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Original Research Article

The Comparative Study of Pulmonary Function Tests between Healthy Non-Smoking Rural Women using Biomass Fuel and Liquefied Petroleum Gas

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Abstract: Indoor air pollution from burning of traditional biomass fuel such as wood, dung and agricultural wastes for daily household cooking is a major problem in rural India. Indoor fuels include solid, liquid, gas and electricity. Solid fuels include biomass and coal. Liquid fuel includes kerosene and liquefied petroleum gas (LPG). Gas fuels include methane and natural gas. Biomass fuel refers to any plant or animal-based material that is deliberately burned by humans as fuel such as wood, twigs, dried animal dung, charcoal, grass or agricultural crop residues. Indoor smoke from biomass burning is the most important health hazard due to gases or particulates causing respiratory impairment if inhaled in adequate concentration over a long period of time. In the present study we compared the pulmonary function tests (PFT) in two groups of healthy nonsmoking rural women as a study group having 50 women more than 30 years of age exposed with biomass fuel and another control group of 50 women using LPG as cooking fuel. Our study showed significantly decreased PFT like FVC (2.34 ± 0.38), FEV1 (2.03 ± 0.37), FEV1/FVC% (87.43 ± 11.64) and PEFR (4.33 ± 1.09) in biomass user than LPG user group (FVC=2.51 ± 0.31, FEV1=2.21 ± 0.26, FEV1/FVC% =88.21 ± 6.4 and PEFR=4.86 ± 0.79). Chronic exposure ≥15 years for biomass fuel showed the significant reduction in FVC (2.21 ± 0.3 versus 2.36 ± 0.23), FEV1 (1.91 ± 0.29 versus 2.08 ± 0.18), FEV1/FVC (87.33 ± 13 versus 88.49 ± 7.27) and PEFR (4.1 ± 1.09 versus 4.55 ± 0.69) values. Thus awareness about the harm of biomass fuels, regular monitoring of health and use of smokeless chulha, proper kitchen ventilation and easily availability of cleaner fuel such as LPG are necessary objects to reduce health hazards of biomass fuel.
Keywords: Pulmonary Function Tests, Biomass, Liquefied Petroleum Gas, Nonsmoking, Rural, Women

INTRODUCTION:

Air is first need for life which is available easily but clean air to breathe is as important as clean water and food while it is a major problem due to air pollution. Air pollution emissions are released from both natural and anthropogenic sources. Air pollution is generally perceived as an urban problem associated with automobiles and industries but indoor air pollution emitted from traditional fuels and cooking stoves is a potentially large health threat in rural regions.

There are four principal categories of indoor air pollution - combustion products, chemicals, radon and biological products. Indoor fuels include solid, liquid, gas and electricity. Solid fuels include biomass and coal. Liquid fuel includes kerosene and liquefied petroleum gas (LPG). Gas fuels include methane and natural gas. LPG and natural gas, in addition to electricity, are widely viewed as clean fuels. Worldwide, wood is the most common solid fuel used, although coal is predominantly used in China and dried cow dung is commonly used in rural South Asia [1]. Biomass fuel refers to any plant or animal based material (wood, animal dung, crop residues such as rice husks) deliberately burned by humans, usually for cooking or heating on Chulha. Many millions of people, predominantly women from poor or developing countries, are obliged to breathe air polluted with bio-fuel emission products [2]. Indoor smoke due to biomass fuel contains a complex mixture of a large number of pollutants [3, 4]. These pollutants includes respirable particulate matter with diameter less than 10 (PM10) and 2.5 microns (PM2.5) or even less (ultra-fine), carbon monoxide (CO), oxides of nitrogen and sulfur, benzene, formaldehyde, 1,3-butadiene, polycyclic aromatic hydrocarbons such as benzo(α)pyrene, free radicals, volatile organic compounds, chlorinated dioxins, oxygenated and chlorinated organic matter, and endotoxin.

Air pollution is either due to gases or particulates; these individually or in combination can cause respiratory impairment if inhaled in adequate concentration over a long period of time [5]. It has been causally linked to acute respiratory infections [6], chronic obstructive pulmonary diseases [7], otitis media [8], tuberculosis [9], asthma [10], interstitial lung disease [11], cataract [12], blindness [13], cor pulmonale [14], lung cancer [15], cancer of nasopharynx [16] and uterine cervix [17]. Forced spirometry is one of the best tests for volume assessment [18]. These simple breath pulmonary function tests are used extensively in assessing the pattern of ventilatory impairment in restrictive and obstructive group of pulmonary diseases [19].

MATERIAL AND METHODS:

The present study was designed to compare the pulmonary function tests (PFT) between two groups of rural healthy nonsmoking women of western Rajasthan during the year of 2015-16. In the study group we selected 50 women exposed with biomass fuel and in control group we selected age, height and weight-matched 50 women using liquefied petroleum gas (LPG) as cooking fuel.

Inclusion criteria:

- Non-smoking healthy females
- Age 30 or more than 30 years.
- Exposure to cooking fuel more than 10 years.
- Principal family cook.
- Minimum 3-4 hours cooking per day.
- Separate kitchens.

Exclusion criteria:

- Age less than 30 years.
- Any respiratory problems.
- Any other local or systemic illness.
- Any acute or chronic medications.
- Smokers.
- Pregnancy.

The type of ventilation in the kitchen, number of windows, presence or absence of chimney in the kitchen and presence or absence of soot deposits in kitchen cooking variables included the time spent in hours in household cooking per day and the number of years of cooking, the anthropometric data i.e., age, height, weight, blood pressure, respiratory rate, medical history, clinical examination. The age (in years), height measured in centimeters in standing position without shoes and weight measured in kilograms. Informed and written consent of all the subjects had taken before conducting the study.

PROCEDURE:

Pulmonary function tests were performed using electronic spirometer (Spiro Excel PC/Laptop based spirometer, Medicaid Systems). It consists of an ergonomic handset with digital turbine transducer which was connected directly to a PC/Laptop’s USB port. Subjects were shown demonstration of tests. The subject was made to sit in front of the electronic spirometer on the table with the mouth piece of spirometer at the level of his lips. Initially the subjects were made comfortably and breathe in and out normally to familiarize themselves with the equipment. After feeding the anthropometric and other necessary details of the subject, asked to close nostrils by nose clip and inhale to their maximum capacity and then after clicking the start button in FVC test menu, exhale forcefully into the sensor as hard as and for as long as possible and take full and unhurried inspiration in continuation through the mouth without leaking air in between lips and mouth piece of the spirometer. The results were displayed on screen and recorded in laptop. This procedure was repeated and the best of three readings was considered for analysis. The parameters which measured were FVC (Forced Vital Capacity), FEV1 (Forced Expiratory Volume in 1 second), FEV1/FVC% (percentage of the ratio of FEV1 with FVC) and PEFR (Peak Expiratory Flow Rate).

STATISTICAL ANALYSIS:

Mean and standard deviation of all parameters of both study and control groups of subjects were calculated by Microsoft Excel. The data were compared by t-test in “Open Epi” software. The p value <0.05 was considered as statistically significant.

RESULTS AND DISCUSSION:

Table 1: Comparison of Anthropometric Parameters

Parameters	Biomass users	LPG users
	Mean ± SD	Mean ± SD
Age (Year)	41.48 ± 6.87	39.34 ± 5.72
Height (cm)	154.28 ± 4.3	153.34 ± 3.51
Weight (kg)	64.52 ± 7.44	57.9 ± 4.67
BMI (kg/m^2)	27.13 ± 3.13	24.62 ± 1.66

Table no1 is showing anthropometric parameters between biomass user and LPG user group. Age, height, weight and BMI were found almost similar in both the groups. (P>0.05)

Table 2: Statistical Analysis of Pulmonary Function Tests

Parameters	Biomass users	LPG users	p-value
	Mean ± SD (n=50)	Mean ± SD (n=50)	
FVC (L)	2.34 ± 0.38	2.51 ± 0.31	< 0.05 S
FEV1 (L)	2.03 ± 0.37	2.21 ± 0.26	< 0.01 HS
FEV1/FVC%	87.43 ± 11.64	88.21 ± 6.4	< 0.01 HS
PEFR(L/s)	4.33 ± 1.09	4.86 ± 0.79	< 0.01 HS

Note: - S = significant, HS = highly significant

Table no 2 is showing the PFT parameters between biomass and LPG user group. The result is showing that in biomass user group all parameters like FVC, FEV1, FEV1/FVC% and PEFR are significantly lower as compared to the group using LPG as cooking fuel.

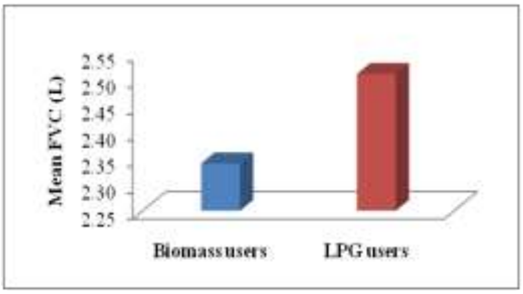

Fig 1: Comparison of mean FVC

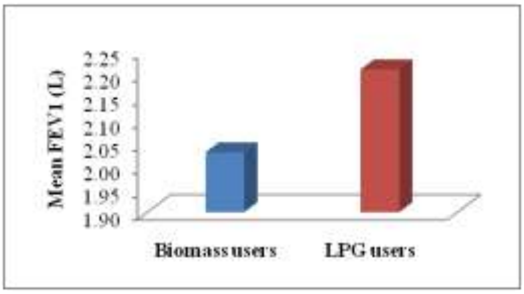

Fig 2: Comparison of mean FEV1

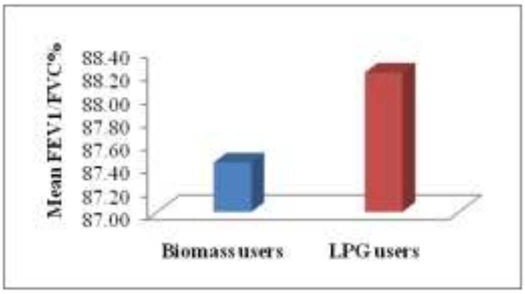

Fig 3: Comparison of mean FEV1/FVC%

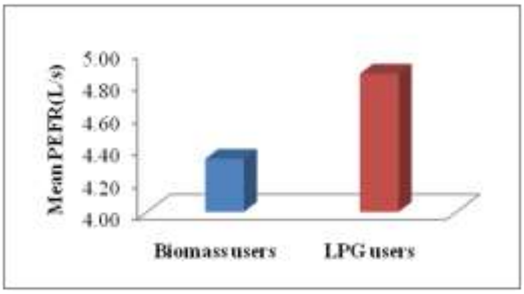

Fig 4: Comparison of mean PEFR

Table no 2 & figure1-4 are showing that mean Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), percentage of the ratio of Forced Expiratory Volume in 1 second (FEV1) with Forced Vital Capacity (FEV1/FVC%) and Peak Expiratory Flow Rate (PEFR) in biomass user group 2.34 ± 0.38 while in LPG user group FVC is 2.51 ± 0.31 which is are significantly lower on comparing to LPG user group.

Table 3: Statistical Analysis of Pulmonary Function Tests between Different Duration of Exposure

Parameters	Duration of Exposure (Years)	Biomass users	LPG users	p-value
		Mean ± SD (n)	Mean ± SD (n)	
FVC (L)	< 15	2.87 ± 0.16 (10)	2.87 ± 0.14 (15)	> 0.05 NS
	≥ 15	2.21 ± 0.3 (40)	2.36 ± 0.23 (35)	< 0.05 S
FEV1 (L)	< 15	2.52 ± 0.15 (10)	2.51 ± 0.12 (15)	> 0.05 NS
	≥ 15	1.91 ± 0.29 (40)	2.08 ± 0.18 (35)	< 0.01 HS
FEV1/FVC%	< 15	87.87 ± 2.29 (10)	87.57 ± 3.8 (15)	> 0.05 NS
	≥ 15	87.33 ± 13 (40)	88.49 ± 7.27 (35)	< 0.01 HS
PEFR(L/s)	< 15	5.27 ± 0.3 (10)	5.58 ± 0.5 (15)	> 0.05 NS
	≥ 15	4.1 ± 1.09 (40)	4.55 ± 0.69 (35)	< 0.01 HS

Note: - NS = Nonsignificant, S = significant, HS = highly significant

Table no 3 is showing changes in different parameters of PFT in both groups according to years of exposure. Each parameter is decreasing in biomass group upon increasing exposure years to biomass fuel but significantly difference between two groups was observed when duration of exposure was ≥15 years. For duration of exposure <15 years; biomass users and LPG users has shown no significantly difference between two groups for all the PFT-parameters.

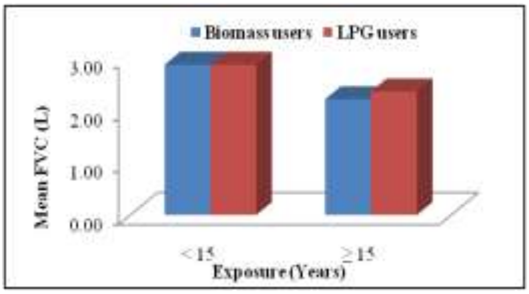

Fig 5: Comparison of mean FVC

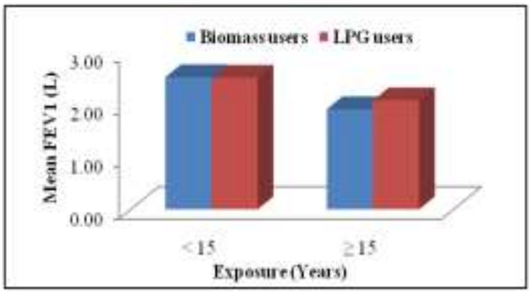

Fig 6: Comparison of mean FEV1

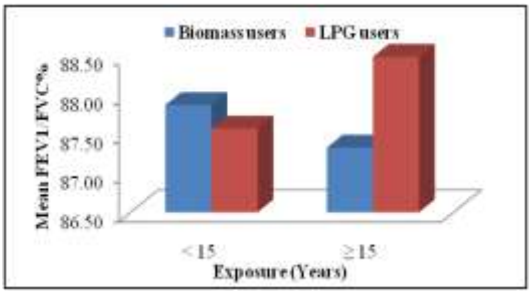

Fig 7: Comparison of mean FEV1/FVC%

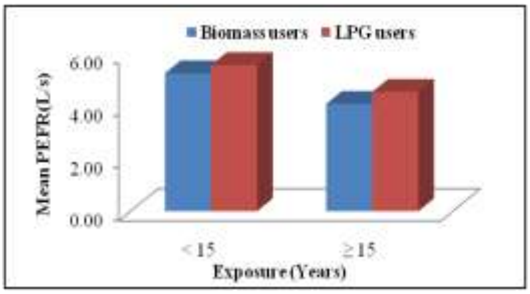

Fig 8: Comparison of mean PEFR

Table 4: Comparison of PFT in Biomass & LPG users

Pulmonary Function Tests	No. of Subjects		
	Biomass users	LPG users	Total
Abnormal PFT	32	12	44
Normal PFT	18	38	56
Total	50	50	100

Table no3 and figure 5-8 are showing that mean FVC, FEV1, FEV1/FVC% and PEFR are significantly lower in biomass group subjects having exposure ≥15 years as compared to LPG group while those subjects who have exposure <15 years are not showing any significantly changes in both the groups. Table no 4 shows the PFT interpretation that in biomass users 32 subjects while in LPG users 12 subjects have abnormal PFT (restrictive and obstructive) out of 50 subjects.

One half of the world's population uses biomass fuel as firewood, plant residues and cow/buffalo dung for cooking [20]. Rural India still relies on unprocessed biomass such as wooden sticks or cow dung for their cooking purpose. According to the WHO Indoor Air Pollution (IAP) from solid fuel ranks fourth amongst risk to human health in developing countries and ranks still higher in India (third). As compared to other countries, India has among the largest burden of disease and 28% of all deaths due to IAP in developing countries occur in India alone [21]. The incomplete combustion of biomass fuels like wood, coal, cow-dung cakes and crop residue releases by products like carbon monoxide, carbon dioxide, sulphur dioxide, polycyclic and polyaromatic hydrocarbons which are known to produce adverse health effects on respiratory system, that can manifest from simple cough to COPD and even cancer [22].

Hence we endeavored to conduct this study for analyzing the pulmonary function tests in rural women routinely exposed to biomass cooking fuel. Upon comparison of pulmonary function in both groups it was observed that almost 32 out of 50 women using biomass fuel had impaired lung function tests (Table no 4). Cooking fuel produces irritants such as oxides of nitrogen, sulphur dioxide and burnt hydrocarbons. They produce changes in lung function. Biomass fuel is more hazardous as it emits large amount of soot particles. These particles cause inflammatory reaction [23] in the mucous lining of respiratory tract causing luminal narrowing by excess mucus, edema, cellular infiltration and smooth muscle hypertrophy. This leads to small airway obstruction. These particles also cause inflammation or scarring of lung tissue result in filling of air space with exudates and debris. This leads to restrictive lung disease and also accompanied by reduced gas transfer [24].

Table 5: Comparison of Present Study with other Studies

Studies		Present Study (2016)	Jeneth *et al.;* [29] (2014)	Priya *et al.;* [30] (2014)	Vijayesh *et al.;* [31] (2014)	Empreet *et al.;* [32] (2013)	Ankit A *et al.;* [33] (2013)	Reddy *et al.;* [34] (2004)
FVC (L)	Study Group	2.34 ±0.38	1.96 ±0.34	1.57 ±0.3	1.49 ±0.75	1.7 ±0.52	1.62 ±0.38	2.79 ±0.52
	Control Group	2.51 ±0.31	2.22 ±0.42	2.12 ±0.35	3.25 ±0.86	1.89 ±0.16	1.94 ±0.37	2.76 ±0.54
	p-value	< 0.05	< 0.01	< 0.01	< 0.05	>0.05	< 0.01	>0.05
FEV1 (L)	Study Group	2.03 ±0.37	1.61 ±0.3	1.06 ±0.38	1.22 ±0.68	1.34 ±0.41	1.44 ±0.36	2.27 ±0.4
	Control Group	2.21 ±0.26	1.8 ± 0.31	1.7 ±0.26	2.74 ±0.75	1.78 ±0.13	1.74 ±0.33	2.28 ±0.43
	p-value	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.01	>0.05
FEV1/FVC %	Study Group	87.43 ±11.64	83.36 ±1.8	63.34 ±14.5	80.09 ±13.24	79.88 ±11.2	98.15 ±9.55	81.2 ±8.49
	Control Group	88.21 ±6.4	86.23 ±5.36	81.54 ±9.87	83.14 ±7.89	85.24 ±2.99	90.74 ±6.31	82.36 ±6.13
	p-value	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	>0.05	>0.05
PEFR (L/s)	Study Group	4.33 ±1.09	6.53 ±0.46	3.72 ±1.24	2.31 ±1.49	2.36 ±1.07	3.11 ±1.05	5.71 ±0.9
	Control Group	4.86 ±0.79	6.34 ±0.57	5.44 ±0.56	4.69 ±2.09	9.16 ±1.24	4.19 ±1.17	6.14 ±0.84
	p-value	< 0.01	>0.05	< 0.01	< 0.05	< 0.01	< 0.01	< 0.05

Note: - p-value >0.05 = nonsignificant, < 0.05 = significant, < 0.01 = highly significant

The obstruction is due to the chronic inflammation and the restrictive lung disease is due to scarring of lung tissues caused by respiratory irritants emitted by biomass fuel combustion. This finding was similar to the observation of Behera *et al.;* [25], Pandey *et al.;* [26], Asim Saha *et al.;* [27], Haldun Summer *et al.;* [28].The decrease in lung function in biomass fuel users may be due to the chronic inhalation of particulate matter and toxic gases emitted during biomass combustion leading to inflammatory changes. FVC reduction could be due to the changes in the lungs by chronic irritation of biomass combustion products. PEFR & FEV1 reduction in the pulmonary function can be due to the obstruction of airways during expiration. The FEV1/FVC ratio in biomass group was above normal which indicated restrictive lung disorders.

This study showed that healthy non-smoking women using biomass fuel for cooking had subclinical respiratory impairment. There were significant relation between exposure of biomass fuel and decrease in PFT like FVC (2.34 ± 0.38 versus 2.51 ± 0.31), FEV1 (2.03 ± 0.37 versus 2.21 ± 0.26), FEV1/FVC% (87.43 ± 11.64 versus 88.21 ± 6.4) and PEFR (4.33 ± 1.09 versus 4.86 ± 0.79). Chronic exposure ≥15 years for biomass fuel showed the significant reduction in FVC (2.21 ± 0.3 versus 2.36 ± 0.23), FEV1 (1.91 ± 0.29 versus 2.08 ± 0.18), FEV1/FVC (87.33 ± 13 versus 88.49 ± 7.27) and PEFR (4.1 ± 1.09 versus 4.55 ± 0.69). These findings of the present study were similar to the observation of various studies. (Table no 5)

CONCLUSION:

In this study we assessed the effect of biomass fuel smoke exposure on pulmonary function testes in healthy nonsmoking rural females and found that incomplete combustion of biomass fuels like wood, coal, cow-dung cakes and crop residue have made adverse health effects on respiratory system. Upon comparison of pulmonary function in both groups it was observed that women using chronic biomass fuel had impaired lung function tests. This study showed a significant relation between exposure with biomass fuel and decrease in PFT (FVC, FEV1, FEV1/FVC% and PEFR). This could be due to exposure to high concentration of respiratory irritants emitted during biomass fuel combustion and poor ventilation.

Biomass smoke contains a wide spectrum of potentially toxic compounds. Its effect on public health is relatively unexplored. The administrators, policy makers as well as the people are largely unaware about the harm of biomass fuels on their health. Millions of poor people of the country who cannot afford cleaner fuel have no other alternative but to use traditional biomass for cooking and room heating. Considering the extensive use of these fuels in the country and their potential health hazard, immediate measures should be taken by all concerned to reduce indoor air pollution level. The need is regular monitoring of health of the biomass users, extensive research on the mechanism of biomass-smoke toxicity and susceptibility. As long-term measures the authority should consider introduction of smokeless chulha, proper kitchen ventilation in all biomass using households and supply of cleaner fuel such as LPG at an affordable price to the rural people.

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