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International Journal of Collaborative Research on Internal Medicine & Public Health
Vol. 4 No. 1 (January 2012)

International Journal of Collaborative Research on Internal Medicine & Public Health (IJCRIMPH)

ISSN 1840-4529 | Journal Type: Open Access | Volume 4 Number 1

Journal details including published articles and guidelines for authors can be found at:
http://www.iomcworld.com/ijcrimph/

To cite this Article: Sukhsohale ND, Narlawar UW, Phatak MS, Ughade SN. Does domestic cooking environment influence risk of respiratory morbidities in rural Indian women? *International Journal of Collaborative Research on Internal Medicine & Public Health*. 2012; 4(1):34-44.

Article URL: http://iomcworld.com/ijcrimph/ijcrimph-v04-n01-04.htm

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Paper publication: 16 January 2012

Does domestic cooking environment influence risk of respiratory morbidities in rural Indian women?

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ABSTRACT

Background and objectives: Whether continued use of biomass fuels along with other fuels in presence of poor domestic cooking conditions is as detrimental to respiratory health as the exclusive use of biomass fuels is unknown. The present study is an attempt to assess the risks associated with indoor air pollution in the context of adverse domestic cooking environmental conditions in rural women of central India.

Methods: We conducted a community based, cross-sectional study in 760 non-smoking, rural women of central India – 265 used non-biomass fuels (Group A), 243 biomass and other fuels (Group B) while 252 exclusively biomass fuels (Group C). Exposure to domestic smoke was estimated according to the average time per day spent near the fireplace (exposure index). Abnormal pulmonary function of the study subjects was assessed by the measurement of peak expiratory flow rate (PEFR) according to standards recommended by American thoracic society. PEFR less than 80% of the predicted was considered as abnormal pulmonary function.

Results: Robust multivariate analyses which adjusted for height, illiteracy, physical activity, environmental exposure to tobacco smoke (ETS), mud house, overcrowding, inadequate ventilation and respiratory morbidity revealed that illiteracy (OR 2.48, 95 % CI 1.04-5.87); physical activity (OR 3.93, 95 % CI 1.52-10.14); inadequate cross ventilation (OR 2.43, 95 % CI 1.23-4.77) and respiratory morbidity (OR 2.65, 95 % CI 1.38-5.08) were significant predictors of low PEFR for group C ($P<0.05$); whereas none of the predictors were found to be significantly associated with group B.

Conclusions: Since women using partial biomass fuels showed no association of low PEFR with domestic cooking environment and respiratory morbidity even after robustly adjusting for confounding variables, we can conclude that even partial abolition of biomass use may be beneficial in improving the lung function of rural, non-smoking women in spite of having inadequate domestic cooking environment.

Keywords: Indoor air pollution, biomass, cooking fuels, cooking environment, environmental exposure to tobacco smoke (ETS), rural

Running title: *Cooking environment and respiratory morbidity*

Introduction

Indoor air pollution is a major environmental and public health hazard for many of the world's poorest, most vulnerable people. Approximately half of the world's population relies on biomass (primarily wood, cow dung cakes and agricultural residues) or coal fuels (collectively termed solid fuels) for heating, lighting and cooking. The incomplete combustion of such materials releases byproducts which increases the risk of many respiratory and other diseases as well as death. Among these conditions are acute as well as chronic respiratory impairment, malignancies of the aero-digestive tract and lungs and eye diseases.[1-4]

Exposure to environmental tobacco smoke (ETS) which is a combination of exhaled smoke from active smokers and a smoke coming from smoldering tobacco between puffs contains the same toxic substances as identified in mainstream tobacco smoke.[5, 6] It induces serious negative health consequences, of which the increased risk of cardiovascular diseases, cancer and respiratory symptoms appear to be most important.[7, 8] The effects of passive smoking on lung function, may be of similar magnitude as that found in light smokers. However, current evidence is based on a limited number of studies, few of which have measured smoke exposure directly.[9] Also, in addition to passive smoking, cooking done in poor domestic environmental conditions (ill-ventilated, overcrowded and mud dwellings) adversely affects respiratory health.[10]

Whether continued use of biomass fuels along with other fuels in presence of poor domestic cooking conditions are as detrimental to respiratory health as the exclusive use of biomass fuels is unknown. We took an environmental health perspective with the objective of assessing the risks associated with indoor air pollution in the context of adverse domestic cooking environmental conditions in rural women of central India.

Methods

We conducted a community based, cross-sectional study of 760 women in Raipura village (total population 7635 as per Census 2001), Hingna Tehsil, Nagpur district in central India. This village is a field practice area of rural health training center, Hingna, and is under the administrative control of the Department of Preventive and Social Medicine, Indira Gandhi Government Medical College (IGGMC), Nagpur. The area is totally free from industrial and atmospheric pollution. Eligibility criteria for this study were: i) age>15 years; ii) principal cook of family; iii) non-smoker; and iv) an informed consent. On the basis of pilot study done on 100 study subjects, the estimated prevalence of abnormal PEFR was found to be 40 %. Taking p = 40%, 95% Confidence Interval (CI) and assuming 10% allowable error; the minimum sample size required was calculated as 576. But in our study sample, the number of women aged 15 years and above was found to be 760. Therefore the final study constituted 760 women who spend considerable time near the fireplace and were consistently using the same type of cooking fuels throughout the study period. The study was conducted in 2004 over a period of two years and was approved by the Institutional Ethics Committee of IGGMC, Nagpur.

Women were interviewed in a house-to-house survey and were subjected to detailed socio-demographic and culinary profiling. Environment of the residence of each study subject, particularly cooking environment of the kitchen with regards to size of the kitchen, type of construction, type of floor, roof, walls, number of rooms, windows, site where kitchen was located, presence or absence of chimney/smoke vent in the kitchen and presence or absence of soot deposits in kitchen was noted. Also noted were other characteristics like adequacy of kitchen ventilation, overcrowding, time spent (hours) in household cooking per day, number of years of cooking experience, physical activity (occupational and leisure time), anthropometry and findings of complete clinical examination. Exposure index (EI) was calculated by multiplying the number of hours spent in a day on cooking and the number of years of cooking experience.[10, 11]

Details of ETS exposure,[12-14] were obtained using a structured questionnaire having separate sections for exposure before and after marriage. The study subjects were inquired regarding the number of smokers in family, type of tobacco product smoked and approximate number of cigarettes/bidis smoked per day and years of passive exposure to tobacco smoke. Overall exposure to ETS was estimated by multiplying number of cigarettes/bidis smoked daily in the household and years of exposure.

Finally, pulmonary function was assessed in the field by estimating the peak expiratory flow rate (PEFR) as recommended by the American Thoracic Society.[15] PEFR (L/min) was measured with a calibrated Mini Wright's Peak Flow Meter (highest of three readings) after explaining and demonstrating the procedure to each study subject. Expected PEFR was calculated as 3.310*height (cms) – 1.865*age (years) – 81.0.[16] Abnormal pulmonary function or low PEFR was defined as PEFR less than 80% of the predicted.

Few definitions:

1. Environmental exposure to tobacco smoke (ETS) or passive smoking is defined as the presence of one or more members of the household (besides the respondent) who is ever a smoker (smoked one or more cigarette or bidi everyday for more than a year, or has lifetime consumption of more than 20 packs of cigarettes or bidis) and is known to smoke at home.[6]
2. Overcrowding was assessed by noting the number of persons per room and adequacy of ventilation was assessed by the presence or absence of cross ventilation (i.e. doors and windows facing opposite to each other).[17]
3. Grades of PEFR: Based on low levels of PEFR (percentage reduction of PEFR from predicted) women were categorized as having mild (70-80%), moderate (60-70%), severe (50-60%), profound (40-50%) and very profound grades (<40 %) of abnormal pulmonary function.[16]

For statistical analysis, between-group comparisons were conducted using chi-square tests, Fisher's exact test and analysis of variance using a statistical software package EPI Info, version 6.0. The influences of various confounders were analysed by multivariate logistic regression models and linear trend across ordered groups by Cuzick test using statistical software STATA version 10.1 (2009). Statistical significance was assessed at a type I error rate of 0.05.

Results

Depending on the use of biomass fuels, our study subjects were classified into one of the following three groups: A – none (n = 265); B – partial (that is along with other fuels, n = 243); and C – exclusive (n = 252). Thus the prevalence of exclusive and partial biomass fuel use was 33.2 % and 32 %, respectively. Domestic smoke pollution was considerable in the study area because dwellings were overcrowded, ill-ventilated and without chimneys. In our study, 33.2% of the households used exclusively biofuels for cooking of which the share of wood alone was 46.5% and that of cow dung, crop residues and other agricultural waste was 53.6%.

The study subjects in the three groups did not differ significantly in mean age, weight, body mass index, duration of cooking and exposure index (P >0.05) as shown in Table 1. Thus the groups are comparable. The socio-demographic characteristics (Table 2) showed that illiteracy, presence of mud house and overcrowding was significantly more common in Group C. This group also showed a significantly reduced PEFR with twice higher prevalence of abnormal PEFR and respiratory morbidities (chronic cough with phlegm and chronic obstructive pulmonary disease) as compared to the other two groups. Interestingly, there was no difference in the PEFR and respiratory symptoms between Groups A and B.

The influences of various confounding factors like illiteracy, height, physical activity, ETS, mud house, overcrowding, inadequate cross ventilation and presence of respiratory morbidity were eliminated by using multiple logistic regression (MLR) analysis. The overall MLR model in observations of 760 revealed that illiteracy [OR 2.12, 95 % confidence interval (CI) 1.44-3.11]; overcrowding (OR 1.71, 95 % CI 1.22-2.39); inadequate ventilation (OR 0.66, 95 % CI 0.46-0.95) and presence of respiratory morbidity (OR 1.49, 95 % CI 1.05-2.09) were significant predictors of low PEFR (Table 3a). Whereas group wise MLR model (Table 3b) revealed that none of the predictors were significantly associated with low PEFR in group B (P>0.05). For group A, illiteracy (OR 1.84, 95 % CI 1.05-3.21) and overcrowding (OR 2.92, 95 % CI 1.69-5.03) were significant predictors of low PEFR. For group C, illiteracy (OR 2.48, 95 % CI 1.04-5.87); physical activity (OR 3.93, 95 % CI 1.52-10.14); inadequate ventilation (OR 2.43, 95 % CI 1.23-4.77) and respiratory morbidity (OR 2.65, 95 % CI 1.38-5.08) were significant predictors of low PEFR.

Respiratory morbidity and environmental factors was found to increase with increase in severity of grades of low PEFR (Table 4).

Discussion

The present study imply and supports the widely prevalent belief that only exclusive (but not partial) use of biomass fuels in presence of poor domestic cooking environmental conditions (inadequate ventilation, overcrowding) was associated with reduced pulmonary function after robustly adjusting for the confounding factors. Moreover the severity of grades of pulmonary function also affected the respiratory morbidity. However, ETS did not seem to affect the outcome variable (low PEFR) in the present study. These findings are consistent with the findings of other investigators. Aggarwal A.N. et al.[6] reported no statistically significant difference between women exposed to ETS and the women not exposed to ETS women, although PEF (peak expiratory flow) and FEV1 (forced expiratory flow in first second) values were marginally lower among women exposed to household ETS. However cumulative life time ETS exposure was not significantly related to a reduction in PEF after adjustment for confounding factors (age, place of residence, type of cooking fuel used and presence of polluting industry in neighbourhood). Behera D et al.[11] reported that passive smoking as a co-morbid condition did not affect the outcome of asthmatic rural women exposed to cooking fuels. Reddy T.S. et al.[10] also reported that passive smoking showed no significant difference between the non-smoking women using either biomass or LPG as their sole cooking fuel. However, PEFR was significantly lower ($P<0.01$) in women using biomass as cooking fuel. Also, the biomass users had greater overcrowding than the LPG users ($P<0.001$) the ventilation was adequate in the biomass users.

We have several women in our study who complain of the development of symptoms of wheezing and/cough after marriage. Many of them attribute the development of symptoms to spousal smoking. This is corroborated by the findings of our study on non-smoking, rural women married to smokers having a higher respiratory morbidity.

At present, no reliable biological marker is available for assessment of long term ETS exposure. Although cotinine level may be used as a surrogate for exposure to tobacco smoke, its validity as an indicator of long term ETS exposure is not clearly established.[18] Self-reported duration and magnitude of exposure in questionnaire-based studies also had low reliability.[19] Dichotomous questions, on whether one was ever exposed to passive smoking or not, have shown much better reliability.[20]

Thus domestic cooking environmental factors may be of great importance in etiology of reduced pulmonary function. Substantial deposition of carbon in the lung (anthracosis) occurred consistently in subjects exposed to biomass. This effect of domestic smoke may result from reduced resistance to lung infection. Exposure to smoke interferes with the mucociliary defenses of the lungs and decreases several antibacterial properties of lung macrophages, such as adherence to glass, phagocytic rate and the number of bacteria phagocytosed.[21]

The present work has some advantages over the previous reports as only never-smoker study subjects were enrolled. Although the study findings are consistent with a number of other studies, none of the studies reviewed has systematically examined the extent of strong associations with confounding variables in rural settings. This strengthens the ability of present observational study to define the effect of indoor air pollution adequately by the elimination of confounding factors. The study could have been more elaborative had we got control group and exposure to indoor pollutants could have been directly measured. We could not include control group of women not exposed to cooking fuels because an Indian woman with this socio-economic background (even higher socio-economic groups) is exposed to one or other type of fuel since cooking in some form is a part of social obligation.

Conclusions

The study findings indicate that partial use of biomass fuels even with poor cooking conditions is not associated with reduced pulmonary function. This has important public health implication since it indicates that behavioral change towards mixed fuel use may be as beneficial as avoiding biomass fuels altogether. It is noteworthy that adopting and improving cooking environment conditions may not be an immediately cost-effective solution in certain economically challenged societies.[22] An alternative in such scenarios would be to rely on public awareness programs that promote a switch from biomass to more efficient and less toxic fuels.[23, 24] Our findings urge that even a partial success of such awareness programs may be beneficial from the perspective of respiratory health.

Thus, we infer that future research aimed at assessing the potential benefits of a behavioral change may be at least as much needed as that for the anticipated impact of the improved biomass stoves and improved domestic cooking environmental conditions.

List of abbreviations:

PEFR - Peak expiratory flow rate
ETS - Environmental exposure to tobacco smoke
COPD – Chronic obstructive pulmonary disease

IRB permissions:

The project has been approved by Clinical ethics Committee, Indira Gandhi Government Medical College, Nagpur
Approval date: 27-04-04
IRB permission number: 10/17/3/04

Grant Registration Number: This is a non-funded study

Competing interests: Nil

Conflict of interest: None to declare

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Table 1: Distribution of age, weight, body mass index, duration of cooking and exposure index amongst study subjects. (Mean ± SD)

Characteristic of study subjects	Group A None (N = 265)	Group B Partial (N = 243)	Group C Exclusive (N = 252)	Analysis of variance	P value
Age (years)	35.95 ± 15.46	32.38 ± 17.13	37.16 ± 17.51	F = 1.41	0.24
Weight (kg)	45.65 ± 9.96	45.0 ± 9.87	42.52 ± 8.93	F = 2.54	0.08
Body mass index (kg/m^2)	19.5 ± 4.11	19.17 ± 3.72	18.65 ± 3.2	F = 1.15	0.31
Duration of cooking (years)	25.13 ± 16.38	21.13 ± 17.33	25.82 ± 17.15	F = 1.39	0.25
Exposure index	89.48 ± 61.64	74.36 ± 61.07	84.15 ± 54.28	F = 0.97	0.38

Table 2: Demographic and other characteristics of study subjects.

Characteristics	Group A None (N = 265)	Group B Partial (N = 243)	Group C Exclusive (N = 252)	P value
Education				
Illiterate	30 (11.3)	37 (15.2)	96 (38.1)	<0.001
Literate	235 (88.7)	206 (84.8)	156 (61.9)	
Physical activity				
Sedentary	25 (9.4)	24 (9.9)	19 (7.5)	0.62
Non-sedentary	240 (90.6)	219 (90.1)	233 (92.5)	
Factors in cooking environment				
Mud house	68 (25.7)	103 (42.4)	190 (75.4)	<0.001
Overcrowding	89 (33.6)	106 (43.6)	177 (70.2)	<0.001
Inadequate ventilation	76 (28.7)	90 (37.0)	64 (25.4)	0.01
ETS	65 (24.5)	69 (28.4)	70 (27.8)	0.56
PEFR				
Low PEFR	60 (22.6)	52 (21.4)	109 (43.3)	<0.001
PEFR grades (%reduction of PEFR from predicted)				
*Mild (70-80%)	46 (76.7)	37 (71.2)	75 (68.8)	
Moderate (60-70%)	8 (13.3)	9 (17.3)	20 (18.3)	
Severe (50-60%)	4 (6.7)	4 (7.7)	10 (9.3)	0.97
Profound (40-50%)	2 (3.3)	2 (3.8)	2 (1.8)	
Very Profound (<40%)	0	0	2 (1.8)	
Respiratory morbidity				
Asthma	5 (1.9)	3 (1.2)	10 (3.9)	0.11
COPD	11 (4.1)	4 (1.6)	20 (7.9)	0.003
Chronic cough with phlegm	33 (12.4)	20 (8.2)	42 (16.7)	0.01
Dysnoea	5 (1.9)	3 (1.2)	11 (4.4)	0.06
Any respiratory morbidity	20 (7.5)	18 (7.4)	31 (12.3)	0.09

Figures in parentheses indicate percentage.

Table 3a: Results of multiple logistic regression analysis showing association between low PEFR and different predictors

Overall model (n = 760)	**Outcome Variable**	**Predictors**	Odds Ratio	95% Confidence Interval	P value
	Low PEFR	Illiteracy	2.12	1.44 - 3.11	<0.001
		Height	1.01	0.98 - 1.04	0.25
		Physical activity	1.47	0.85 - 2.55	0.16
		ETS	1.12	0.78 - 1.61	0.52
		Mud house	0.90	0.62 - 1.30	0.58
		Overcrowding	1.71	1.22 - 2.39	0.002
		Inadequate ventilation	0.66	0.46 - 0.95	0.02
		Respiratory morbidity	1.49	1.05 - 2.09	0.02

Table 3b: Results of subgroup analysis by type of cooking fuel

Outcome variable Low PEFR	**Group A (N=265)**			**Group B (N=243)**			**Group C (N=252)**		
Predictors	**OR**	**95 % CI**	**P value**	**OR**	**95 % CI**	**P value**	**OR**	**95 % CI**	**P value**
Illiteracy	1.84	1.05 -3.21	0.03	1.67	0.69-4.06	0.25	2.48	1.04 –5.87	0.03
Height	0.99	0.95 - 1.03	0.91	1.04	0.98-1.10	0.11	1.01	0.96 –1.07	0.44
Physical activity	0.94	0.34 - 2.57	0.90	0.91	0.32-2.62	0.87	3.93	1.52 -10.14	0.005
ETS	1.28	0.71- 2.30	0.39	1.04	0.52-2.06	0.90	0.95	0.45 - 1.96	0.89
Mud house	0.58	0.30 - 1.11	0.10	1.03	0.52-2.06	0.91	0.82	0.38 - 1.74	0.61
Overcrowding	2.92	1.69 - 5.03	0.000	1.03	0.53-2.00	0.91	1.04	0.52 - 2.04	0.90
Inadequate ventilation	0.98	0.51- 1.87	0.96	1.13	0.55-2.30	0.73	2.43	1.23 - 4.77	0.01
Respiratory morbidity	1.12	0.63 - 1.99	0.68	1.04	0.54-2.02	0.89	2.65	1.38 - 5.08	0.003

Table 4: Distribution of Linear trends of respiratory morbidities and cooking environment factors by severity of grades of low PEFR.

	Low PEFR Grades				
	Mild grade (n = 158)	Moderate grade (n = 37)	Severe grade (n = 18)	Profound and very profound grade (n = 8)	P value
i)Respiratory morbidity					
Asthma	7 (4.4)	0	1 (5.6)	1 (12.5)	0.65
COPD	9 (5.7)	4 (10.8)	0	4 (50)	0.007
Chronic cough with phlegm	27 (17.1)	5 (13.5)	1 (5.6)	5 (62.5)	0.23
Dysnoea	6 (3.8)	2 (5.4)	4 (22.2)	2 (25)	0.001
Any respiratory morbidity	31(19.6)	5 (13.5)	1 (5.6)	3 (37.5)	0.006
ii)Factors in cooking environment					
ETS	45 (28.5)	12 (32.4)	5 (27.8)	4 (50)	0.64
Overcrowding	88 (55.7)	21 (56.8)	10 (55.6)	2 (25)	0.29
Inadequate ventilation	89 (56.3)	21 (56.8)	11 (61.1)	5 (62.5)	0.67
Mud house	82 (51.9)	23 (62.2)	9 (50)	5 (62.5)	0.81

Figures in parentheses indicate percentage.
*P values derived from linear trend across ordered groups by Cuzick test.