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EFFECTS OF INDOOR AIR POLLUTION BY BIOMASS FUELS ON RESPIRATORY FUNCTIONS OF WOMEN IN GONDAR, NORTH WEST ETHIOPIA

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Abstract

Poor households in Ethiopia depend heavily on wood, dung, and other biomass fuels for cooking. Inhalation of pollutants from these fuels may cause deleterious effects on health. The objective of this study was to investigate the effects of exposure to indoor air pollution from the use of biofuels on lung functions and respiratory symptoms in women. A cross-sectional study was conducted at Gondar town, 750 kilometers from Addis Ababa, between June and August 2010. Lung function parameters (FVC, FEV_1 AND PEFR), CO level were measured following the standard procedures. Socio-demographic data and respiratory symptoms were collected by using structured questionnaire. The data entered and analyzed by SPSS version 16.0 statistical software and $p<0.05$ was considered as statistically significant. The prevalence of wheeze (OR=8.11), phlegm (OR=17.1), bronchitis (OR=2.08) and asthma (OR=7.01) were significantly higher in the exposed groups relative to the no-exposure group. The mean measured value of ventilatory capacity FVC (2.20± 0.89 for biomass users and 2.62±0 .89 for controls, p=0.0004); FEV_1 (1.67±0 .77 for biomass users and 2.24± 0.82 for controls, p=0.0002) and PEFR (181.45± 72.14 for biomass users and 243.52±98.13 for controls, p=0.0003) were found to be significantly reduced in exposed group compared with controls and predicted values. Mean indoor CO level (238± 40 ppm) were higher than Occupational Safety and Health Administration (OSHA) exposure limit (101-200 ppm) and negatively correlated with reduction in the mean lung function parameters. Indoor air pollution had deleterious effect on the respiratory function of women. There must be intervention that educates women about behavioral possibilities to reduce the exposure to themselves and their children to cooking fire.

Keywords: Indoor air pollution, Carbon monoxide, Lung function parameters, Respiratory symptoms.

Introduction

The Use of Biomass Fuels in the World: Biomass is defined as the group of biologic materials (living organisms, both animal and vegetable, and their derivates) present in a specific area, collectively considered. Some of this material is used as fuel for cooking or home heating.[1]

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Close to 50% of the world 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.[2] In the rural areas of Latin America, approximately 30 to 75% of households use biomass fuels for cooking.[3]

Wood is the biomass fuel most frequently used both as unprocessed wood and as charcoal, the latter having far lower impact in indoor air pollution. In some regions, especially in sub-Saharan Africa, roughly 20% of the wood energy harvest is processed into charcoal and could reach 50% in some countries. Use of animal dung, crop residues, corncobs, and grass increases when wood is scarce or the forests are situated far away from the community.[4]

The use of solid fuels is linked to the gross national product per capita, and in general, in the same geographic zone, the use of solid fuels is higher in households with lower income. The global energy derived from biomass fuels has fallen from 50% in 1900 to nearly 13% in 2000, but recently it seems to be increasing, especially among the poor.[5] The current socioeconomic situation in many developing countries suggests that the use of biomass fuels will continue in the coming decades. In these countries, nearly 2 billion kilograms of biomass are burned every day.[6] In rural India, nearly 90% of the primary energy is derived from biomass (wood, 56%; crop residues, 16%; dung, 21%). The total annual average of wood production used for fuel in developing countries increased approximately 16.5% over the past decade to about 1.55 billion cubic meters.[7]

Studies specific to East Africa demonstrate that air pollutants originating from biomass are indeed problematic in that region. The study conducted in one region in Ethiopia found that the level of NO_2 in households that used biomass fuel for cooking was twice the WHO guideline for NO_2 concentrations.[8] A study in rural southwestern Ethiopian communities documented the biomass fuel-related problems. These included the conditions that produced exposure such as no separate kitchen and lack of windows and elevated particulate matter concentrations.[9] Another study in rural northern Ethiopia documented that 80% of cooking was done indoors with biomass.[10] In this same study only 13% of the women thought the smoke exposures were of concern.

Contribution of the Use of Biomass Fuels to Air Pollution

In general, the household use of solid fuels (biomass or coal) is the main source of indoor air pollution and, in certain geographic zones and seasons, also of outdoor pollution. The pollutant emissions from burning solid fuels usually exceed considerably the health-based national standards for outdoor pollution.[11]

Indoor air pollution

Cooking is the most important activity contributing to indoor air pollution. However, in some regions, especially in Asia, heating is another important source.[12] The majority of rural households in developing countries burn biomass fuels in open fireplaces or in nonairtight 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.[13]

The mean 24-hour levels of CO in the same households are in the range of 2 to 50 ppm, and can reach 500 ppm during cooking. The measurement of indoor air pollution from biomass combustion is complex because of the temporal and spatial distribution within the household, and the characteristics of the ventilation. In developing countries, the levels of indoor air pollution in homes using biomass fuels for cooking far exceed the health-based standards in the whole household, in both cooking and sleeping or living areas, with repeated episodes of intense emissions .Cooking or heating with biomass fuels in stoves or fireplaces vented to the outdoors (airtight stoves) also produces high indoor air pollution. Several important pollutants exceed substantially the total global outdoor exposures, although there is a substantial reduction in indoor concentration of pollutants compared with houses with unvented stoves.[14]

Studies from China and from other developing countries provide data supporting the large contribution of indoor pollution to total exposure, especially for women and children. In China, it has

been estimated that 80 to 90% of the total exposure to PM10 results from indoor air pollution due to solid fuel use in the rural population and this contribution is less than 60% in the urban population. The level of exposure of a population or an individual who uses solid fuels is extremely variable. Up to half of the total exposure in women who cook with solid fuel may be due to high-intensity episodes when they are close to the fire, especially when starting or stirring the fire.[15]

Indoor air pollution and acute lower respiratory infection

Acute respiratory infections from indoor air pollution from burning wood, animal dung, and other biofuels are estimated to kill one million children annually in developing countries.[16] Pneumonia, the most common type of Acute Lower Respiratory Tract Infection (ALRI), is now the single most important cause of death worldwide among children under 5 years of age. The risk is highest in the first year of life, and especially in the first six months. A growing number of studies have reported an increased risk of ALRI associated with exposure to bio-mass smoke, although for a number of reasons to do with the methods and study design, the evidence from these studies is not reckoned to be particularly strong.[17]

Chronic Obstructive Pulmonary Disease (COPD) and Biomass Smoke

Chronic Obstructive Pulmonary Disease is one of the leading causes of morbidity and mortality in the industrialized and developing countries. It is predicted that by 2020, COPD will be the third leading cause of death and the fifth leading cause of lost disability-adjusted life years (DALYs) worldwide.[18] A large number of cross-sectional and case-control studies of people in developing countries exposed to solid fuel smoke have suggested that chronic exposures are associated with chronic airflow obstruction in adult.[19] However, most of the studies only investigate the prevalence of COPD in different fuel-type groups. One study investigated the relationship between COPD and air pollutant concentrations of SO_2, NO_2, CO and particulate matter with an aerodynamic diameter of 10 µm or less (PM10). They found that air pollutant concentrations in the kitchen and adjacent living area and the SO_2 concentration in the kitchen of patients with COPD were significantly higher than for those without COPD. In these studies SO_2 was significantly associated with the prevalence of nonsmoking women with COPD.[20]

The results of a population based case-control study of childhood asthma conducted in Shunyi county located in suburban Beijing showed an increased risk for use of coal for heating and cooking without ventilation.[21] The finding of another study showed that exposure to solid fuel smoke exacerbates asthma for children between 5 and 14 years and for persons older than 15 years.[22] Another study in large size group of 7058 elementary school children living in four large Chinese cities was done to assess exposure – response relations. When lifetime exposures to coal smoke from heating were classified according to four ordinal levels (no, light, moderate and heavy exposure), monotonic and positive exposure-response relationships were observed for odds ratio estimates of phlegm, cough with phlegm and bronchitis. In addition, cough, wheeze and asthma were all more in the exposed groups relative to the no-exposure group.[23]

One survey study on respiratory illness and domestic pollution from fires in an arid high altitude region of northern India found prevalence of chronic cough with chronic phlegm rose steeply with age, and was greater among women than men. Lung function was significantly worse in those reporting chronic cough, independently of age and sex. Carbon monoxide (CO) measurements were used to assess domestic pollution from fires. In non-smoking men and the women, levels of exhaled CO were very significantly higher in winter than in summer, in summer, as were the levels of CO measured in the houses. Negative association was found between the winter value of CO in exhaled air and FEV1/FVC ratio in women. During winter, fires without chimneys gave higher levels of house pollution and individual CO in exhaled air than those with chimneys.[24]

In general, approximately one half the world's population relies on biomass fuel (wood, charcoal, crop residues, or dung) as a primary source of domestic energy. This practice results in widespread exposure to indoor air pollution (IAP), predominantly in developing countries where other sources of energy are becoming increasingly inaccessible and unaffordable. The health effects of

indoor air pollution are severe affecting women and children on their mothers back. On top of indoor air pollution there are confounders such as unventilated house and domestic crowding.[2]

The empirical base for the health effects of biomass fuels is comparatively narrow, with few empirical studies in relation to the magnitude of the global public health importance of the problem. Most existing reports consistently indicate that indoor air pollution is indeed a risk factor for respiratory disease, but studies are generally small and use indirect indicators of pollution, such as use of biomass fuel or type of stove.[15] The present study uses direct exposure measurement to pollution by measuring CO level in each kitchen and measures lung function parameters during cooking. Based on the findings, the study provide information for users about the adverse health effect of indoor air pollution and prepare methods to improve their stove and to use separate ventilated kitchen from living room.

Materials and methods

Study design, area, and period: A cross sectional study was conducted at Gondar town 750 kilometers from Addis Ababa between June and August 2010.

Source population and study participants: A total of 285 women (200 biomass fuel users, 85 non users) between ages 18 and 59 years were selected by multistage cluster sampling technique

Sample size and sampling procedures: Sample size was determined by using Open EPI, Version 2 using the formula which compares two means.

Inclusion and exclusion criteria

All selected subjects were non-smokers and used to cook 3-4 hr/ day regularly. Those who cook in open air without kitchen and smokers were excluded from the study.

Socio-demographic data collection procedures

A closed ended respiratory symptom questionnaire was administered at the house where the study participants were cooking. The questionnaire included history of smoking in the family, type of cooking fuel used, and duration of cooking and respiratory symptoms experienced, frequency of the signs and symptoms, past illness, etc.

Pulmonary function measurement by spirometry

Lung function measurement was performed using a portable, digital Spiro pro spirometer mini-Wright peak flow meter assessments were made by a trained laboratory technician according to standard protocols. The spirometer was calibrated daily and used in ambient temperature. The lung function test of the present study was based on the operation manual of the instrument, with special reference to the official statement of the American Thoracic Society of Standardization of Spirometry.

Each subject was instructed to sit and practice with the instrument, to place the mouthpiece in the mouth keeping the nose closed, to make a maximal inspiratory effort, and to blow out with a maximal effort. The test was repeated five times after adequate rest, and results were recorded by the spirometer. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were derived from best spirogram recorded. Three peak expiratory flow rate (PEFR) were recorded using Wright peak flow meter and the maximum record was used.

FEV_1 percent, the FEV_1 expressed as a percentage of the FVC was calculated. The data were compared with individual predictive values based on age, sex, body weight, standing height and calculated by using prediction formula (Mengesha, 1985 and Mashalla, 1994).

Exposure to air pollution

Daily integrated pollution exposure was measured by using information on concentrations of carbon monoxide (Ppm) in conjunction with information on time activity patterns. The CO level was measured by using CO meter Metavico/09 and sampling protocol was based on instruction on the manual. Briefly, CO concentrations were measured in the microenvironments of exposure (kitchen) in each selected households while cooking. The measurements were done at three levels, near the fire, far away from the fire and in the living room and the average value were taken. The households' kitchen and living room were not separate.

Statistical analysis

Analysis of data was done by SPSS 13 statistical package. Descriptive analyses were done for the variables of the present study. Individual pollution

exposure was estimated by using information on the concentrations of CO in each kitchen. T-test was used to compare the mean FVC , FEV_1 and PEFR with readings in biomass users and controls .Odds ratio with 95% confidence intervals was calculated to compare the prevalence of respiratory symptoms in case and controls. Correlations between exposure indicator (CO level) and lung function were estimated using Pearson correlation coefficients and $p<0.05$ was considered. Finally, to explore the relationship between respiratory symptoms and the exposure to pollutants, logistic-regression analysis was used. The adjusted odds ratios (ORs) and their 95% confidence intervals (CIs) were computed.

Ethical Consideration

The investigation was started after getting ethical clearance of study on human participants by Addis Ababa University Institute Research Board and Physiology department, Department Research Committee. The attached consent form was read in the local language and a copy given to the women upon request. Those selected were informed of the general purpose, possible risks, and benefits of the study in their language. Participation in the study was voluntary. To ensure confidentiality, participants' data was linked to a code number.

Result

Socio-demographic characteristics

Descriptive characteristics of biomass fuel user and control women are compared as shown in Table 1. It is evident that they were similar with respect to age**.** Mean ages of the study participants were 29.7 (±9.14) years for biomass users (n = 200) and 30.83(±11.07) years for controls (n = 85). In case of biomass users almost 22(11%) of subjects were <20 years old, 138(60%) of subjects were in 20–39 years age group, 40(18%) of subjects in 40–59 years age. In case of control participants almost 11 (12.9 %) were <20 years old, 55 (40.6%) of subjects were in 20–39 years age group, 19 (28.5%) of subjects in 40–59 years age group and 18.2% subjects were more than 59 years old. Mean height was 159 cms (± 5.65) for control subjects and 159 cms (± 7.63) for exposed subjects. Similarly mean weight was 53.88 kg (±8.15) and 56.33 kg (±10.05) for control and exposed groups, respectively.

Air Pollutant Concentrations

Table 2 presents the results of the air sampling. Carbon monoxide concentrations exceeded the Occupational Safety and Health Administration (OSHA) standard at most kitchens. The carbon monoxide levels in most households (146) were at OSHA exposure limit (101-200 ppm). No household was found at normal background level (CO□10ppm). The numbers of households with CO level at OSHA standard for living areas (11-50ppm) were only 2 and at OSHA standard for enclosed space for 8-hour average (51-100ppm) were 3 5households.

Respiratory symptoms and diseases

Respiratory symptom and illness data are summarized in Table 3. Biomass users had higher prevalence of breathlessness (61.5% in user vs. 45.1% in control; OR=1.88), wheezing (49% in users vs. 10.6% in controls; OR=8.11), cough (41.5% in users vs. 14.1 in control; OR=4.31), and phlegm (39.5 in users vs. 3.5 in control). The biomass users exhibited increased prevalence of respiratory diseases; bronchitis (25.5% in users vs. 14.1% in control; OR= 2.08), pneumonia (7.5% in users vs. 5.9% in control; OR=1.29), pleurisy (2.5% in users vs. 1.2% in control; OR=0.70), asthma (14.5% in users vs. 2.4% in control; OR =7.03) and hay fever (47.5% in users vs. 28.2% in controls; OR=2.30).

Carbon monoxide levels and lung functions

Carbon monoxide was found negatively correlated with lung volumes. At CO level greater than 100, the mean ±SD of, PEFR=212±13.58; FVC=2.66±0.155; FEV1=2.10±0.118.At CO level 101-200, the mean ±SD of PEFR, FVC, FEV1 decreased to 176±5.42; 2.09± 0.69; 1.57±0.06, respectively. At CO level >200 the lung volumes further decreased to PEFR=149± 24.1; FVC=2.02±0.252 and FEV1=1.53±0.29.Also the Pearson correlation (r) shows the CO level was negatively correlated with mean reduction in lung volumes. Multiple regressions were used to test the association between indoor air-pollutant concentrations and lung-function variability among study subjects. The results of pulmonary-function tests regressed on indoor air-pollution data are presented in Table 6. We found statistically significant ($p<0.01$) relationships between air-pollution level and pulmonary-function tests in the biomass user groups. CO exposure was associated

with statistically significant decrease in all three measures of pulmonary functions

Relation between lung disease symptoms and lung volumes

Correlation between lung volumes and respiratory symptoms were found statistically insignificant (p>0.05). Statically significant difference was observed only between PEFR of participants who respond "yes" and "no" to cough and phlegm (PEFR, NO=207.47±92.9, YES= 184.9±65.9; t=2.1, p=0.03)

Table No. 01: Demographic characteristics of study participants

Variable	Control (n=85) Mean±SD	Biomass user (n=200) Mean±SD
Age (year) Range 18-58 years	30.83±11.07	29.7±9.14
Height (cm)	159±5.65	159± 7.63
Weight (kg)	53.88± 8.15	56.33± 10.05

Table No. 02: CO concentration and frequency (n) of households

Co level (ppm)	Frequency (n)	OSHA standard
0-10	0	normal background level
11-50	2	standard for living areas
51-100	35	enclosed space 8-hour average
101-200	146	exposure limit
>200	17	mild headache, fatigue, nausea, dizziness

*U.S. Department of Labor, OSHA Regulation 1917.24

Table No. 03: Prevalence of respiratory symptoms in biomass users and controls, Frequency (%)

Variables	Controls	Biomass users	OR	CI (95%)
Breathlessness	39(45.1)	123(61.5)	1.88	1.12-3.147
Wheezing	9(10.6)	98(49)	8.11	3.85-17.08
Cough	12(14.1)	83(41.5)	4.31	2.20-8.45
Phlegm	3(3.5)	79(39.5)	17.8	5.44-58.45

- R: odds ratio
- CI: confidence interval

Table No. 04: Prevalence of respiratory disease in biomass users and controls

Disease	Controls N (%)	Biomass users N (%)	OR	CI (95%)
Bronchitis	12(14.1)	51(25.5)	2.08	1.04-4.14
Pneumonia	5(5.9)	15(7.5)	1.29	0.456-3.69
Pleurisy	1(1.2)	5(2.5)	0.70	0.16-3.00
Asthma	2(2.4)	29(14.5)	7.03	1.64-30.20
Hay fever	24(28.2)	95(47.5)	2.30	1.33-3.97

- OR: odds ratio
- CI: confidence interval

Table No. 05: Lung function data observed and predicted value of biomass users and control, mean±SD

		Observed			Predicted		
Group	**number**	**FVC (l/s)**	**FEV_1(l/s)**	**PEFR(l/min)**	**FVC(l/s)**	**FEV_1(l/s)**	**PEFR(l/min)**
Biomass users	200	2.20± 0.89	1.67±0 .77	181.45± 72.14	3.22± 0.30	2.61± 0.25	310±28
Controls	85	2.62±0 .89	2.24± 0.82	243.52±98.13	3.18± 0.26	2.58± 0.25	306±34

t=5.9, p=0.0003(PEFR), t= 3.6, p=0.0004 (FVC), t= 5.6, p=0.0002(FEV1)

- PEF: peak expiratory flow
- FEV1: forced expiratory volume in one second
- FVC: forced vital capacity

Table No. 06: Regression Coefficient and 95% Confidence Interval of Pulmonary Function Tests on Indoor Air Pollutants

Pulmonary function	Biomass users
Pollutant +	regression coefficient (CI)
PEFR	
CO	-0.386 (-.626 – -0.145)*
FVC	
CO	-0.005 (-0.008 – -0.002) **
FEVI	
CO	-0.004 (-0.007 – -0.002) **
FEV1/FVC (%)	
CO	-0.118 (-0.180 – -.055) **

* p< 0.05 **p<0.01

PEF: peak expiratory flow

FEV_1: forced expiratory volume in one second

FVC: forced vital capacity

Table No. 07: Correlation between the lung volumes and respiratory symptoms (mean±SD)

Variables	Presence/absence	PEFR	FVC	FEV_1
Breathlessness	NO	203.66 ± 8.53	2.27±0.078	1.83±0.073
	YES	197.16 ± 6.12 (t=0.63,p=0.52)	2.36±0.074 (t=0.76,p=0.44)	1.85±0.066 (t=0.26,p=0.78)
Wheezing	NO	203.65±91.15	2.29±0.82	1.85±0.78
	YES	193.83±75.0 (t=-0.94,p=0.34)	2.37±1.04 (t=0.67,p=0.50)	1.82±0.90 (t=-0.33,p=0.74)
Cough	NO	207.47±92.9	2.38±0.86	1.91±0.75
	YES	184.9±65.9 (t=-2.1,p=0.03)*	2.21±0.99 (t=-1.49,p=0.13)	1.71±0.85 (t=-1.94,p=0.05)
Phlegm	NO	206.95±90.44	2.36±0.86	1.88±0.80
	YES	182.68±69.17 (t=2.18,p=0.03)*	2.24 ±1.01 (t=-0.99,p=0.32)	1.74±0.88 (t=1.29,p=0.1)

*P<0.05

Table No. 089:Relation between the lung volumes and respiratory diseases (mean±SD)

Variables	Presence/ absence	PEFR (mean±SE)	FVC(mean±SE)	FEV_1 (mean±SE)
Bronchitis	NO	206.94±88.95	2.4118 ±0.90	1.91± 0.84
	YES	175.39±66.86 (t=2.6,p=0.009)*	2.0276±0.89 (t=2.987,p=0.003)*	1.60± 0.73 (t= 2.64,p=0.009)*
Pneumonia	NO	201.85±86	2.34±0.92	1.74±0.74
	YES	175.00±69 (t=1.35,p=0.01)*	2.13±0.68 (t=0.97,p=0.03)*	1.85±0.83 (t=0.782, p=0.049)*
Pleurisy	NO	226.2±114	2.54±1.2	2.18±1.1
	YES	199.2±84.6 (t=0.88,p=0.037)*	2.3±0.90 (t=0.69, 0.048)*	1.83±0.82 (t=1.17,p=0.024)*
Asthma	NO	203±88	2.32±0.92	1.97±0.8
	YES	174±54 (t=1.78,p=0.045)*	2.03±0.82 (t=0.316,p=0.03)	1.81±0.71 (t=0.22,p=0.08)
Hay fever	NO	208±93	2.39±0.87	1.95±0.8
	YES	187±71 (t=2.01,p=0.045)*	2.2±0.9 (t=1.474,p=0.035)*	1.69±0.8 (t=2.563,p=0.011)*

*p<0.05

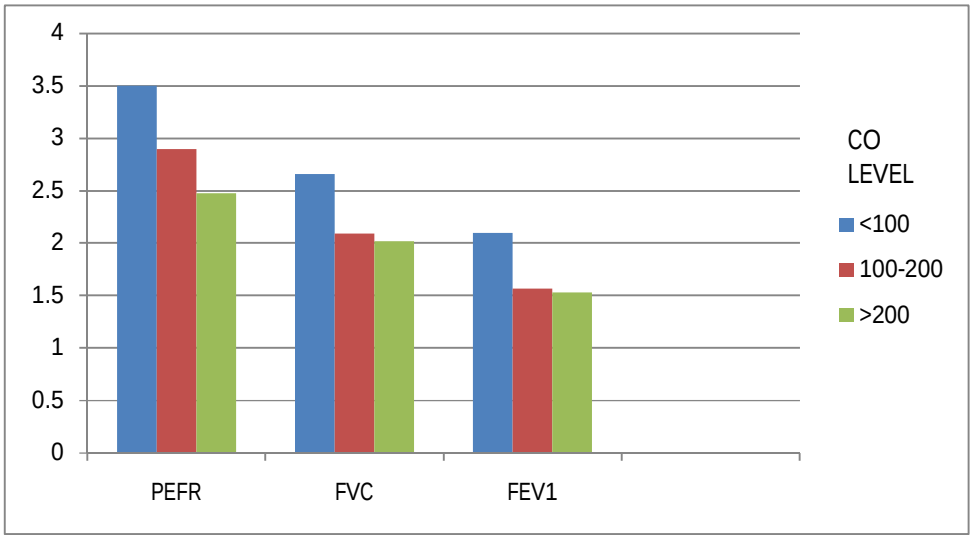

Fig. No. 01: Correlation between lung volumes and CO category

Discussion

This study has come up with the finding that the use of biomass as a cooking fuel produces high concentrations of CO (238± 40 ppm) in the indoor environment. Related study in solid-fuel-using households of rural India reported an average concentration of CO (237.8 ±40.5 ppb).[26] Respiratory disease symptoms were higher in the exposed group than in the control group. Similar result was reported in an Australian study [26], where the presence of wood heaters at home was significantly associated with increased prevalence of asthma in females. Wood cooking was also associated with increased risk of respiratory symptoms and impaired lung function in nonsmoking women in Singapore.[27] Phlegm was the most prevalent respiratory symptom in biomass users group, 17.8 times more in biomass users than control (OR=17.8) and significantly correlated with carbon monoxide level (correlation coefficient =0 .478, p< 0.01).In the present study, as carbon monoxide levels increase the phlegm increase. Wheezing was also higher, 8.11 times, more in biomass group than the control group (OR= 8.11). Related study showed that smoke from solid fuels is a complex mixture of many potentially relevant components many of which are toxic to the bronchial mucosa and alveoli because of their ability to form free radicals. When inhaled in sufficient concentrations it tend to produce acute neutrophilic airway inflammation associated with symptoms consisting of cough, bronchorrhea, and dyspnea and wheezing.[28] From the respiratory disease asthma was the most prevalent, 7.03 times more in biomass users than the controls (OR= 7.03). Similar study showed that repeated exposures to low concentrations of smoke may contribute to the development of chronic respiratory illness including asthma,[29] chronic bronchitis and chronic obstructive pulmonary disease (COPD).[30]

Lung volumes, especially PEFR (181.45± 72.14, p=0.0003) and FEV_1 (1.67±0 .77, p=0.0002) in biomass users were highly reduced than the predicted value compared to the control PEFR (243.52±98.13) and FEV_1 (2.24± 0.82) which was close to the predicted value. The reason may be that the measurement was done at the time of cooking which may be resulted in an acute decrease in upper respiratory tract diameter. Related study of British adults[31] showed a significantly reduced forced expiratory volume in one second (FEV_1) in subjects who currently used wood for cooking compared to those who used electricity. Another related study conducted in Turkey reported highly significant reduction of FEV_1, FVC, and FEV1/FVC ($P < 0.00001$) in case of biomass fuel users.[32] Also study conducted in an urban Indian slum showed significantly lower FVC, FEV_1, FEV_1% and PEFR values in bio-fuel using women in comparison to modern fuel users (kerosene and LPG),[33] Whereas a similar study undertaken involving rural Indian women could show the prominent adverse effect of biomass fuel use on FVC only.[34] Another study reported that there were no effects observed on FVC.[35] These conflicting reports may be due to the extent of lung

volumes deterioration that depends on biomass fuel type. Confounding effect of different other factors may also be responsible for this kind of conflicting findings and the need of more such studies including intervention studies must be stressed in order to gather stronger scientific evidence.

Lung volumes were negatively associated with CO level, (CO<100, PEFR=212±13.58; FVC=2.66 ±0.155; FEV1=2.10±0.118: CO=101-200, PEFR=176±5.42, FVC=2.09±0.69; FEV1=1.57 ±0.06: CO level >200 the lung volumes further decreased to PEFR=149± 24.1; FVC=2.02±0.252 and FEV1=1.53±0.29. (r= -0.219, p=0.002(PEFR), r = -0.249, p=0.0003 (FVC), r = -0.228, p=0.001(FEV_1)). Related study also showed Changes in NO_2, CO and black smoke concentrations were found to be negatively associated with FVC, FEV_1 and PEF, but only the associations of NO_2 and CO with PEF, and CO with FEV_1 reached the nominal level of statistical significance.[36]

Another interesting finding in the current study is that even though the CO level was associated negatively with the lung volumes, the strength of association was weak i.e. r< 0.5.This may show that there are plenty of pollutants that reduces lung volumes and must be measured in biomass fuel pollution study.Another peculiarity observed in this study was that no correlation was found between respiratory symptoms and reduction in the lung function indices. This may be due to that the respiratory status was measured when acute exposure was considered. To sum up, the present overall mean reductions in lung function indices, especially PEFR and FEV_1 observed in biomass users (while cooking) were considerable. The CO concentrations recorded in the kitchen seem to correlate fairly with reduction in the lung function indices.

There was no correlation observed between respiratory symptoms and reduction in the lung function indices. However, since these reduction correlate with respiratory diseases that shows presence of cumulative pulmonary impairment in women's subjected to prolonged exposure. This deterioration of pulmonary function in biomass fuel users has been attributed to the fact that the amount and concentration of particulate matter and other toxic gases emitted during biomass combustion while cooking.[16]

Conclusion

This study shows the adverse effects of biomass fuels use on the deterioration of pulmonary function. The findings of this study also point towards an important environmental health problem involving mostly the poor women and indicate that the health consequences of exposure from biomass and other solid fuels in developing countries should not be ignored not only because the health burden is high but also because of the fact that such fuels will continue to be used throughout the world by a large number of households in the foreseeable future. Intervention technologies such as adding chimney to kitchen and modernizing uses of bio energy must be given due attention.

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