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Original Research Article

Effect of Biomass Fuel use on Pulmonary Functions in Non-smoking Healthy Women

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Abstract

Background: Several studies have been done in developing countries that established varying associations between biomass fuel use and pulmonary functions in young healthy non-smoking women. This study is a first of its kind conducted in Taladanda Canalside slum of Ranihat, Cuttack, Odisha to determine the effects of biomass fuel use on pulmonary functions in non-smoking healthy women.

Objective: This study was done with an objective to determine the effects of Biomass fuel use on pulmonary functions in non-smoking healthy women and its comparison with LPG users.

Methodology: The study was conducted for 1 year and 6 months from November 2014 to April 2016 including 160 non-smoking healthy women [Biomas Group(n=80) and LPG Group(n=80)]. Computerized Spirometry was done to determine the pulmonary functions of all subjects.

Results: Baseline parameters of the two groups were similar except for number of persons sleeping per room, socio-economic status. Biomass Group had a significantly lower FEV1, FEV1/FVC% without any significant change in FVC as compared to LPG Group.

Conclusion: A significantly lower FEV1, FEV1/FVC% without any significant change in FVC in the Biomass fuel user group is indicative of Obstructive Lung disease. This can be attributed to the adverse effects of indoor air pollutants generated due to the incomplete combustion of biomass fuel in indigenous Chulhas.

Keywords: Biomass, LPG, FVC, FEV1, Obstructive Lung Disease

Introduction

Food, clothing, and shelter are the basic necessities of human life. Cooking of food and its improper relation to shelter may have adverse effects on the Pulmonary Functions of women involved in cooking. Cooking increases the edibility of food. Cooking requires a wide variety of fuels ranging from Biomass, Kerosene, Liquid Petroleum Gas (LPG), Electricity, Solar energy. A major portion of the population in developing countries like India uses Biomass fuel for cooking [1,2]. Biomass

fuels most commonly used are coal, wood, charcoal, dried animal dung, and crop residues such as straw and sticks [3,4]. These biomass fuels when burnt in Chulha [Traditional Cooking stoves] lead to its inefficient combustion and release of a large variety of air pollutants including inhalable particulate matter and harmful gases like carbon monoxide, sulphur oxides, nitrogen oxides, aromatic hydrocarbons, formaldehyde [5,6,7]. Exposure to these pollutants generated during biomass combustion may lead to several respiratory diseases (Upper and Lower respiratory tract infections, Chronic Obstructive Lung Disease, Tuberculosis, Lung Cancers, etc.) and Non-Respiratory diseases (Cardiovascular diseases, Cataract, Nasopharyngeal, and Laryngeal cancers) leading to premature mortality and morbidity in women involved in cooking [4,8,9]. Biomass smoke also increases the incidence of low birth weight and infant mortality rates in the babies of mothers involved in cooking using Biomass. Biomass smoke exposure accounts for approximately 4% of the Global Burden of Diseases [10,11].

The WHO Indoor Air Quality Guidelines emphasized the use of clean fuel for cooking to check the household air pollution [12]. Liquid Petroleum Gas (LPG) is a widely available clean fuel that can be used as a source of household energy for cooking [13]. In India, the contribution of Biomass fuel as a source of household energy has declined in the last few decades [14]. This transition from traditional Biomass use to LPG use as a source of domestic energy will help to check the indoor air pollution and its deleterious effects on lung functions of the individuals involved in cooking activity. Therefore, this study was designed with the objective to determine the effects of Biomass fuel use on pulmonary functions in non-smoking healthy women and its comparison with LPG users.

Material and Methods

Study Design: This is a community-based cross-sectional study designed to compare the pulmonary functions of non-smoking healthy women using either Biomass fuel or LPG as a sole source of fuel for cooking.

Study Approval: The study was approved by the Institutional Ethics Committee of SCB Medical College and Hospital, Cuttack, Odisha, India. Informed written consent was mandatorily obtained from the participants before participating in the study.

Study Duration: The study was conducted for a period of 1 year and 6 months from November 2014 to April 2016.

Study Place: The study was conducted in only one center i.e., Department of Physiology, S.C.B Medical College and Hospital, Cuttack, Odisha, India.

Study Population: The study participants were non-smoking healthy females recruited from Taladanda Canalside slum of Ranihat, Cuttack, Odisha, India.

Inclusion Criteria: The eligible participants were lifetime non-smoking healthy females between the age group of 25 to 50 years. The participants must be using either Biomass fuel or LPG as a sole cooking fuel for at least an average cooking duration of 04 (Four) hours per day for a minimum period of 10 years.

Exclusion Criteria: Subjects using both LPG and Biomass fuel or any other fuel for cooking were excluded from the study. Subjects with respiratory diseases, cardiac diseases, pregnancy, bony deformities like kyphosis and/or scoliosis, Space Occupying Lesions (SOL) in the thoraco-abdominal region or any other severe illness were excluded from the study.

Sample Size: A total of 160 eligible participants participated in the study. The study participants were divided into two groups:-

- LPG Group (n=80)
- Biomass Group (n=80)

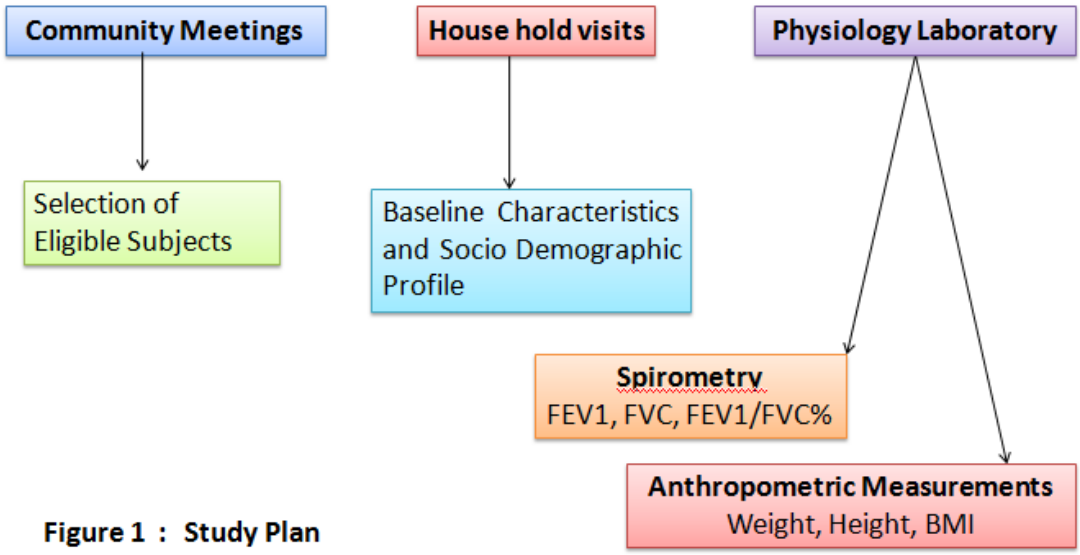

Figure 1 : Study Plan

Study Procedure: The study involved Community meetings, Household visits, and Tests in the Physiology Laboratory, Department of Physiology, SCB Medical College and Hospital, Cuttack.

- **Community meetings:** Five community meetings were conducted. Community Meetings involved detailed discussions on the types of cooking fuel (Biomass fuel/LPG), the Hazardous effect of Biomass smoke exposure on lung function, Advantages of using a clean source of fuel for cooking like LPG, Electricity, Solar Energy, etc. Motivation and Recruitment of eligible participants for the study. The study participants were divided into two groups:-
  - ✓ LPG Group (n=80): Women using LPG as a sole source of fuel for cooking.
  - ✓ Biomass Group (n=80): Women using Biomass as a sole source of fuel for cooking.
- **Household visits:** Household visits were done for the collection of baseline data and socio-economic profile. The information on the cooking fuel used i.e. Biomass fuel or LPG. The cooking method is used like indigenous Chulhas or LPG Gas stoves. Place of cooking ie open space or Verandah or separate kitchen or in the same living room. Ventilation at the site of cooking with an emphasis on windows, ventilators, chimneys, and scope for proper or cross ventilation. Cooking parameters like average cooking duration in hours per day and period of cooking in years. Thereby, calculating the Cooking Index or Biomass Exposure Index which is the product of hours utilized in cooking per day and duration of cooking in years [6,15]. Housing conditions like Kaccha or Kaccha-pucca or Pucca house. The number of persons sleeping per room and Exposure to passive smoking. Educational Status like Illiterate, Primary school, Middle school, and above. Socio-economic status based on Modified Kuppuswamy's Socioeconomic scale 2012 into Upper, Upper middle, Lower middle, Upper lower and Lower class [16].
- **Physiology Laboratory Tests:**
  - **Anthropometric Measurements:** Measurement of Anthropometric parameters like Height, Weight, Body Mass Index (BMI), etc.
  - **Spirometry:** Spirometry of eligible participants was done in the Department of Physiology, SCB Medical College and Hospital, Cuttack

between 9:00 am to 11:00 am to avoid diurnal fluctuations using Computerised Spirometry, Model 'RMS HELIOS 401' and Serial No. 'HELS/0025/401' (Manufactured by Recorders & Medicare Systems (P) Ltd.). Detailed information regarding the procedure was given to the subject followed by a demonstration of the procedure. By applying nasal clips, three satisfactory spirometric readings were taken and the best one of the three spirometric readings was considered as the subject's representative spirometric value. Predicted values of FEV1 and FVC were calculated by the manufacturer's 'RMS HELIOS 401' software based on the subject's sex, age, height, and weight. In this study, we recorded the subject's representative spirometric values like Forced Vital Capacity (FVC), Forced Expiratory Volume in 1s (FEV1), FEV1/FVC%. The systems inbuilt software 'RMS HELIOS 401' provided the subject's Spirometric Interpretation as Normal, Mild Obstruction, Severe Obstruction, etc.

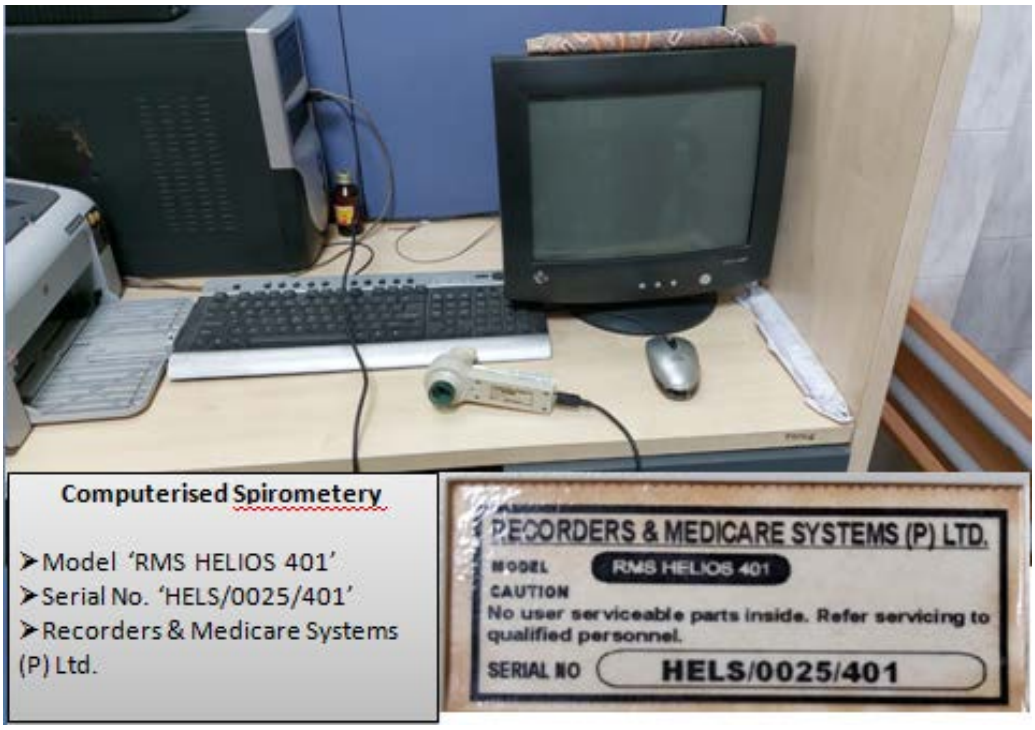

Figure – 2: Computerised Spirometry (Model 'RMS HELIOS 401')

Statistical Analysis: Data entry was done in Microsoft Excel 2016 and Statistical Software version **SPSS 22.0.** The level of significance of 0.05 (5%) was taken for test statistics. Frequency, Percentage, descriptive Statistics, and Chi-Square tests were applied to analyze the data.

Results:

A total of 254 women attended the community meetings. 210 women were motivated to participate in the study but 164 women were eligible participants for the study and 46 women (04 women-Pregnancy; 01 woman – Pleural Effusion; 01 woman - Kypho-scoliosis; 01 woman-Cardiac disease; 18 women – Using both Biomass and LPG; 15 women- Using both Biomass and Kerosene; 06 women - Using both Biomass and Electric Heater) were excluded based on the exclusion criteria. Informed written consent was obtained from 164 eligible participants. Again, 04 eligible participants were unable to perform

the spirometry satisfactorily. Finally, 160 participants performed the spirometry satisfactorily and their spirometric findings were considered for analysis.

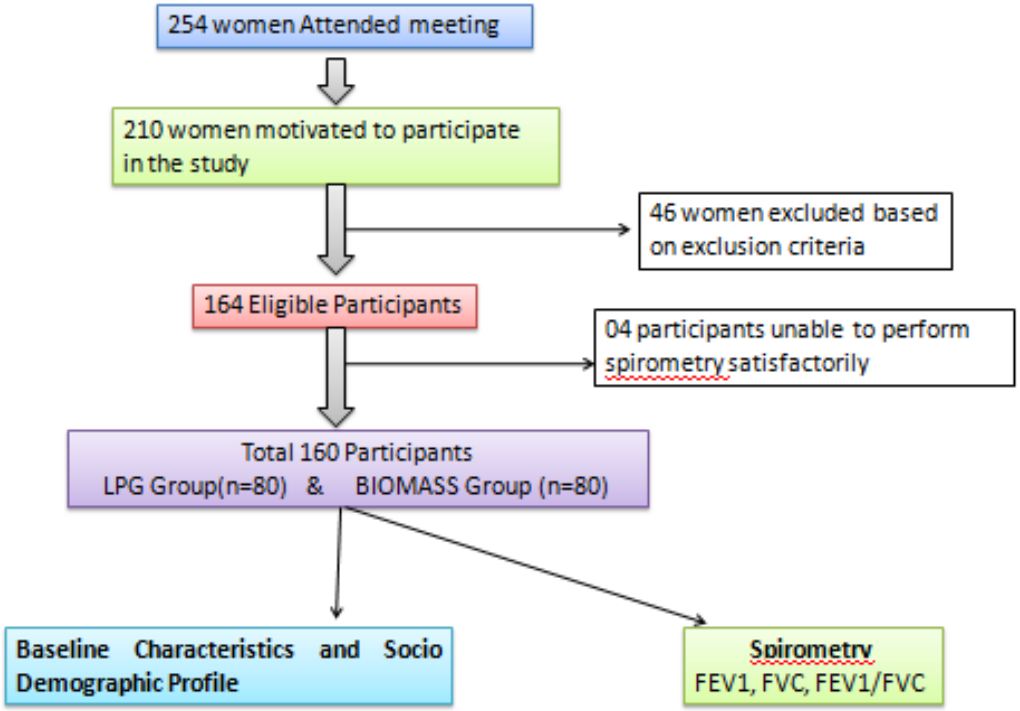

Figure 3 : Schematic representation of Study Procedure.

Table – 1: Baseline Characteristics and Socio-Demographic variables

Variables		LPG Group (n=80)	Biomass Group (n=80)
Age (years)		39.04 ± 7.02	39.80 ± 7.92
Weight (kg)		49..52± 9.92	46.12 ± 7.82
Height (cm)		148.18± 4.30	146.34 ± 4.70
BMI		22.76± 4.38	21.08 ± 3.08
Number of persons sleeping per room *		2.32± 0.66	3.90± 1.80
Housing	Kuccha	15 %	32.5%
	Kuccha-Pucca	57.5%	62.5%
	Pucca	27.5%	5%
Ventilation	No window	1 (1.25%)	4 (5%)
	One widow	35 (43.75%)	44 (55%)
	Atleast one window and ventilator / Chimney	44 (55%)	24 (30%)
	Open space / Verandah	0	5 (6.25%)
Educational Status	Illiterate	62.5%	77.5%
	Primary School	22.5%	17.5%
	Middle school and above	15%	5%%
Socio-Economic Status (Based on Modified Kuppuswamy's	Upper	Nil	Nil
	Upper Middle	5%	2.5%
	Lower Middle	32.5%	12.5%
	Upper Lower	60%	37.5%

Socioeconomic scale 2012)	Lower	2.5%	47.5%

*p<0.05 Significant

Data are either mean±SD or Percentage (%)

Table - 2 : Spirometric Recordings

Pulmonary Function Parameters	LPG Group	Biomass Group
FVC	2.42±0.52	2.26±0.64
FEV1	2.18±0.52	1.96±0.58 *
FEV1/FVC%	92.16±4.02	86.40±8.88 *

*p< 0.05 Significant

The age, height, weight, and BMI of subjects in the two groups were not significantly different. The number of persons sleeping per room was significantly higher in the Biomass Group with respect to the LPG Group. In both groups, the majority of the houses were Kuccha-Pucca type. In LPG Group, none of the subjects was cooking in open space or Verandah because the subjects of LPG Group found that the flame of LPG Stoves gets disturbed in open space due to the free blowing air. In both groups, the majority of the subjects were illiterate. Based on socio-economic status, none of the subjects either in LPG or Biomass Group belonged to the Upper class. The majority of the subjects in the LPG Group belonged to Lower Middle and Upper Lower classes. However, the majority of the subjects in the Biomass Group belonged to Upper Lower, and Lower classes. More than 70% of women in the Biomass Group had Biomass Exposure Index > 60. Spirometric recordings show no significant difference in FVC values between the two groups. However, FEV1 and FEV1/FVC % were significantly lower in the Biomass Group as compared to the LPG Group.

Discussion:

Inefficient combustion of Biomass fuels in Chulha (Traditional Cooking stoves) leads to the release of a wide variety of air pollutants [5,6,7]. Exposure to these pollutants generated during biomass combustion may lead to several respiratory diseases (Upper and Lower respiratory tract infections, Chronic Obstructive Lung Disease, Tuberculosis, Lung Cancers, etc.) and non-respiratory diseases (Cardiovascular diseases, Cataract, Nasopharyngeal, and Laryngeal cancers) leading to premature mortality and morbidity in women involved in cooking [4,8,9].

The threshold value of the Biomass Exposure Index to cause a significantly high risk of chronic bronchitis is above 60[17]. In our study, more than 70% of women in the Biomass Group have Biomass Exposure Index > 60. FEV1 and FEV1 / FVC % were significantly lower in the Biomass Group as compared to the LPG Group. However, no significant difference in FVC was observed between the two groups. A significantly lower FEV1 and FEV1/FVC without any significant change in FVC in the Biomass user group is an indication of the obstructive type of lung disease. Other studies too observed obstructive airway diseases in women exposed to Biomass smoke [18,19]. Women involved in cooking with Biomass fuel are at 2.4 times more risk of developing Obstructive Lung diseases compared to other cleaner cooking fuels like LPG, Electricity, Solar energy.[20]

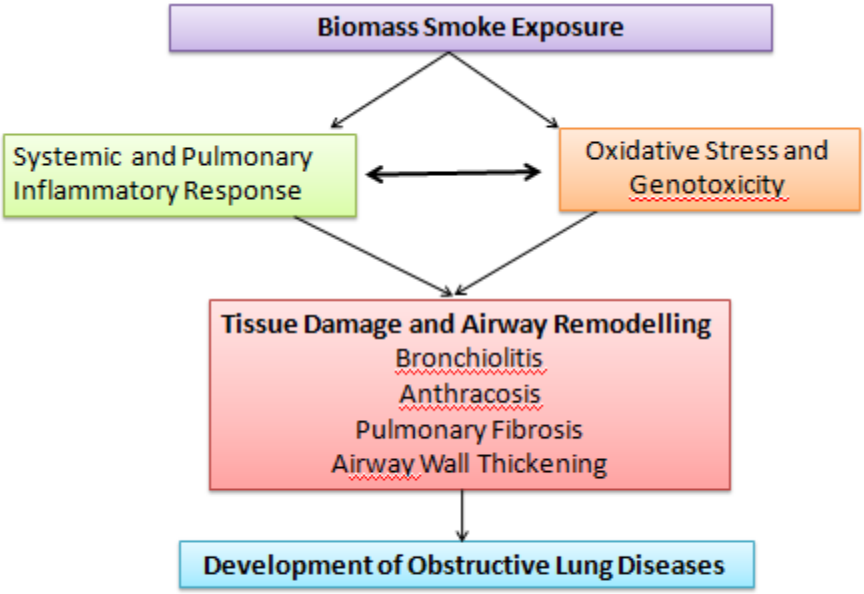

Figure 4 : Biomass Smoke exposure and Pathogenesis of Obstructive Lung Disease.

Current studies have shown that Biomass smoke exposure has an important role in the pathogenesis of Obstructive Lung Diseases. It is found that PM (Particulate Matter of Respirable size) in Biomass smoke induces Inflammatory changes and Oxidative stress. Inflammatory responses are brought by activation of pulmonary TRP (Transient Potential Receptor) ion channels and TLR (toll-like receptors). This results in the recruitment of inflammatory cells like macrophages, neutrophils, eosinophils, etc in the lung and creates a state of Systemic and Pulmonary inflammation. Inflammatory cells also bring Oxidative Stress by more generation of ROS. Oxidative Stress is brought by PMs in the Biomass smoke. PMs lodged in lower airways cause sequestering of iron from epithelial tissues (disturbances in iron metabolism). This results in low iron availability in the cells followed by the importation of iron and reduction of iron by Fenton reaction ($Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + {}^{\bullet}OH + OH^-$). It generates Reactive Oxygen Species (ROS) causing Oxidative Stress and oxidizing macromolecules like protein, lipids, carbohydrates, and DNA adding to tissue damage and genotoxicity. Oxidative stress also activates the production of more Pro-Inflammatory mediators. The Inflammatory changes and Oxidative stress induced by Biomass Smoke exposure results in Tissue Damage (bronchiolitis, anthracosis, and pulmonary fibrosis) and Airway Remodelling (airway wall thickening) leading to the development of Obstructive Lung Disease [21,22,23].

Conclusion

A significantly lower FEV1 and FEV1/FVC% without any significant change in FVC in the Biomass user group is indicative of Obstructive Lung disease. This can be attributed to the adverse effects of indoor air pollutants generated due to the incomplete combustion of biomass fuels in indigenous Chulhas. Biomass smoke exposure accounts for approximately 4% of the Global Burden of Diseases [10,11]. Remedial steps that may be adopted to reduce the adverse effects of Biomass Fuel use are 1. Use of Combustion Efficient better-designed Biomass stoves, 2. Proper ventilation and installation of Chimneys in the cooking area, 3. Separation of the living room from the cooking area, 4. Use of masks while cooking, 5. Shifting from Biomass fuel to other cleaner sources of energy like LPG, Electricity, Solar energy,

etc. 6. Community awareness on the hazardous effects of Biomass Smoke Exposure. 7. Policymaking for promoting the use of clean fuel as a source of domestic energy. The Ujjwala Yojna of the Government of India is playing a pivotal role in promoting the LPG used for cooking activities.

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