameters (Mean values).

Parameter	Group I (Mean ±S.D)	Group II (Mean ±S.D)	Group I Vs. Group II (p value)
FEV1 (litres)	1.06±0.38	1.70±0.26	p<0.01 (S)
FVC (litres)	1.57±0.3	2.12±0.35	p<0.01 (S)
(FEV1 litres/ FVC litres) ×100	65.34±14.5	81.54±9.87	p<0.01 (S)
FEF 25-75% (litres/sec)	1.95±0.65	2.97±0.30	p<0.01 (S)
PEFR (litres/min)	3.72±1.24	5.44±0.56	p<0.01 (S)
MVV (litres/min)	59.4±21.17	92.77±8.35	p<0.01 (S)

DISCUSSION

In the present study we aimed to see the effect of biomass fuel and clean fuel smoke on various respiratory parameters. House type is related to ventilation status of the house. In our study rural women were more exposed to biomass fuel smoke as kutcha houses are not provided with proper ventilation (no chimney or vent). Majority of the urban women resided in pakka houses with proper ventilation, so the exposure to fuel smoke is less.

In this study most of the rural women (66.67%) cooked in separate but closed kitchens and were more exposed to biomass fuel smoke as compared to women who cooked in open non separate kitchen and were less exposed. Ventilation status is known to influence pulmonary functions. A study conducted in Porur, Chennai reported that cooks using an open outdoor kitchen had less exposure to fuel smoke than cooks using an enclosed kitchen as emissions are dispersed outdoors.[29]

Biomass index was 85.68±3.69 (Group I) in the present study. This indicates significant exposure to biomass smoke in Group I rural females. A study stated that the minimum threshold of biomass exposure index of 60 is necessary to have a significant risk of developing chronic bronchitis in women.[15] The Colombian study with more than 5500 subjects showed that the exposure to biomass fuels for more than 10 years is a risk factor for COPD.[30]

In a recent study conducted in Nigeria on relationship between household air pollution from biomass smoke exposure and pulmonary dysfunction in rural women and children; the percentage predicted values of pulmonary function parameters (FVC-78.63±10.99; FEV1 69.78±16.58; FEF25-75% 59.32±25.21; PEFR 58.47±23.21) and FEV1/FVC ratio (74±13) were significantly reduced in the biomass exposed women. The woman taken in Nigerian study were from age group 20-60 years but the quantum of exposure in hours and in years was not taken in the study. However the median indoor $PM_{2.5}$ level was taken.[31] In our study the percentage predicted values [FVC-72.1±11.96; FEV1 61.03±21.1; FEF25-75% 65.5±19.96; PEFR 63.7±20.13 as shown in Table 8] and FEV1/FVC ratio (65.34±14.5- Table 9) were significantly reduced in biomass smoke exposed rural women. The female subjects taken in our study were of age group 30-45 years. The mean exposure in our study was 4.08±0.84 hours/day with mean duration of exposure being 21±4.39 years and biomass index being 85.68±3.69.

In another recent study on pulmonary function test in rural women exposed to biomass fumes it was found that pulmonary function parameters {FEV1 in litres (1.44±0.36), FVC in litres (1.62±0.38), PEFR in litres/second (3.11±1.05), MVV in litres/minute (49.70±14.11)} were significantly reduced in biomass fuel users as compared to clean fuel users and the mean exposure in hours was 3.5 hours/day with duration of exposure ranging from 8 to 30 years.[25] Whereas in our study the mean values {FEV1 in litres (1.06±0.38); FVC in litres (1.57±0.3); PEFR in litres/min (3.72±1.24); MVV in litres/min (59.4±21.17) as shown in Table 9} were significantly reduced in Group I biomass exposed rural females. The mean exposure in our study was 4.08±0.84 hours/day with mean duration of exposure being 21±4.39 years and biomass index being 85.68±3.69.

In a study conducted in Karnataka, it was observed that the lung function parameters (FEV1, FVC, FEV1/FVC%, FEF 25-75%, PEFR) were significantly lesser in the study group exposed to biomass fuel. The mean duration of cooking in the study was 3.5±1.3 hrs/day with mean cooking years being 12.2±5.2 years and biomass index as calculated came out to be 42.7±6.76.[32]

Another study on biomass exposed rural women of Tamil Nadu found that COPD prevalence was higher in biomass fuel users than the clean fuel users. It was further stated that COPD prevalence was much higher in women who spend more than 2 hours/day in cooking and have been involved in cooking for more than 15 years. Biomass exposure index of our study (85.68±3.69) is much higher than this study (as calculated came out to be >30).[13]

The deterioration in our study is slightly more as compared to the above mentioned studies due to the fact that the Quantum of exposure of females to biomass fuel smoke is much more as highlighted by significant cooking hours, chronicity of cooking years and high biomass exposure index. Probably inadequate ventilation status also contributed to the impairment of pulmonary function parameters.

A study observed that peak expiratory flow rate (PEFR) was reduced in biomass fuel users as compared to clean fuel users.[23] In a study by Saha et al; FEV1, FEV1/FVC%, FEF 25-75%, PEFR values were significantly lower in females using biomass fuels than the females using LPG.[19] A Turkish study observed that mean values of pulmonary function test parameters FEV1, FVC and FEF25-75% were decreased statistically among the biomass affected group.[33] A recent meta-analysis has shown that biomass fuel exposure is associated with a significant risk for chronic bronchitis and COPD[34] and the strength of association was similar to that of cigarette smoking.[35] There is strong evidence linking inhalation of biomass fuel smoke and chronic bronchitis in women aged above 30 yr with a relative risk of 3.2 (95% CI 2.3-4.8).[4]

Studies both in India and other countries have confirmed that exposure to biomass fuels has a significant association to decline in objective lung function parameters.[14,20-22] Population based studies have demonstrated a clear link between exposure to smoke from biomass fuels and COPD in India[14,36], Colombia[30], China[37], Spain[38] and Mexico[20]. Comparative analysis has demonstrated that biomass and cigarette smoke activate pathogenic processes, such as inflammation and protease expression, that are linked to the development of COPD. Biomass is found to activate mechanisms in the lung that are central to the development of COPD.[39]

Our findings indicate obstructive pattern of pulmonary dysfunction in biomass fuel exposed females. The impairment in lung function could be due to chronic inhalation of high concentration of respiratory irritants present in biomass fumes.

Many studies have quoted adverse effect of biomass fuel smoke on quality of life[27,40] and interventions should be done to avoid ill health impacts of biomass fuel smoke.

CONCLUSION

Biomass fuel is having detrimental effect on health of human beings. Biomass fuels are used inside homes without proper ventilation. So use of more advanced stoves with chimneys/vent and usage of fuels that do not produce such fumes (such as LPG) is recommended to avoid exposure of women who are practicing cooking on biomass stoves. Women in developing countries who cook over a wood stove for years and inhale the smoke can experience the same clinical characteristics, diminished quality of life and increased mortality rates as tobacco smokers. There is a need to expand the limited amount of knowledge and to create effective intervention programs with an objective to provide a better quality of life to individuals exposed to biomass smoke pollutants. Further research is recommended as very little research has been done on chronic effects of biomass smoke.

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