PEAK EXPIRATORY FLOW RATES AMONG WOMEN EXPOSED TO DIFFERENT COOKING FUELS IN RURAL INDIA

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Abstract. Plant or animal based material burned for cooking or heating (biofuels) can cause indoor air pollution. We studied the effect of exposure to biofuel and other types of fuel smoke on peak expiratory flow rates (PEFR) among rural Indian women. We conducted a community based cross-sectional study of 760 non-smoking women who cooked using one of four types of fuel: biofuel, kerosene, liquefied petroleum gas (LPG) or a combination of two or more fuels. A PEFR <80% of predicted was considered abnormal. An abnormal PEFR was seen in 43.3% of women using biofuels, 20.5% of those using kerosene, 23.4% of those using LPG and 21.4% of those using mixed fuel. Multivariate logistic regression analysis showed among those using mixed fuel, age [OR: - 2.08, 95% confidence interval (CI): 1.32 - 3.28, *p* = 0.00], height (OR: -1.06, 95% CI: 1.00 - 1.12, *p* = 0.02) and exposure index (estimated hours spent cooking daily multiplied by the years cooked) (OR: -2.74, 95% CI: 1.68 - 4.47, *p* = 0.00) were significant predictors of abnormal PEFR. Among women using biofuels and LPG, only exposure index was found to be a significant predictor of abnormal PEFR (*p*<0.05). No significant association was found between abnormal PEFR and exposure index among women who used only kerosene for fuel (*p*>0.05). Using mixed fuel was found to be more likely to cause an abnormal PEFR.

Keywords: indoor air pollution, cooking fuels, peak expiratory flow rate (PEFR), rural India

INTRODUCTION

Clean air to breathe is as important as clean water and food, yet many millions of people, predominantly women from poor or developing countries, are obliged to breathe air polluted with biofuel emission products (WHO, 2002). Biofuel refers to any plant or animal based material deliberately burned by humans, usually for cooking or heating. Wood is the most common biofuel, but animal dung and crop residues are also commonly used. (De Koning *et al*, 1985). Indoor air pollution caused by burning biofuel is a well-recognized cause of acute

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(Behera, 1997) and chronic morbidity, primarily affecting the lungs (Perez-Padilla *et al*, 2010). Indoor air pollution resulting from burning biofuel is estimated to have caused 1.6 million deaths worldwide annually (Viegi *et al*, 2004). The deaths are caused by respiratory morbidities, such as pneumonia in young children (Torres-Duque *et al*, 2008). Among adult women, death may be due to chronic obstructive pulmonary disease (COPD) or lung cancer (Balmes, 2010). There is a growing body of literature on the health impact of indoor air pollution, especially among women and children (Bhat and Sujit, 1997; Behera *et al*, 1998). There have been few studies of the respiratory effects of exposure to biofuels in rural central India where its use for cooking is common (Behera, 1997; Reddy *et al*, 2004). We studied the effect of exposure to smoke caused by various cooking fuels on pulmonary function among women in rural central India.

MATERIALS AND METHODS

We conducted a community based, cross sectional study among 760 women in Raipura Village (population 7,635 in 2001) (Census of India, 2001) central India. This study was approved by the ethics committee of the Indira Gandhi Government Medical College, Nagpur, India.

Eligibility criteria for study subjects were: 1) age ≥15 years; 2) being principal cook in the family; 3) being a non-smoker; 4) the absence of serious illness. On the basis of a pilot study conducted among 100 study subjects, the estimated prevalence of an abnormal peak expiratory flow rate (PEFR) was 40%. Using a 95% confidence level (CI) and assuming 10% allowable error; the minimum sample size required was calculated to be 576. In the study the number of women who met eligibility criteria was 760. All 760 women participated in the study after giving written informed consent. They were each interviewed in a house to house survey asking about socio-demographic characteristics, the types of fuel used for cooking, the number of hours per day spent cooking and the number of years they had cooked. An exposure index (EI) was calculated by multiplying the number of hours spent per day cooking by the number of years cooked (Behera *et al*, 2001; Reddy *et al*, 2004).

The height of each subject was measured without shoes and weights were measured wearing light clothing. A complete physical examination was conducted and a PEFR was measured in each woman following the standards of the American Thoracic Society (Bosse and Criner, 1993) in liters per minute using a calibrated Mini Wright's Peak Flow Meter after explaining and demonstrating the procedure to each study subject in the field. Three readings were obtained from each subject and the highest of these three readings was used for the study.

The predicted PEFR for each woman was calculated as follows:

3.310xheight (cms) – 1.865xage (years) – 81.0 (Ranga Rao *et al*, 2002).

An abnormal result was 80% of the predicted value.

Percentages, means and standard deviations were calculated. Analysis of variance (ANOVA) was used to compare the mean PEFR among the four fuel groups: biofuel, kerosene, liquefied petroleum gas (LPG) and mixed (using 2 or more types of fuel). The ANOVA was calculated using Minitab, version 14 (2004). The influences of various confounders were analyzed by multivariate logistic regression using STATA, version 10.1 (2009). Statistical significance was assessed at a type I error rate of 0.05.

Table 1
Anthropometric and other characteristics of study subjects (Mean ± SD).

Characteristics	Biomass *N*=252	Kerosene *N*=73	LPG *N*=192	Mixed *N*=243	ANOVA *p*-value
Age (years)	34.69 ± 16.83	32.19 ± 12.77	30.93 ± 12.72	31.59 ± 14.77	F = 2.86 $p = 0.03$
Height (cm)	150.65 ± 6.44	151.86 ± 6.13	152.36 ± 6.12	151.75 ± 6.15	F = 2.97 $p = 0.03$
BMI (kg/m^2)	9.11 ± 3.26	20.18 ± 4.27	20.21 ± 3.97	19.79 ± 3.68	F = 3.83 $p = 0.009$
Duration of cooking (years)	25.81 ± 17.15	20.6 ± 14.67	26.64 ± 16.74	21.13 ± 17.32	F = 2.71 $p = 0.05$

LPG, liquefied petroleum gas.

Table 2
Peak expiratory flow rates among study subjects.

PEFR	Biomass *N*=252 (33.2%)	Kerosene *N*=73 (9.6%)	LPG *N*=192 (25.3%)	Mixed *N*=243 (31.9%)	Total *N*=760 (100%)
Normal PEFR, *n* (%)	143 (56.7)	58 (79.5)	147 (76.6)	191 (78.6)	539 (70.9)
Abnormal PEFR, *n* (%)	109 (43.3)	15 (20.5)	45 (23.4)	52 (21.4)	221 (29.1)

PEFR, peak expiratory flow rate.

RESULTS

Of the 760 women studied, 252 (33.2%) used only biofuel, 73 (9.6%) used only kerosene, 192 (25.3%) used only LPG and 243 (31.9%) used mixed fuel. The mean age of the subjects was 32.5 ± 14.9 years (median: 29; range: 15-80). Table 1 shows the anthropometric and other characteristics of study subjects. The study subjects in the four groups differed significantly by mean age, height, body mass index (BMI) and duration of cooking (p<0.05). Of the 760 study subjects, 539 (70.9%) had a normal PEFR and 221 (29.1%) had an abnormal PEFR. Of the study subjects using biofuel only 43.3% had an abnormal PEFR, of those using kerosene only 20.5% had an abnormal PEFR, of those using LPG only 23.4% had an abnormal PEFR and of those using mixed fuel 21.4% had an abnormal PEFR (Table 2).

The influences of age, height and exposure index were analyzed by multivariate logistic regression (MLR) analysis (Table 3). Among all 760 study subjects age (OR: -1.40, 95% confidence interval (CI): 1.13-1.7, p=0.001), type of cooking fuel (OR: -1.5, 95% CI: 1.27-1.8; p=0.000) and exposure index (OR: -2.39, 95% CI: 1.85-3.0; p=0.000) were significant predictors of abnormal PEFR, but no significant association was found with height (OR: -1.02, 95% CI: 0.99-1.0; p=0.06).

Table 3
Results of logistic regression analysis showing association between abnormal PEFR and different predictors.

Overall model (N= 760)	Outcome variable	Predictors	OR	95% Confidence interval	p-value
	Abnormal PEFR	Age	1.40	1.13-1.72	0.001
		Height	1.02	0.99-1.05	0.067
		Exposure index	2.39	1.85-3.08	0.000
		Cooking fuel	1.52	1.27-1.80	0.000

PEFR, peak expiratory flow rate.

Table 4
Results of subgroup analysis by type of cooking fuel.

Overall model (N= 760)	Outcome variable - Abnormal PEFR											
Predictors	Biomass (n = 252)			Kerosene (n = 73)			LPG (n =192)			Mixed (n = 243)		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Age	1.23	0.90-1.67	0.18	1.02	0.45-2.31	0.94	1.44	0.90-2.28	0.11	2.08	1.32-3.28	0.00
Height	1.00	0.96-1.04	0.70	1.01	0.91-1.12	0.79	1.03	0.97-1.10	0.20	1.06	1.00-1.12	0.02
EI	1.83	1.25-2.68	0.00	2.1	0.74-6.41	0.15	3.79	2.10-6.81	0.00	2.74	1.68-4.47	0.00

PEFR, peak expiratory flow rate; EI, exposure index; LPG, liquefied petroleum gas.

When analyzed by type of cooking fuel used (Table 4) among those using biofuel only and LPG only, only exposure index was a significant predictor of abnormal PEFR (p<0.05). Among those using mixed fuel, age (OR: -2.0; 95% CI: 1.32-3.2; p=0.00), height (OR: -1.0; 95% CI: 1.00-1.1; p=0.02) and exposure index (OR: -2.7; 95% CI: 1.68-4.4; p=0.00) were significant predictors of abnormal PEFR. Among those using kerosene only, no factors were significantly associated with abnormal PEFR (p>0.05).

DISCUSSION

The primary purpose of this study was to examine the effects of various cooking fuels on PEFR among rural, otherwise healthy, non-smoking women aged ≥15 years. The overall prevalence of an abnormal PEFR among study subjects was 29.1% (221/760) and the prevalence of an abnormal PEFR among those using biofuel only was 43.3%. This high prevalence of an abnormal PEFR is probably due to the fact that rural woman spend a lot of time cooking indoors where ventilation is poor. Similar findings were found in Northern India (Behera, 1997; Behera *et al*, 2001).

Based on our findings of women study subjects using biofuel only having a higher prevalence of an abnormal PEFR, and a greater exposure index, we hypothesized lung function is impaired more among those using biofuel only. However, after adjusting for age, height and exposure index by MLR we found having an abnormal PEFR among mixed fuel users was only significantly related to age, height and exposure index. Mixed fuel use was significantly associated with an abnormal PEFR after adjusting for age, height and exposure index. This finding is consistent with a number of other studies (Behera and Jindal, 1991; Behera, 1997 Behera *et al*, 1998); none systematically examined this in the rural setting.

The present study would have been more useful if we had a control group and exposure was directly measured. Rural Indian women may be exposed to other types of fuel since cooking is a social obligation.

Biofuels produce visible smoke containing higher proportions of toxic chemicals, such as carbon, nitrogen, oxygen, hydrogen, oxides of nitrogen, sulphur dioxide and unburnt suspended particulate matter (SPM) compared to other types of fuel (Behera *et al*, 2001). Biofuels contain potent respiratory irritants (Behera *et al*, 1994). Soot, which is generated is greater amounts from burning biofuel is probably more likely to cause lung function changes (Behera, 1997). While the precise mechanism of how exposure causes impairment in lung function is still unclear, small particles and several other pollutants contained in indoor smoke cause inflammation of the airways and lungs and impair the immune response (WHO, 2002). Carbon monoxide also results in systemic effects by reducing the oxygen-carrying capacity of the blood. Oxidizing radicals are present in biofuel smoke and released by inflammatory cells resulting in oxidative stress (WHO, 2002).

Our findings have important implications for India, where a large proportion of the population uses biofuels for cooking and heating. Public awareness programs should promote a change from biofuel to more efficient, less toxic fuels. Use of smokeless devices for cooking and heating and adequate ventilation may help to reduce these negative effects on respiratory function. A smokeless device or fuel is a substance that can be burned without releasing any visible airborne particulates. Some common fuels typically regarded as smokeless are anthracite coal, coke, charcoal and hexamine fuel tablets (WHO, 2002). It is necessary to keep in mind the close interrelationship between poverty and dependence on polluting fuel, consequently socio-economic development should be at the core of efforts to achieve good health.

Intervention studies involving direct measurement of exposure offer the best means of obtaining information needed to guide methods for reducing indoor air pollution. Further research regarding the health effects of indoor air pollution is also needed.

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