COMPARATIVE REPORT ON PULMONARY FUNCTIONS IN RURAL AND URBAN WOMEN IN WESTERN MAHARASHTRA, INDIA- A TIME FOR SCREENING RURAL POPULATION?

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ABSTRACT

BACKGROUND

Around 3 billion people still cook and heat their homes using solid fuels (i.e. wood, crop wastes, charcoal, coal and dung) in open fires and leaky stoves. Most are poor and live in low- and middle-income countries. In rural India, nearly 90% of the primary energy is derived from biomass (wood, 56%; crop residues, 16%; dung, 21%).

We took up this study with an aim to compare the lung functions of both rural and urban population in Maharashtra, India.

MATERIALS AND METHODS

324 rural women and 253 urban women in Maharashtra, India, were interviewed with a standard respiratory questionnaire and their pulmonary function test was performed using portable computerised spirometer.

RESULTS

The comparative pulmonary function parameter based on the pulmonary function testing in rural and urban women showed significant lung function abnormalities (FEV1, FEV1/ FVC, PEFR, MEF 25-75) in rural women exposed to biomass fuel as compared to urban women who use LPG (Liquefied Petroleum Gas) for cooking.

CONCLUSION

Biomass fuel exposure poses a great impact on lung functions of rural women. Factors like poor ventilation in kitchen, lack of screening programs and late manifestation of disease cause irreversible damage to lung functions.

KEYWORDS

Lung Function; Biomass Fuel; Rural Population; Urban Population; Indoor Pollution.

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BACKGROUND

Around 3 billion people still cook and heat their homes using solid fuels (i.e. wood, crop wastes, charcoal, coal and dung) in open fires and leaky stoves. Most are poor and live in low- and middle-income countries.[1] Such inefficient cooking fuels and technologies produce high levels of household air pollution with a range of health-damaging pollutants including small soot particles that penetrate deep into the lungs.[1] In poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels for fine particles.

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Exposure is particularly high among women and young children, who spend the most time near the domestic hearth.[1]

In rural India, nearly 90% of the primary energy is derived from biomass (wood, 56%; crop residues, 16%; dung, 21%).[2] The majority of rural households in developing countries burn biomass fuels in open fireplaces or in non-airtight stoves, resulting in substantial emissions which in the presence of poor ventilation produce very high levels of indoor pollution with 24-hour mean PM10 levels in the range of 300 to 3,000 mg/m3, which may reach 30,000 mg/m3 during periods of cooking.[3-4]

A significant number of these wood smoke constituents are known to be toxic or irritants for the respiratory system including respirable PM (PM10), carbon monoxide (CO), nitrogen and sulfur oxides (NO2, SO2), aldehydes (e.g. formaldehyde), polycyclic aromatic hydrocarbons (e.g. benzopyrene), volatile organic compounds, chlorinated dioxins and free radicals.[5–8] Many substances can act as primary pollutants, irritants and carcinogenic or co-carcinogenic compounds.[7]

Central Pollution Control Board, which monitors continuous ambient air quality at Navi Mumbai Municipal Corporation Airoli shows an alarming level of respirable PM (PM10 and PM 2.5).[9]

The World Health Organisation (WHO) estimates that around 4.3 million people every year die prematurely from illness attributable to the household air pollution caused by the inefficient use of solid fuels (2012 data) for cooking.[1]

Among these Deaths

- 12% were due to pneumonia.
- 34% from stroke.
- 26% from ischaemic heart disease.
- 22% from chronic obstructive pulmonary disease (COPD).
- 6% from lung cancer.

A multicentric Indian study on Epidemiology of Asthma, Respiratory symptoms and Chronic Bronchitis (INSEARCH) has been conducted, which concluded that Asthma and Chronic Bronchitis in adults pose an enormous health care burden in India. Most of the associated risk factors are preventable.[10]

Though the urban population is mostly free from biomass exposure and mainly rely on liquefied petroleum gas (LPG) for cooking, external factors like open-air burning of waste, industrial and vehicular pollution pose an impact on lung functions of urban population as studied in numerous studies. Considering the well-studied and documented evidence regarding biomass exposure in the rural population, we took up this study with an aim to compare the lung functions of both rural and urban population in Maharashtra to look for insights of pulmonary functions in both populations.

MATERIALS AND METHODS

Study Design

It is a cross-sectional observational study studied over rural and urban population of western Maharashtra.

Study Population and Sampling

Rural health camps were conducted in 3 different villages named Utroli, Wing and Bajarwadi of Pune and Satara District of Maharashtra. Similarly, health camps were conducted in Pune City and Navi Mumbai of Maharashtra for urban women sampling. We included all women coming to our health camp from the age group of 18 - 60 years in both rural and urban populations. 324 rural women and 253 urban women were selected for the study meeting for our inclusion criteria, whereas all others were excluded from our study. Sample size of 577 subjects was calculated for the study based on the following factors: An expected 2.55% prevalence of COPD for women in Maharashtra; desired confidence level of (α) of 0.05; power of the study (1–β) = 0.80: and design effect= 2 and by using 2 independent sample proportion formula-

$n= (Z a +Z (1-\beta)^2 * (p1q1+p2q2)/d^2$

n= sample size; Z a= Standard normal variation for a= 0.05 (95% CI)

Z1-β= Standard normal variate for 1-β= 0.80 (80%); p1= proportion (%) in one group;

q1= 100 – p1 and similarly for p2; d= p1 - p2

Over the duration of study period, we studied the total number of 577 subjects and the distribution of Rural and Urban is by chance.

Inclusion Criteria

1. Age 18 - 60 years.
2. Non-smoker.
3. Performance of spirometry meeting American Thoracic Society (ATS)/ European Respiratory Society (ERS) criteria.
4. Answers to standard respiratory questionnaires.
5. Willingness to enrol in the study with written consent.

Exclusion Criteria

1. Pregnant women.
2. History of active respiratory infections and cardiovascular diseases.
3. Recent MI (3 - 6 months).
4. Recent stroke, eye surgery, thoracic/ abdominal surgery.
5. Haemoptysis.
6. Known thoracic, aortic or cerebral aneurysm.
7. Recent pneumothorax.
8. Uncontrolled hypertension.
9. Pulmonary embolism.
10. Denial for enrolment in the study.

Villages selected were within the radius of 50 kilometres from Pune city and were free from industrial pollution and with negligible vehicular pollution, so as to avoid the confounding factors. These villages have an average of 1100 women population according to 2011 census.

These subjects were interviewed with a standard respiratory questionnaire based on multicentre study "Indian study on Epidemiology of Asthma, Respiratory Symptoms and Chronic Bronchitis (INSEARCH)." The questionnaire focused on occupation, use of the type of biomass fuel, ventilation in-house, hours of exposure to biomass fuel, etc.

Pulmonary Function Test

Pulmonary function of these subjects was estimated using computerised pulmonary function testing device (EasyOne). To ensure the accuracy of the reading, the devices were calibrated regularly.

As per standard guidelines, the height and weight were measured and the technique was explained and demonstrated prior to the testing. Best of three readings was recorded meeting the ATS (American Thoracic Society)/ ERS (European Respiratory Society) criteria for the flow-volume loop.

The standard predicted value based on Global Initiative for Obstructive Lung Disease (GOLD) guidelines were considered and lung function values were further classified as the GOLD 1 - 4 severity of Chronic Obstructive Pulmonary Disease (COPD).[11]

Statistical Analysis

The type of data is quantitative and qualitative. The relevant clinical, microbiology and long-term outcome data collected was summarised into tables and graphs and was analysed using Microsoft Excel and SPSS (Version 20.0) software with

the help of biostatistical whenever required. Nominal data such as demographic data and symptoms were presented as frequency (n) and percentage (%). Bivariate analyses were conducted using the Chi-square or Fisher's exact test where appropriate. A p-value ⩽ 0.05 was considered statistically significant in all analyses.

Ethics

Our study was approved by our Institutional Ethics Committee and is in accordance with Helsinki statement.

Key Definitions

- Values for the FEV1, FVC and PEFR must be compared with the predicted normal values which depend on the individual's age, height and sex.
- FEV1 (forced expired volume in one second): volume expired in the first second of maximal expiration after a maximal inspiration. It is an important tool for assessment of lung function.
- FEV1/ FVC: FEV1 expressed as a percentage of the FVC, gives a clinically useful index of airflow limitation.
- A FEV1 < 80% predicted and the FEV1/ FVC ratio < 0.70 shows airflow limitation.
- GOLD severity of COPD (In patients with FEV1/ FVC ratio < 0.70).
- GOLD 1; Mild: FEV1 is ≥ 80% predicted.
- GOLD 2; Moderate: FEV1 is 50% - 79% predicted.
- GOLD 3; Severe: FEV1 is 30% - 49% predicted.
- GOLD 4: Very Severe: FEV1 is below 30% predicted.
- The peak expiratory flow rate (PEFR, also known as a peak flow) is the maximal rate that a person can exhale during a short maximal expiratory effort after a full inspiration. A normal PEFR does not exclude significant airflow obstruction. A value less than 80 of predicted is considered abnormal.
- MEF 25% - 75% - Maximal expiratory flow over the middle one-half of the FVC; the average flow from the point at which 25 percent of the FVC has been exhaled to the point at which 75 percent of the FVC has been exhaled.

RESULTS

1. Our study showed that in rural areas, 83.3% used mixed biomass fuel for cooking and 21% of women did not have a separate kitchen from living room, whereas 99% of urban women used Liquefied Petroleum Gas (LPG) for cooking and 100% urban women had a separate kitchen from living room.
2. Rural women without a separate kitchen had abnormal FEV1 (p < 0.003) and with abnormal PEFR, FEV1/FVC, MEF 25% – 75% (p < 0.001).
3. 30.9% rural women had respiratory symptoms with abnormal pulmonary function testing, whereas only 2.53% of urban women had respiratory symptoms.
4. In the present study, we found that n- 290 (89.51%) of rural population and n- 77 (30.43%) of urban population had abnormal FEV1, i.e. FEV1 < 80% predicted which symbolises airflow limitation. On comparing both populations using Chi-square test, it was found to be statistically significant (P-value < 0.001). FEV1 distribution is summarised below in Table 1.
5. In the present study, we found that n- 41 (12.65%) of rural population and n- 0 of the urban population had FEV1/ FVC ratio < 0.70, which symbolises airflow limitation. On comparing both populations using Chi-square test, it was found to be statistically significant (P-value < 0.001) as summarised below in Table 2.
6. PEFR value less than 80 of predicted are considered abnormal. PEFR was found lesser in rural population as compared to the urban population relating with the airflow limitation. On comparing both populations using Chi-square test, it was found to be statistically significant (P-value < 0.001). The PEFR comparison of rural and urban population is summarised below in Table 3.
7. MEF 25% - 75% - Maximal expiratory flow over the middle one-half of the FVC. MEF 25% - 75% values less than 80% of predicted are considered abnormal and represent small airway obstructive pattern. These abnormalities are earliest obstructive changes to be detected on pulmonary function testing. The affected urban population could signify outdoor pollution. A comparative value of the rural and urban population is summarised below in Table 4.

		Population		Total
		Rural	Urban	
FEV1	≥ 80	n-34 (10.4%)	n-176 (69.57%)	n-210
	< 80	n-290 (89.51%)	n-77 (30.43%)	n-367
Total		**n-324**	**n-253**	**n-577**

P-value < 0.001
n- number in frequency, Chi-square test used
FEV1- Forced Expiratory Volume in 1 Sec

Table 1. Comparison of FEV1 (Rural v/s Urban)

		Population		Total
		Rural	Urban	
FEV1/ FVC Ratio	< 70	n- 41 (12.65%)	n- 0 (0.00%)	n-41
	70 - 80	n- 32 (9.88%)	n- 4 (1.58%)	n-36
	> 80	n- 251 (77.47%)	n-249 (98.42%)	n-500
Total		**n-324**	**n-253**	**n-577**

P-value < 0.001
n- number in frequency, Chi-square test used
FEV1- Forced Expiratory Volume in 1 Sec, FVC- Forced Vital Capacity

Table 2. Comparison of FEV1/FVC Ratio (Rural v/s Urban)

		Population		Total
		Rural	Urban	
PEFR	≤ 20	n-56 (17.28%)	n-0 (0.00%)	n-56
	21 - 40	n-121 (37.35%)	n-13 (5.14%)	n-134
	41 - 60	n-83 (25.62%)	n-41 (16.21%)	n-124
	61 - 80	n-41 (12.65%)	n-69 (27.27%)	n-110
	81 - 100	n-18 (5.56%)	n-99 (39.13%)	n-117
	> 100	n-5 (1.54%)	n-31 (12.25%)	n-36
Total		**n-324**	**n-253**	**n-577**

P-value < 0.001
n- number in frequency, Chi-square test used
PEF- Peak Expiratory Flow

Table 3. Comparison of PEFR- Peak Expiratory Flow Rate (Rural v/s Urban)

		Population		Total
		Rural	Urban	
MEF_{25-75}	≤ 20	n-84 (25.93%)	n-00 (0.0%)	n-84
	21 - 40	n-97 (29.94 %)	n-7 (2.77%)	n-104
	41 - 60	n-70 (21.60%)	n-64 (25.30%)	n-134
	61 - 80	n-37 (11.42%)	n-88 (34.78%)	n-125
	81 - 100	n-22 (6.79%)	n-68 (26.88%)	n-90
	> 100	n-14 (4.32%)	n-26 (10.28%)	n-40
Total		**n-324**	**n-253**	**n-577**

P-value < 0.001
n- number in frequency, Chi-square test used
MEF_{25-75} - Maximal Expiratory Flow 25 - 75

Table 4. Comparison of MEF_{25-75} - Maximal Expiratory Flow $_{25-75}$ (Rural v/s Urban)

DISCUSSION

Biomass is defined as the group of biologic materials (living organisms, both animal and vegetable and their derivatives) present in a specific area collectively considered. Some of this material is used as fuel for cooking or home heating.[12] Close to 50% of the world's population, around 3 billion people, use biomass fuels as their primary source of domestic energy for cooking, home heating and light, ranging from near 0% in developed countries to more than 80% in China, India and Sub-Saharan Africa.[12-15] Our study showed that in rural areas, 83.3% used mixed biomass fuel for cooking in the form of wood, cow dung cakes etc.

In India, approximately 500,000 premature deaths, representing 6% to 7% of the national burden of disease may be attributable to indoor air pollution.[16]

A large number of mainly cross-sectional and case-control studies,[17, 18-22] have found an association of exposure to solid fuel smoke with COPD, chronic bronchitis, chronic airway disease and airflow obstruction, especially in women. The overall risk of COPD in women exposed to indoor air pollution from domestic solid fuel use, especially wood, estimated by Smith and co-workers[12] was consistently higher (OR, 3.2; 95% CI, 2.3 - 4.8) than in men (OR, 1.8; 95% CI, 1.0 - 3.2), who were likely less exposed. In our study, a majority of the rural women depend on biomass for cooking on daily basis in various forms increasing their risk for various cardiorespiratory and systemic disorders.

In a similar study like ours was conducted in Turkey where a highly significant ($p < 0.00001$) reduction of FEV1, FVC, FEV1/ FVC and FEF 25 - 75 was observed in case of biomass fuel users.[23]

In another similar study from India, the values of FEV1, PEFR and FEF 25 - 75 were significantly less ($p < .01$ in FEV1 and $p < .05$ in others) in wood users than the respective non-users. When biomass users (either alone or in combination) were compared with nonusers, values of FEV1 ($p < .05$), FEV1% ($p < .01$), PEFR ($p < .05$) and FEF 25 - 75 ($p < .01$) were significantly less in biomass fuel users. Similarly, only biomass fuel users were having significantly lower values of FEV1% ($p < .01$), PEFR ($p < .05$) and FEF 25 - 75 ($p < .01$) in comparison to only LPG users and only wood users were having significantly lower values of FEV1% ($p < .001$) and FEF 25 - 75 ($p < .001$) in comparison to only LPG users. The difference of PEFR values in the later case was also nearly significant ($p= 0.055$) statistically.[24] Our study was found to be similar to the above studies, where we found that rural women exposed to biomass fuel exposure had abnormal FEV1 ($p < 0.003$) and with abnormal PEFR ($p < 0.001$), FEV1/FVC ($p < 0.001$) and MEF 25 - 75 ($p < 0.001$) in comparison with urban women who used LPG for cooking.

A study which measured the effect of biomass burning on respiratory symptoms and lung function in rural Mexican women found that the population had 5.1% prevalence of asthma diagnosed by a physician, 23% were obese, 13% had an FEV1/ FVC < 70% and 37% reported having cough or phlegm most of the day.[25] In comparison, our study showed that 30.9% rural women had respiratory symptoms with abnormal pulmonary function testing, whereas only 2.53% of urban women had respiratory symptoms. The main respiratory symptoms noticed in our study were chest discomfort, cough or phlegm production and breathlessness.

A case-controlled study was undertaken to find out the possible relationship of biomass fuel and pulmonary tuberculosis. No association was found between type of fuel used and TB. However, it was found that low socioeconomic status, smoky rooms, the location of the kitchen, ventilation and associated respiratory symptoms during cooking are likely to be important contributors.[26] Our study showed that in rural areas, 21% of women did not have a separate kitchen from the living room which risks them for many chronic cardiorespiratory diseases including infectious disease like tuberculosis.

COPD is a major national health burden worldwide and is the 3rd leading cause of death worldwide as estimated by World Health Organisation (WHO).[27] A systematic analysis of the Global Burden of Disease Study 2016, COPD has been escalated as the 2nd leading cause of death worldwide.[28] It is a great concern worldwide as the rural population in most of the population worldwide continue using biomass for cooking resulting in increased prevalence and burden of the disease.

WHO states that there is strong evidence that exposure to household air pollution can lead to a wide range of child and adult disease outcomes including acute and chronic respiratory conditions (e.g. pneumonia, chronic obstructive pulmonary disease), lung cancer, ischaemic heart disease, stroke and cataract. There is also supporting evidence suggesting exposure to household air pollution is linked with adverse pregnancy outcomes, tuberculosis, upper aerodigestive tract, cervical and other cancers.

Broader impacts of household energy are interrelated with poverty, environmental issues like global warming and deforestation, gender issues, health impact and income of family etc.

Improved ventilation of the cooking and living area can contribute significantly to reducing exposure to smoke. WHO has highlighted a number of ways to achieve better ventilation of the living environment including chimneys, smoke hoods (with flues), eaves spaces enlarged and repositioned windows (cooking window).

A study carried out by the Intermediate Technology Development Group (ITDG) has shown that appropriate low-cost interventions (smoke hoods, eaves spaces) could reduce smoke and personal exposures substantially in two rural communities in Kenya.[29]

Similar studies and initiatives are required worldwide, especially in developing country like India where a majority of the rural household relies on biomass fuel for cooking.

CONCLUSION

Biomass fuel exposure poses a great challenge to growing economy, as it is continuously adding to the prevalence and burden of chronic cardiorespiratory diseases around the world. The escalation of COPD to world's second cause of death from third is a serious challenge to be tackled in the most innovative way.

The rural population which lacks adequate ventilation, proper housing designs, education and continued use of biomass fuel are at higher risk for development of COPD than counter urban population.

WHO has been taking initiative by various innovative techniques to develop technology to reduce the biomass exposure around the world, which needs to be supported and applied by respective government agencies and healthcare sectors.

A time has come when the thought of screening the rural population for COPD needs to be implemented, so as to reduce and check the silent growing population with COPD which would be a national threat in coming future.

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Abbreviations

- FEV1- Forced Expired Volume in one second.
- FEV1/ FVC- Ratio of Forced Expiratory Volume in one second and Forced Vital Capacity.
- PEFR- Peak Expiratory Flow Rate.
- MEF_{25-75}- Maximal Expiratory Flow over the middle one-half of the FVC.
- PM- Particulate Matter.
- COPD- Chronic Obstructive Pulmonary Disease.
- WHO- The World Health Organisation.
- LPG- Liquid Petroleum Gas.
- GOLD- Global Initiative for Obstructive Lung Disease.
- ATS- American Thoracic Society.
- ERS- European Respiratory Society.
- ITDG- Intermediate Technology Development Group.

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