ORIGINAL ARTICLE

Prevalence of chronic obstructive pulmonary disease in rural women of Tamilnadu: implications for refining disease burden assessments attributable to household biomass combustion

Priscilla Johnson[1]*, Kalpana Balakrishnan[2], Padmavathi Ramaswamy[1], Santu Ghosh[2], Muthukumar Sadhasivam[3], Omprakash Abirami[1], Bernard W. C. Sathiasekaran[4], Kirk R. Smith[5], Vijayalakshmi Thanasekaraan[6] and Arcot S. Subhashini[1]

[1]Department of Physiology, Sri Ramachandra University, Chennai, India; [2]Department of Environmental Health Engineering, Sri Ramachandra University, Chennai, India; [3]Department of Physiology, Muthukumaran Medical College, Chennai, India; [4]Department of Community Medicine, Sri Ramachandra University, Chennai, India; [5]School of Public Health, University of California, Berkeley, CA, USA; [6]Department of Chest Medicine, Sri Ramachandra University, Chennai, India

Background: Chronic obstructive pulmonary disease (COPD) is the 13th leading cause of burden of disease worldwide and is expected to become 5th by 2020. Biomass fuel combustion significantly contributes to COPD, although smoking is recognized as the most important risk factor. Rural women in developing countries bear the largest share of this burden resulting from chronic exposures to biomass fuel smoke. Although there is considerable strength of evidence for the association between COPD and biomass smoke exposure, limited information is available on the background prevalence of COPD in these populations.

Objective: This study was conducted to estimate the prevalence of COPD and its associated factors among non-smoking rural women in Tiruvallur district of Tamilnadu in Southern India.

Design: This cross-sectional study was conducted among 900 non-smoking women aged above 30 years, from 45 rural villages of Tiruvallur district of Tamilnadu in Southern India in the period between January and May 2007. COPD assessments were done using a combination of clinical examination and spirometry. Logistic regression analysis was performed to examine the association between COPD and use of biomass for cooking. R software was used for statistical analysis.

Results: The overall prevalence of COPD in this study was found to be 2.44% (95% CI: 1.43–3.45). COPD prevalence was higher in biomass fuel users than the clean fuel users 2.5 vs. 2%, (OR: 1.24; 95% CI: 0.36–6.64) and it was two times higher (3%) in women who spend >2 hours/day in the kitchen involved in cooking. Use of solid fuel was associated with higher risk for COPD, although no statistically significant results were obtained in this study.

Conclusion: The estimates generated in this study will contribute significantly to the growing database of available information on COPD prevalence in rural women. Moreover, with concomitant indoor air pollution measurements, it may be possible to increase the resolution of the association between biomass use and COPD prevalence and refine available attributable burden of disease estimates.

This paper was orally presented in the Annual conference International Society of Environmental Epidemiology held in Pasadena in 2008.

Citation: Global Health Action 2011, **4**: 7226 - DOI: 10.3402/gha.v4i0.7226

Keywords: *chronic obstructive pulmonary disease*; *prevalence*; *biomass fuel users*; *rural women*; *disease burden*

Received: 25 April 2011; Revised: 7 August 2011; Accepted: 29 September 2011; Published: 3 November 2011

Chronic obstructive pulmonary disease (COPD) is the fourth leading cause of death and 13th leading cause of burden of diseases worldwide with projected increases in its contributions over the next decade (1). The global initiative for chronic obstructive lung disease (GOLD) has classified COPD as 'a disease state characterized by airflow limitation that is not fully reversible. The airflow limitation is usually both progressive and associated with an abnormal inflammatory response of the lungs to noxious particles or gases' (2, 3).

Active smoking is the major risk factor for COPD worldwide, and the risk attributable to active smoking in COPD varies from 40 to 70% according to the country (4). Although smoking remains the predominant risk factor (5–7), it needs to be emphasized that prevalence of COPD in non-smokers suggests the existence of other risk factors such as passive smoking, occupational exposure, and indoor air pollution (8–10).

Recently, exposure to biomass smoke resulting from household combustion of solid fuels has been identified as an important risk factor for COPD, with rural women in developing countries bearing most of this disease burden (11). In addition to respirable particulate matter, biomass combustion results in high levels of pollutants such as carbon monoxide, oxides of nitrogen and sulphur, formaldehyde, benzo(a)pyrene, and benzene that are a major source of respiratory irritants in the etiopathogenesis of COPD (12).

Although COPD affects twice as many males as females, this difference will diminish, given the fact that more and more females throughout the world have taken up smoking in the past few years in developed countries, and non-smoking females are exposed to biomass combustion products in developing countries.

Recent studies have made important contributions in examining temporal, spatial, or multipollutant patterns, in addition to day-to-day or seasonal variability in household concentrations and exposures in biomass using homes (13–15). Collectively, the evidence from these studies shows that rural women, children in solid fuel using settings experience extremely high levels of air pollutants often at least an order of magnitude higher than what is commonly considered as safe levels of exposure. WHO's Comparative Risk Assessment (15) estimated that about 950,000 children die each year from acute lower respiratory infections as a result of these exposures worldwide along with about 650,000 premature deaths of women from COPD and lung cancer (10).

Baseline information on prevalence of COPD is an important input for disease burden estimations as well as for estimations of attributable disease burdens for important risk factors. Most previous studies have focused on prevalence of COPD in men addressing primarily smoking as a risk factor. Few studies have attempted to assess prevalence among non-smoking rural women in developing countries using primarily biomass for cooking. Estimates based on health care resource utilization in this setting may underestimate true prevalence and probably be biased toward the more severe and symptomatic cases. Hospital-based estimates of COPD prevalence are also often hindered by unavailability of health care data, inaccuracies in coding as well as inconsistent physician recognition of early disease.

With this background, we report here results of a community-based cross-sectional assessment for COPD that included physician diagnosis for COPD using pulmonary function testing with bronchodilatation, among rural women of Southern India.

Materials and methods

This cross-sectional study was conducted in Tiruvallur, a district that has 605,866 households comprising a population of 2,738,866 persons with approximately an equal distribution of males and females in the southern India state of Tamilnadu in India (16). The study was approved by the Institutional Ethics committee of Sri Ramachandra University on 24 August 2006 (MEC/06/52/44) and the study was conducted between January and May 2007. Sample size of 900 subjects was calculated for the study based on the following factors: an expected 2.55% prevalence of COPD for women in South India; desired confidence level of (α) of 0.05; power of the study $(1-\beta) = 0.80$: and design effect = 2.

The study subjects were selected through cluster sampling using probability proportion to size criteria. This approach resulted in the selection of 45 rural villages out of 612 small villages with population less than 10,000 in Tiruvallur district (Census 2001). In each village that was selected by cluster sampling method, the center of the village was located by spinning a pencil and seeing the direction in which it stopped, the street in that particular direction comprising various households was selected. Twenty females from that particular street of that village were selected for study, so that a total of 900 female subjects were recruited.

The selection criteria included women aged 30 years and above who have been residents of the villages in

Tiruvallur district for a minimum period of 5 years who did not report a history of bronchial asthma, pulmonary tuberculosis, cardiac diseases, pregnancy, diabetes, and cancer. Only one female member from each household who fulfilled the selection criteria was finally recruited. In certain occasional households with more than one eligible member, a random selection was done. Ten (0.92%) subjects refused consent. About 1,016 households including approximately 1,087 members were contacted to reach the desired sample size of 900 participants.

Informed written consent was obtained before recruiting any person into the study. Once the persons gave informed consent, to be part of the study, questionnaire was administered that collected information on known risk factors for COPD, details on type of fuel (biomass, clean), duration of cooking involvement in years (time interval between start and stop of cooking/till the date of interview), average total hours involved in cooking in a day, kitchen configuration, and so on (kitchen indoor/outdoor, with or without windows/openings). A detailed clinical history on respiratory symptoms was also obtained. All symptomatic women were then subjected to pulmonary function tests. COPD cases were diagnosed based on the three criteria: (1) cough with expectoration on most days of the week for 3 months of the year for at least 2 consecutive years, (2) forced expiratory volume in 1 second (FEV_1) and (FEV_1)/FVC value lower than 80% predicted as diagnosed by spirometry, and (3) reversibility test result of $<15\%$ or <200 ml improvement in FEV_1 compared to prebronchodilator FEV_1. All the three criteria were considered as essential for diagnosis of COPD.

Subjects were instructed to avoid the activities such as performing vigorous exercise within 30 min of testing, wearing clothing that substantially restricts full chest and abdominal expansion, and eating a large meal within 2 hours of testing, and these requirements were given to the patient at the time of making the recruitment (17). The patient's age, height, and weight (wearing indoor clothes without footwears) were recorded for use in the calculation of reference values basically to arrive at the classification of the derived values with respect to a reference population. Body mass index was calculated as kilogram per meter square. The height was measured without footwear, with the feet together, standing as tall as possible with the eyes level and looking straight ahead using a stadiometer.

Pulmonary function test was performed following American Thoracic Society guidelines using a portable data logging Spirometer (MIR Spirobank) (17). This test was performed in a sitting position with nose closed by nose clips and a mouthpiece placed in mouth making sure that the lips were sealed around the mouthpiece and that the tongue did not occlude it. The subject was then asked to inhale completely and rapidly with a pause of 1 second at total lung capacity and exhale maximally until no more air can be expelled while maintaining an upright posture. The subjects were verbally encouraged to continue to exhale the air at the end of the maneuver to obtain optimal effort, for example, by saying 'keep going.' The same was repeated for a minimum of three maneuvers and not more than eight was done for acceptability and repeatability. Spirobank is a spirometer that is designed to facilitate the total valuation of lung function such as forced vital capacity (FVC), vital capacity (VC), and maximal voluntary ventilation (MVV) tests with pre and post comparison. FVC, forced expiratory volume in 1 second (FEV_1), peak expiratory flow rate peak expiratory flow rate (PEFR), and mid expiratory volume (FEF 25–75%) values were recorded. A complete flow volume loop was obtained from the spirometer. The values of the largest FVC and the largest FEV_1 were taken from all of the three reproducible and usable curves (acceptable start of test and free from artifact). The data were compared with individual predictive values based on age, sex, body weight, standing height, and ethnic group and were interpreted to arrive at the diagnosis (18). Most of the sources of variation in pulmonary function assessment such as motivation and effort and body position were controlled by following American thoracic society (ATS) guidelines and using standardized verbal encouragement phrases (17, 19, 20).

Spirometry with bronchodilation testing after inhalation of 200 μg of Salbutamol was carried out in order to confirm COPD (21). COPD cases were defined as follows: reversibility test result of $<15\%$ improvement in FEV_1 compared to prebronchodilator FEV_1, or postbronchodilator improvement of $FEV_1 <200$ mL, and FEV_1/FVC $<70\%$ and no history of atopy or pattern of disease suggestive of asthma. Data collectors were trained on questionnaire administration, Anthropometry measurement, Pulmonary Function Tests (PFT) assessment as per ATS guidelines and the same set of investigators were involved in the collection of information from the study population to avoid the information bias and to minimize the interobserver variability. All the data recorded on data forms were stored in locked cabinets to maintain confidentiality. Questionnaire data were entered in Microsoft Access for data analysis. Statistical analysis was performed using 'R' Version 2. Prevalence was expressed in terms of percentage. Logistic regression analysis was performed to examine the association between selected risk factors and COPD. The odds ratios were calculated.

Results

Table 1 provides important descriptive characteristics of the study population. Most study subjects (66%) were under the age of 50 while only a third of the subjects were above 50. Majority of the women were illiterate and of low socioeconomic status (with household income $<$Rs.

Table 1. Descriptive characteristics and prevalence of COPD of the study population of Tiruvallur district, Tamilnadu

Variables		Frequency	Prevalence (%) with 95% CI
Overall		900	2.44 (1.43, 3.45)
Age	30–50	598	1.8 (0.73, 2.87)
	51–70	302	3.6 (1.49, 5.70)
Religion	Muslim/ Christian	122	4.1 (0.55, 7.65)
	Hindu	778	2.1 (1.09, 3.12)
Marital status	Single/ Widow	252	3.5 (1.23, 5.77)
	Married	648	2.0 (0.9, 3.08)
Literacy status	Literate	198	1.5 (−0.19, 3.19)
	Illiterate	702	2.7 (1.5, 3.9)
House type	Pucca/ Semipucca[a]	545	2.3 (1.04, 3.56)
	Kutcha[b]	355	2.5 (0.87, 4.12)
Kitchen type	Outdoor	457	2.4 (0.97, 3.82)
	Indoor	443	2.5 (1.06, 3.93)
Fuel type	Clean	147	2.0 (−0.26, 4.26)
	Biomass	753	2.5 (1.38, 3.61)
Passive smoking	No	668	2.3 (1.16, 3.44)
	Yes	232	2.9 (0.74, 5.1)
Income	>25,000	173	3.4 (0.69, 6.1)
	<25,000	727	2.2 (1.13, 3.27)
Cooking duration	≤15 years	241	1.2 (−0.17, 2.57)
	>15 years	659	2.9 (1.62, 4.18)
	≤2 hours/ day	330	1.5 (0.5, 2.5)
	> 2 hours/ day	570	3.0 (1.16, 4.84)
Main occupation	Outdoor	444	2.25 (0.87, 3.63)
	Indoor	456	2.63 (1.16, 4.1)

[a]Pucca – house with cemented walls and roof; [b]Kutcha – crude, imperfect, temporary house with walls and roof made of mud or thatch.

2,000 or $40 per month). Although the study subjects were all non-smokers, 25% reported exposure to passive smoking from male smokers within their household. Nearly 50% reported spending most of their time indoors on household chores and the rest reported working outdoor during the day. A high proportion of study participants used biomass as their primary fuel (83.7%) in unimproved stoves with only 16.3% using cleaner fuels such as kerosene and LPG. Nearly 50% of study households had indoor kitchens and the rest of the households were cooking outdoors most part of the year. The years of cooking ranged from 5 to 55 years with an average of 29.3±11.2 years per woman. The mean time spent in cooking was 3.1±1.2 hours per day. 40.3% were exposed to other particle sources such as mosquito coils and incense smoke. Although 5% of participants reported to have positive symptoms such as chronic cough with phlegm, only 2.4% turned out to be COPD positive clinically and spirometrically. Distribution of the study population in the several descriptive categories such as age, religion, literacy status, house type, kitchen type, and so on was similar to the distribution given in census data indicating the robustness of the data (16).

Prevalence of COPD

Overall, 2.44% (1.43, 3.45) of the study participants (22 of 900 subjects) were diagnosed with COPD. Table 1 also provides the prevalence of COPD among several subcategories within the study population. Although the difference in prevalence of COPD across subcategories was not statistically significant, we describe the differential prevalence across select subcategories to illustrate possible contributions from risks related to biomass fuel use. Prevalence of COPD was higher among the elderly women (>50 years), biomass users, women exposed to Environmental tobacco smoke (ETS), women who spent >2 hours/day in the kitchen for cooking, and women who have been involved in cooking for more than 15 years. As seen in Table 1, the majority of women were biomass users with greater than 15 years of cooking experience. Thus, although the observed differences in prevalence were all in the direction indicating an effect of biomass use, the sample lacked adequate power to detect statistically significant differences.

Table 2 shows the univariate odds ratio and the adjusted effects of type of cooking fuel and other variables on prevalence of COPD. The odds ratio for the use of solid fuels and COPD was 1.43 with 95% confidence interval of 0.36–5.73. Similarly, the odds ratio calculated for other related variables such as age (OR: 1.4; 95% CI: 0.49, 4.01), indoor kitchen type (OR: 1.1; 95% CI: 0.43, 2.8), cooking duration (OR: 2.05; 95% CI: 0.73, 5.72), and history of passive smoking (OR: 1.16; 95% CI: 0.44, 3.05) also showed increased risk, although not statistically significant.

Discussion

This population-based epidemiological study was carried out for estimating the prevalence of COPD as there have been few community-based prevalence assessments for COPD in India, especially among non-smoking rural women and men, and potential contributions from other risk factors such as biomass combustion and ETS have not been extensively studied. In a recent multicentric study in

Citation: Global Health Action 2011, 4: 7226 - DOI: 10.3402/gha.v4i0.7226

Table 2. Univariate OR and adjusted effects of type of cooking fuel and other variables on prevalence of chronic obstructive pulmonary disease

Study variables		Univariate OR with 95% CI	Adjusted OR with 95% CI
Age	30–50	2.02 (0.86, 4.71)	1.4 (0.49, 4.01)
	51–70		
Religion	Muslim/Christian	0.52 (0.19, 1.44)	0.55 (0.19, 1.54)
	Hindu		
Marital status	Single/Widow	0.55 (0.23, 1.31)	0.72 (0.27, 1.95)
	Married		
Literacy status	Literate	0.55 (0.16, 1.89)	0.73 (0.2, 2.7)
	Illiterate		
House type	Pucca/Semipucca[a]	1.06 (0.45, 2.52)	1.01 (0.41, 2.49)
	Kutcha[b]		
Kitchen type	Outdoor	1.03 (0.44, 2.41)	1.1 (0.43, 2.8)
	Indoor		
Fuel type	Clean	1.24 (0.36, 4.25)	1.43 (0.36, 5.73)
	Biomass		
Passive smoking	No	1.08 (0.42, 2.8)	1.16 (0.44, 3.05)
	Yes		
Income	$>$25,000	0.63 (0.24, 1.62)	0.52 (0.19, 1.47)
	$<$25,000		
Cooking duration	$\leq$15 years	2.36 (0.69, 8.03)	1.76 (0.45, 6.83)
	$>$15 years		
	$\leq$2 hours/day	2 (0.73, 5.47)	2.05 (0.73, 5.72)
	$>$2 hours/day		
Main occupation	Outdoor	1.17 (0.5, 2.74)	1.02 (0.41, 2.54)
	Indoor		

[a]Pucca – house with cemented walls and roof; [b]Kutcha – crude, imperfect, temporary house with walls and roof made of mud or thatch.

India, prevalence of smoking in women was found to be only 2% with most of them residing in urban areas (22).

In this study, a meticulous diagnostic approach was chosen for identification of the COPD cases, including a complete clinical evaluation with spirometry before and after bronchodilation, to minimize misclassification of asthmatics as COPD cases. Few community-based studies have used such rigorous criteria. The prevalence estimate of COPD of 2.44% obtained in this study population of Indian, rural, and primarily biomass-using women of $>$30 years of age is higher than the world prevalence of 0.8% (as reported by WHO). The prevalence in developed countries assessed mostly on smokers ranges from 4% to as high as 57% and prevalence tended to vary by the method used to estimate prevalence, namely spirometry (11 studies), respiratory symptoms (14 studies), patient-reported disease (10 studies), or expert opinion. The lowest prevalence was based on expert opinion (23, 24). Prevalence estimates obtained in this study are similar to what has been reported in other Indian studies [1.2% by Thiruvengadam et al. in Chennai urban, 2.5% by Ray et al. in rural South India, 3.9% by Jindal et al.in rural North India, 3.2% by Jindal et al. in rural India, a multicentric study] (22, 25–27) albeit slightly lower, where PEFR and sets of questions were used for the diagnosis of COPD. The estimate is higher than what has been reported for an urban population in the neighboring urban area in Chennai (25).

However, because most studies were hospital-based studies and as prevalence estimates were done using smoking rates in the study population, results were likely to bias estimates toward higher prevalence (28–30). Moreover, insufficient information on biomass use was available in most of the previous studies to make detailed comparisons. Furthermore, biases resulting from the use of alternative diagnostic protocols such as self-reporting and evaluation without spirometry or without broncho-dilation that could all contribute to the differences in the prevalence observed between the studies could not be sufficiently examined (23, 24). Prevalence of COPD in subjects aged $\geq$50 years in the study sample was 3.6% (1.49–5.7) as compared to subjects $<$50 years (1.8%). Although prevalence of COPD in younger subjects is lower than in older individuals, it is of public health importance as the younger population with a long life expectancy will continue to be exposed to several risk factors such as biomass fuel use, passive smoking, and occupational exposures.

Logistic regression analysis has shown increased risk of COPD in women using biomass fuel for cooking, in older women, in women involved in cooking for longer duration, in women living in kutcha houses, and in women with history of passive smoking, although statistically not significant. The lack of statistical significance is probably due to the sample size and power of the sample size. The sample size for this study was calculated for generating the prevalence of COPD, and the study design and the sampling frame work were also chosen for the same. Hence, this study is not adequately powered to examine the association between COPD and its risk factors, although the direction of the association of the select risk factors is similar to what is reported in the literature.

As studies have demonstrated that improved cook stoves reduce considerably the smoke, either by having a far better combustion or by having an excess of air or with a combination of both, the health impacts of smoke from open fires inside dwellings can be reduced using such improved cook stoves, changes to the environment (e.g. use of a chimney), and changes to user behavior (e.g. drying fuel wood before use, using a lid during cooking) (31). Hence, young adults have to be targeted early by the health authorities to promote awareness of the disease and its risk factors and thereby reduce the morbidity and mortality due to COPD.

Implications for refining disease burden assessments attributable to biomass combustion

This prevalence estimate can also be used for calculation of global burden of COPD as COPD is the 13th leading cause of global burden of disease worldwide with projected increase in its contribution over the next decade.

The association between household biomass combustion and increased risk of COPD in rural women has been documented in many studies (32, 33) and has been used in the WHO lead comparative risk assessments (CRA) and burden of disease calculations in 2002 (34, 35). An increasing body of animal studies also lend mechanistic support for this association (36, 37). Most disease burden calculations have to rely on routinely collected secondary health data to estimate baseline prevalence. These estimates are often aggregated at the national level, masking differences that may exist across states in India both in terms of exposures and outcomes.

An increasing body of exposure information now available on solid fuel-using households across multiple states in India show that 24-hour household concentrations of respirable suspended particulate matter (RSPM) from biomass combustion may range from 200 to 2000 $\mu g/m^3$ resulting in substantial differences in individual exposure across geographical regions (12, 13, 38). With an increasing body of prevalence information across regions (states), where concomitant indoor pollution measurements are being made, it may be possible to increase the resolution of the association between biomass use and COPD prevalence across a continuum of population exposures. The study has contributed by providing large scientific database of health data and has also developed methods and protocols for large-scale health assessments related to COPD for future applications in similar areas of research. Biomass will remain the principal cooking fuel for a large majority of rural households for many years to come. Hence, an effective mitigation strategy should employ a variety of options, from improvements in fuels and cooking technologies to housing improvements. Epidemiological studies such as what has been accomplished in this study pave the way for understanding opportunities for intervention design as well as in monitoring and evaluation of intervention effectiveness.

Moreover, it is difficult to estimate the effectiveness of an intervention in situations where preintervention estimates of health parameter are inadequate, which requires a demanding study design and analysis to examine or quantify causal associations (39). Such baseline prevalence information in biomass using populations is also useful for future cross-sectional assessments that may be used to assess intervention efficacy or for making comparisons with other populations to frame an intervention.

Conclusion

In conclusion, this cross-sectional population-based study has estimated the COPD prevalence in a non-smoking, primarily biomass-using rural women population, using objective lung function measurements in addition to clinical criteria. The burden of disease attributable to indoor air pollution has only been recently recognized as an important contributor to national burden of disease. Integration of the results from this study with exposure studies will help in refining disease burden estimates that are attributable to indoor air pollution. It is hoped that the baseline prevalence estimate for COPD generated in Tiruvallur district of Tamilnadu can be used by the researchers as well as local public health officials in future for the implementation of interventions to reduce the morbidity, mortality, and economic burden due to COPD.

Acknowledgements

The authors would like to thank Sri Ramachandra University, Prof. Michael Bates of University of California, Berkeley, the research team, and the subjects. This study was approved by the Institutional Ethics committee on 24 August 2006 (MEC/06/52/44).

Conflict of interest and funding

All authors have no conflicts of interest to disclose. This work was supported by grant awarded under the Growth and Advancement Towards Excellence (GATE) scheme of Sri Ramachandra University and co-supported by funds provided through The Fogarty International Centre ITREOH [Grants 2D43TW000 815–11] jointly awarded to University of California, Berkeley and Sri Ramachandra University.

References

1. The Global Burden of Diseases: World Health Organization. 2004. Available from: http://www.who.int/healthinfo/global_burden_disease/2004...update/en/. [cited 8 May 2011].
2. World Health Organization. Global strategy for diagnosis, management, and prevention of COPD. Geneva: World Health Organization; 2006. Available from: http://www.goldcopd.com/Guidelineitem.asp?l1=2&l2=1&intId=989. [cited 7 March 2007].
3. Celli BR, MacNee W. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J 2004; 23: 932–46.
4. Raherison C, Girodet PO. Epidemiology of COPD. Eur Respir Rev 2009; 18: 213–21.
5. Jindal SK, Aggarwal AN, Gupta D. A review of population studies from India to estimate national burden of COPD and its association with smoking. Indian J Chest Dis Allied Sci 2001; 43: 139–47.
6. Feenstra TL, Van Genugten ML, Hoogenveen RT, Wouters EF, Rutten-van Molken MP. The impact of ageing and smoking on the future burden of chronic obstructive pulmonary disease: a model analysis in the Netherlands. Am J Respir Crit Care Med 2001; 164: 590–6.
7. Klaus FR, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P, et al. Global strategy for diagnosis, management, and prevention of COPD. Am J Respir Crit Care Med 2007; 176: 532–55.
8. Yin P, Jiang CQ, Cheng KK, Lam TH, Lam KH, Miller MR, et al. Passive smoking exposure and risk of COPD among adults in China: the Guangzhou Biobank Cohort Study. Lancet 2007; 370: 751–7.
9. Eisner MD, Balmes J, Katz PP, Trupin L, Yelin EH, Blanc PD, et al. Lifetime environmental tobacco smoke exposure and the risk of chronic obstructive pulmonary disease. J Environ public Health 2005; 4: 7.
10. Smith KR, Mehta S, Maeusezahl-Feuz M. Indoor air pollution from household solid fuel use. In: Ezzati M, Lopez AD, Rodgers A, Murray CJL, eds. Comparative quantification of health risks: global and regional burden of disease attributable to selected major risk factors. Geneva: World Health Organization; 2004 pp. 1435–93.
11. Naeher LP, Michael Brauer, Michael Michael, et al. Woodsmoke health effects: a review. Inhal Toxicol 2007; 19: 67–106.
12. Balakrishnan K, Sankar S, Parikh J, et al. Daily average exposures to respirable particulate matter from combustion of biomass fuels in rural households of southern India. Environ Health Perspect 2002; 110: 1069–75.
13. Balakrishnan K, Sankar S, Padmavathi R, et al. Exposures to respirable particulate matter associated with household fuel use in Andhra Pradesh, India. J Expo Anal Environ 2004; 14: S14–25.
14. He G, Ying B, Liu J, Gao S, Shen S, Balakrishnan K, et al. Patterns of household concentrations of multiple indoor air pollutants in China. Env Sci Tech 2005; 39: 991–8.
15. Ezzati M, Lopez AD, Rodgers A, Murray CJL. Comparative quantification of health risks: the Global and regional burden of disease attributable to selected major risk factors (Volumes 1 and 2). Geneva: World Health Organization; 2004.
16. Census of India 2001. Available from: http://web.archive.org/web/20040616075334/ and http://www.censusindia.net/results/town. [cited 12 August 2006].
17. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Series "ATS/ERS task force: Standardisation of lung function testing" – Standardisation of spirometry. Eur Respir J 2005; 26: 319–38.
18. Vijayan VK, Kuppurao KV, Venkatesan P, Sankaran K. Reference values and prediction equations for maximal expiratory flow rates in non-smoking normal subjects in Madras. Indian J Physiol Pharmacol 1993; 37: 291–7.
19. Wise JB, Posner A, Walker GL. Verbal messages strengthen bench press efficacy. J Strength Cond Res 2004; 18: 26–9.
20. Moggridge C, Barnes H, Dixon L, Catrin J. Effects of verbal encouragement on spirometry measurements in healthy adults. Health Soc Work 2010; 2: 54–65.
21. Manríquez J, Díaz OP, Medoza LI, Borzone GTY, Lisboa CB. Spirometric reversibility in COPD patients: 200 or 400 mg salbutamol should be used? Rev Chil Enferm Respir 2006; 22: 168–75.
22. Jindal SK, Aggarwal AN, Chaudhry K, Chhabra SK, D'Souza GA, Gupta D, et al. A multicentric study on epidemiology of chronic obstructive pulmonary disease and its relationship with tobacco smoking and environmental tobacco smoke exposure. Indian J Chest Dis Allied Sci 2006; 48: 23–9.
23. Halbert RJ, Isonaka S, George D, Iqbal A. Interpreting COPD prevalence estimates. What is the true burden of disease? Chest 2003; 123: 1684–92.
24. Halbert RJ, Natoli JL, Gano A, et al. Global burden of COPD: Systematic review and meta-analysis. Eur Respir J 2006; 28: 523–32.
25. Thiruvengadam KV, Raghva TP, Bhardwaj KV. Survey of prevalence of chronic bronchitis in Madras city. In: Viswanath R, Jaggi OP, eds. Advances in chronic obstructive lung disease. Delhi: Asthma and Bronchitis Foundation of India; 1977 pp. 59–69.
26. Ray D, Abel R, Selvaraj KG. A 5-year prospective epidemiological study of chronic obstructive pulmonary disease in rural south India. Indian J Med Res 1995; 101: 238–44.
27. Jindal SK. A field study on follow up at 10 years of prevalence of chronic obstructive pulmonary disease & peak expiratory flow rate. Indian J Med Res 1993; 98: 20–6.
28. Lacasse Y, Montori VM, Lanthier C, Maltis F. The validity of diagnosing chronic obstructive pulmonary disease from a large administrative database. Can Respir J 2005; 12: 251–6.
29. Cricelli C, Mazzaglia G, Samani F, Marchi M, Sabatini A, Nardi R, et al. Prevalence estimates for chronic diseases in Italy: exploring the differences between self-report and primary care databases. J Public Health Med 2003; 25: 254–7.
30. Stang P, Lydick E, Silberman C, Kempel A, Keating ET. The prevalence of COPD: using smoking rates to estimate disease frequency in the general population. Chest 2000; 117: S354–9.
31. Chengappa C, Edwards R, Bajpai R, Naumoff Shields K, Smith KR. Impact of improved cookstoves on indoor air quality in the Bundelkhand region in India. Energy for Sustainable Development 2007; 11: 33–44.

32. Liu S, Zhou Y, Wang X, Wang D, Lu J, Zheng J, et al. Biomass fuels are the probable risk factor for chronic obstructive pulmonary disease in rural South China. Thorax 2007; 62: 889–97.
33. Hu G, Zhou Y, Yao W, Li J, Li B, Ran P. Risk of COPD from exposure to biomass smoke: a meta analysis. Chest 2010; 138: 20–31.
34. Smith KR. National burden of disease in India from indoor air pollution. Proc Natl Acad Sci USA 2000; 97: 13286–93.
35. Desai MA, Mehta S, Smith KR. Indoor smoke from solid fuels: assessing the environmental burden of disease at national and local levels. WHO Environmental Burden of Disease Series, No.4, Geneva: World Health Organization; 2004.
36. Tesfaigzi Y, McDonald JD, Reed MD, Singh SP, De Sanctis GT, Eynott PR, et al. Low-level subchronic exposure to wood smoke exacerbates inflammatory responses in allergic rats. Toxicol Sci 2005; 88: 505–13.
37. Lal K, Dutta KK, Vachhrajani KD, Gupta GS, Srivastava AK. Histomorphological changes in lung of rats following exposure to wood smoke. Indian J Exp Biol 1993; 31: 761–4.
38. Balakrishnan K, Nigel B. WHO Air Quality Guidelines Global Update. Indoor air pollution quality issues associated with domestic fuel combustion in developing countries. Geneva: World Health Organisation; 2006, pp. 189–207.
39. Arnolda BF, Khush RS, Ramaswamy P, London A, Rajkumar P, Ramaprabha P, et al. Causal inference methods to study nonrandomized, preexisting development interventions. Proc Natl Acad Sci USA 2010; 107: 22605–10. http://www.pnas.org/content/107/52/22605

***Priscilla Johnson**
Department of Physiology
Sri Ramachandra University
No. 1, Ramachandra Nagar, Porur
Chennai, Tamilnadu 600116, India
Tel: +91 44 24765609
Fax: +91 44 24767008
Email: drpriscijohn@yahoo.co.in

Citation: Global Health Action 2011, **4**: 7226 - DOI: 10.3402/gha.v4i0.7226