Evaluation of Clinical and Functional Parameters in Female Subjects With Biomass Smoke Exposure

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BACKGROUND: Indoor air pollution and exposure to biomass smoke is a risk factor for pulmonary diseases among women in developing countries. We aimed to assess clinical and functional findings and exposure duration and to evaluate their relationships in patients who used biomass products as fuel and who presented to the clinic due to respiratory symptoms. METHODS: Fifty-five patients who had been referred to the hospital between January 2008 and December 2010 and who met the inclusion criteria were accepted to the study. Data on the place they live, biomass exposure duration, lung function parameters, and arterial blood gases were recorded. RESULTS: Statistically significant differences in FEV_1%, FEV_1 (L) and, FEV_1/FVC existed between the subgroups of duration of biomass exposure ($P = .001$). FEV_1% and FEV_1/FVC were highest in the < 30 hour-years exposure group. In the presence of animal dung use, the odds ratio and 95% CI for the risk of FEV_1/FVC < 70% was 3.5 (0.88–10.29). Subjects who used animal dung and wood for cooking and heating had severe and very severe FEV_1 stages. CONCLUSIONS: Biomass exposure can have effects on lung function test parameters. Animal dung use is primarily related to risk of deterioration of FEV_1/FVC, when compared to other biomass fuels. Protective health measures should be taken by assessing the risks in areas where biomass exposure is intense, improving poor design of the stoves and ventilation, and switching to better clean energy sources such as natural gas and solar energy. *Key words: arterial blood gases; biomass; pulmonary disease; smoke.*
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Introduction

Biomass exposure in the developing countries is a major health risk. Almost half of the world's population is estimated to use biomass fuels like animal dung, crop residues, wood shavings, and coal for heating and cooking.[1,2] Incomplete burning of biomass fuels releases pollutants such as carbon monoxide, sulfur dioxide, nitrogen dioxide, polycyclic hydrocarbons, and particulate matter to the living environment. Exposure to biomass smoke during household work presents a causative or contributory factor to chronic obstructive airway diseases and respiratory infections, especially for adult women and children.[3-5]

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The World Health Organization has estimated that the biomass exposure accounts for approximately 35% of the COPD in low and middle income countries.[6] In clinical practice this important public health problem is often underestimated when dealing with chronic obstructive airway diseases. A substantial proportion of the population in rural areas of Turkey relies on biomass fuels to meet their basic household energy demand, such as heating and cooking. Unfortunately, there was a lack of detailed data about

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exposure and illness outcomes. Results of the limited number of studies suggest that smoke from biomass exposure may be associated with functional and structural pathological changes in the respiratory system.[7]

The aim of the present study was to assess the clinical and functional findings and biomass exposure index, and to evaluate their relationship, in the lungs of Turkish adult women who used biomass products as fuel and who presented to the clinic due to respiratory symptoms.

QUICK LOOK

Current knowledge

Indoor air pollution and exposure to biomass smoke is an important risk factor for pulmonary disease in women in developing countries. The type of biomass (animal dung, wood, coal) used for heating and cooking, and the efficiency of burning impact the exposure to pollutants. Women and children are at greatest risk, owing to the duration of time spent in the home.

What this paper contributes to our knowledge

Exposure to biomass smoke in the home was associated with a greater incidence of $FEV_1/FVC < 70\%$ in women. Burning animal dung was associated with the greatest decrement in lung function. Reliable, cost-effective methods of respiratory protection are needed for women who cook and heat with biomass fuels.

Methods

A retrospective descriptive study was planned. Fifty-five female patients who had been referred to the clinic of a pulmonary diseases research state hospital due to respiratory symptoms and who met inclusion criteria were included to the study. Data on the place they live, history of biomass exposure, respiratory symptoms, test results of flow, volume, reversibility, diffusion capacity for carbon-monoxide (D_{LCO}), and arterial blood gases were obtained from the records in archives of the hospital between January 2008 and December 2010. Dyspnea was scored according to the modified Medical Research Council dyspnea scale.[8]

Inclusion criteria were as follows: history of biomass exposure, free of signs of infection, and no exacerbation of air-flow limitation within 6 weeks prior to enrollment. Exclusion criteria were as follows: history of myocardial infarction, congestive heart failure and unstable angina within 4 months prior to enrollment period, presence of malignant disease, accompanying systemic metabolic diseases, fibrotic lesions due to lung tuberculosis, and patients who did not perform lung function tests.

Our study was conducted in accordance with the Declaration of Helsinki. Written consent was obtained from the administration of the state hospital to use the archives' data, and the study protocol was approved by the ethics committee of Maltepe Medical Faculty.

Lung Function Tests

Lung function tests were performed by a trained technician using a calibrated spirometer (Flowhandy 100 USB, ZAN Messgeräte, Oberthulba, Germany), in accordance with American Thoracic Society recommendations.[9] In ZAN Messgeräte spirometry systems updated predicted norm sets for age, height, and sex obtained from American Thoracic Society/European Respiratory Society 2005 and European Community for Steel and Coal 1993/1983 studies were used.[10-12] At least 3 acceptable and 2 reproducible (FVC and FEV_1 within 5% and 100 mL) forced expiratory maneuvers were used for analysis. FEV_1 and FVC were expressed in liters and as a percentage of the reference predictive values. Reversibility was defined as $\geq 12\%$ and ≥ 200 mL increase in FEV_1 from the pre-bronchodilator value, after 400 μg of salbutamol inhalation with metered-dose inhaler via a spacer.[13] COPD was defined as a ratio of the post-bronchodilator FEV_1 to $FVC < 0.70$, according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria.[14]

Single-breath D_{LCO} had been measured by single-breath method and expressed as D_{LCO} percentage (mL/mm Hg/min) using a spirometry system (Vmax 22, Viasys Healthcare/SensorMedics, Yorba Linda, California).

Arterial Blood Gases

Arterial blood gas measurements (Rapidlab 248, Siemens, Berlin, Germany) were acquired in subjects with an FEV_1 value of $< 50\%$ or who had an S_{pO_2} of $< 92\%$.[15]

Biomass Exposure Index

A biomass exposure index was defined to compare the clinical and functional parameters of the subjects with the exposure time of biomass. The exposure index in hour-years was used to express exposure, and it was calculated as the average hours spent during daily cooking multiplied by the number of years.[4,5] The duration of biomass exposure was evaluated by using 3 exposure periods: < 30 hour-years, 30–59 hour-years, and ≥ 60 hour-years.

Statistical Analysis

We used statistics software (NCSS 2007, NCSS, Kaysville, Utah) for statistical analysis. Descriptive statis-

Table 1. Population Characteristics of Women Exposed to Biomass Smoke

Age, y	65.30 ± 7.39 (47–75)
Height, m	1.60 ± 0.06 (1.51–1.73)
Weight, kg	76.22 ± 14.51 (48–106.3)
Body mass index, kg/m^2	29.86 ± 6.39 (18.99–43.38)
Symptoms, no. (%)	
Cough	44 (80)
Dyspnea	41 (75)
Phlegm	30 (55)
Wheezing	19 (35)
Smoking Status, no. (%)	
Non-smoker	31 (56)
Passive smoker	24 (44)
Education, no. (%)	
Poor schooling	30 (55)
Primary school	8 (15)
Secondary school	2 (3)
mMRC Dyspnea Score, no. (%)	
1	17 (41.5)
2	24 (58.5)
Lung Function	
FEV_1/FVC > 70%, no. (%)	16 (29)
FEV_1/FVC < 70%, no. (%)	39 (71)
FEV_1, L	0.98 ± 0.42 (0.40–2.28)
FVC, L	1.49 ± 0.42 (0.59–3.40)
FEV_1/FVC	0.68 ± 0.28 (0.27–0.98)

Values are mean ± SD (range) unless otherwise indicated.
mMRC = modified Medical Research Council

Table 2. Smoking Status Versus Age, Dwelling, Biomass Exposure, Lung Function, Symptoms, and Biomass Type

	Non-smoker	Passive Smoker	*P*
Age, mean ± SD y	66.55 ± 6.67	63.71 ± 8.10	.16
Dwelling			
City center	6 (19.4)	5 (20.8)	
Town	16 (51.6)	12 (50.0)	
Village	9 (29.0)	7 (29.2)	.99
Biomass Exposures			
1 exposure	9 (29.0)	4 (16.7)	
2 exposures	13 (41.9)	7 (29.2)	
> 3 exposures	9 (29.0)	13 (54.2)	.16
< 30 hour-years exposure	8 (25.8)	5 (20.8)	
30–59 hour-years exposure	8 (25.8)	10 (41.7)	
≥ 60 hour-years exposure	15 (48.4)	9 (37.5)	.46
Lung Function			
FEV_1/FVC			
> %70	10 (32.3)	9 (37.5)	
< % 70	21 (67.7)	15 (62.5)	.69
FEV_1 Stage			
100–80%	2 (6.5)	4 (16.7)	
79–50%	14 (45.2)	11 (45.8)	
49–30%	12 (38.7)	8 (33.3)	
< 30%	3 (9.7)	1 (4.2)	.58
D_{LCO} Stage			
140–81% Normal	14 (45.2)	9 (37.5)	
80–61% Mild	11 (35.5)	9 (37.5)	
60–41% Moderate	5 (16.1)	6 (25.0)	
≤ 40% Severe	1 (3.2)	0 (0)	.68
Symptoms			
Dyspnea	23 (74.2)	18 (75.0)	.95
Cough	25 (80.6)	19 (79.2)	.89
Phlegm	15 (48.4)	15 (62.5)	.30
Hemoptysis	1 (3.2)	1 (4.2)	.85
Wheezing	10 (32.3)	9 (37.5)	.69
Biomass Types			
Animal dung	20 (64.5)	20 (83.3)	.12
Wood	27 (87.1)	18 (75.0)	.25
Coal	5 (16.1)	8 (33.3)	.14
Wood shavings	5 (16.1)	9 (37.5)	.07
Straw	5 (16.1)	2 (8.3)	.39
Rubbish	0 (0)	3 (12.5)	.07
Tobacco roots	1 (3.2)	0 (0)	.38

Values other than age are number and percent.
D_{LCO} = diffusion of lung for carbon monoxide

tical methods (mean and standard deviation) and one-way variance analysis were used to compare the groups and the Tukey multiple comparison test was used to compare the subgroups. Numerical data were compared by chi-square test. Results were considered to be significant at a value of $P < .05$.

Results

Data were retrospectively evaluated from the archives' records between January 2008 and December 2010. A total of 55 women, with a mean age of 65.30 ± 7.39 years (range 47–75 y), who had biomass exposure history, and who met the inclusion criteria were included in the study. Demographic characteristics of the study group are summarized in Table 1. The study results were checked according to the age, socioeconomic status, and education levels. It was determined that these 3 variables had no effect on respiratory parameters and were not found to be covariate factors.

Cough (80%), dyspnea (75%), phlegm (55%), and wheezing (35%) were common symptoms. According to modified Medical Research Council dyspnea scale, the score for 17 of the 44 cases describing dyspnea was 1, and the score for 24 cases was 2. The educational level of the subjects was poor. Review of the distribution of the subjects according to geographical regions of Turkey showed that most of the subjects live in the Anatolian and Black Sea regions. Thirty-one (56%) subjects were non-smokers, and 24 (44%) were passive cigarette smokers.

Table 3. Lung Function Versus Biomass Exposure

	Exposure, mean ± SD hour-years			
	< 30 (*n* = 13)	30–59 (*n* = 18)	≥ 60 (*n* = 24)	*P*
FEV_1, % predicted	70 ± 14*	55 ± 17	46 ± 15	< .001
FEV_1, L	1.26 ± 0.53	1.1 ± 0.35	0.73 ± 0.24†	< .001
FVC, % predicted	74 ± 28	70 ± 23	63 ± 20	.36
FVC, L	1.52 ± 0.69	1.56 ± 0.33	1.41 ± 0.26	.47
FEV_1/FVC	0.88 ± 0.32‡	0.71 ± 0.19	0.54 ± 0.23	.001
D_{LCO}/V_A, % predicted	97 ± 24	88 ± 16	97 ± 37	.54
S_{pO_2}	89 ± 4	91 ± 5	89 ± 5	.27

* < 30 hour-years exposure > 30–59 and ≥ 60 hour-years exposure $P = .03$, $P < .001$.
† ≥ 60 hour-years exposure > < 30 and 30–59 hour-years exposure $P < .001$, $P = .005$.
‡ < 30 hour-years exposure vs > 30–59 and ≥ 60 hour-years exposure $P = .01$, $P = .001$.
D_{LCO} = diffusing capacity of the lung for carbon monoxide
V_A = alveolar volume

There were no statistically significant differences between the subjects who were exposed to biomass smoke only and those who were exposed to biomass smoke and also passive smokers with regard to symptoms, biomass types, biomass exposure, and lung function (Table 2).

There were highly statistically significant differences in FEV_1 (%) and FEV_1 (L) values of the subgroups regarding duration of biomass exposure ($P < .001$). A statistically significant difference was also observed between the FEV_1/FVC values of the groups ($P = .001$) (Table 3).

The Tukey multiple comparison test revealed that FEV_1 (%) was higher in the < 30 hour-years exposure group, compared to the 30–59 hour-years exposure and ≥ 60 hour-years exposure groups ($P = .03$ and $P < .001$, respectively).

FEV_1 (L) was lower in the ≥60 hour-years exposure group than in the < 30 hour-years exposure and 30–59 hour-years exposure groups ($P < .001$ and $P = .005$, respectively). Also, FEV_1/FVC was higher in the < 30 hour-years exposure group than in the 30–59 hour-years exposure and ≥ 60 hour-years exposure groups ($P = .01$ and $P = .001$, respectively). There was no statistical difference in oxygen saturation among 3 groups of biomass exposure duration ($P = .27$) (see Table 3).

In the presence of animal dung use as biomass fuel, the odds ratio and 95% CI risk of FEV_1/FVC being < 70% was 3.5 (0.88–10.29). For other biomass types this risk never exceeded 2 (Table 4).

In the severe (FEV_1 49–30%) and very severe (FEV_1 < 30%) GOLD FEV_1 stages subgroups, the use of animal dung and wood as biomass fuels were higher than the other FEV_1 stage groups ($P = .04$ and $P = .01$, respectively) (Table 5). No statistically significant difference was found between the D_{LCO} stage subgroups with regard to biomass fuel types (Table 6).

Table 4. FEV_1/FVC Category Versus Biomass Fuel Type

	FEV_1/FVC < 70%, no. (%) (*n* = 19)	FEV_1/FVC > 70%, no. (%) (*n* = 36)	*P*	Odds Ratio	95% CI
Animal dung	11 (57.9)	29 (80.6)	.07	3.5	0.88–10.29
Wood	16 (84.2)	29 (80.6)	.74	0.78	0.18–3.42
Coal	6 (31.6)	7 (19.4)	.31	0.52	0.15–1.86
Wood shavings	5 (26.3)	9 (25.0)	.92	0.93	0.26–3.32
Straw	3 (15.8)	4 (11.1)	.62	0.67	0.13–3.34
Rubbish	1 (5.3)	2 (5.6)	.25	1.05	0.09–12.48
Tobacco roots	16 (29.6)	0 (0)	.46	0.28	0.03–3.58

Table 5. GOLD FEV_1 Stage Versus Biomass Fuel Type

	FEV_1 Stage, no. (%)				
	Mild 100–80%	Moderate 79–50%	Severe 49–30%	Very Severe < 30%	*P*
Animal dung	3 (50.0)	15 (60)	18 (90)	4 (100)	.04
Wood	5 (83.3)	24 (96)	12 (60)	4 (100)	.01
Coal	2 (33.3)	7 (28)	3 (15)	1 (25)	.70
Wood shavings	1 (16.7)	6 (24)	6 (30)	1 (25)	.92
Straw	1 (16.7)	5 (20)	1 (5)	0 (0)	.40
Rubbish	0 (0)	1 (4)	2 (10)	0 (0)	.69
Tobacco roots	0 (0)	1 (4)	0 (0)	0 (0)	.75

GOLD = Global Initiative for Chronic Obstructive Lung Disease

Discussion

The World Health Organization declared biomass-related indoor air pollution as one of the top 10 global health risks and responsible for 1.5 million deaths annually.[16] In rural areas of Turkey, biomass fuels are used by women to meet their household demand, such as heating and especially cooking bread for their homes. Those

Table 6. D_{LCO} Stage Versus Biomass Fuel Type

	D_{LCO} Stage, no. (%)				
	Normal 140–81%	Mild 80–61%	Moderate 60–41%	Severe ≤ 40%	*P*
Animal dung	17 (73.9)	12 (60.0)	10 (90.9)	1 (100.0)	.28
Wood	20 (87.0)	17 (85.0)	7 (63.6)	1 (100.0)	.36
Coal	6 (26.1)	3 (15.0)	4 (36.4)	0 (0)	.53
Wood shavings	6 (26.1)	4 (20.0)	4 (36.4)	0 (0)	.72
Straw	4 (17.4)	3 (15.0)	0 (0)	0 (0)	.51
Rubbish	1 (4.3)	2 (10.0)	0 (0)	0 (0)	.67
Tobacco roots	1 (4.3)	0 (0)	0 (0)	0 (0)	.70

D_{LCO} = diffusing capacity of the lung for carbon monoxide

women are exposed to biomass smoke for long periods during cooking with open combustion. In the east Anatolian region, dried animal dung is widely used, due to low income and long winter conditions. Wood is mostly used in the Black Sea and mid-Anatolian regions. When we grouped the subjects according to the places they lived as city center, town, and village, we found that only 29% of them lived in villages. But it was found that in fact 61% of them were previously living in villages and then moved to a city center. Since they had low income and socioeconomical problems in their new dwelling zone, the use of biomass had continued despite the immigration. The mean age of the group (65.30 ± 7.39 y) was high, and 96% were above 50 years old. This result was consistent with the chronicity of the airway disease (COPD) and its clinical presentation being more prominent in the elderly. Fifty-five percent were poorly educated, and this condition was also associated with their low incomes.

As a widespread disease all over the world, COPD is a disease that reflects socioeconomic status, and it is mainly seen in the poor societies. In a study concerning COPD, low income was associated with low FEV_1 and FVC values.[17] Low socioeconomic status can increase the risk factors and also affect availability of the drugs and the adherence of the patient to the treatment. Cessation of biomass exposure may also be difficult, thus the patients are usually symptomatic with recurrent exacerbations.

COPD due to biomass smoke is specifically seen in women in the countries of the Middle East, Asia, and Africa. It was estimated that indoor air pollution due to biomass exposure is responsible for the annual death of 2 million women and children, and biomass exposure is known to be one of the important causes of COPD, asthma, and bronchitis.[18-20]

Bilir et al investigated the biomass exposure in women in a rural area where 99.2% of the women cook bread on an open fire twice a month. It was observed that they spent > 6 hours cooking bread each time, and they did this for > 30 years. They also used dried animal dung for heating. Ninety-nine percent of these women never smoked, but two thirds of them were passive cigarette smokers. They complained of cough and phlegm as respiratory symptoms. The prevalences of respiratory diseases were: 7.1% COPD, 12.5% chronic bronchitis, and 3.8% asthma.[21] In the present study we found that 44% of the women were also passive cigarette smokers.

Chen et al reported that large amounts of exposure to biomass smoke may pose a risk that is similar to that of tobacco smoke.[22] In various studies, biomass exposure was found to be associated with chronic bronchitis, but the effects on lung function were variable.[23,24] Ramirez et al showed that women with COPD due to biomass smoke had milder air-flow obstruction than patients with COPD associated with smoking.[25] Ekici et al compared the presence of chronic airway diseases in non-smoking women > 40 years old, with and without history of exposure to biomass cooking in Turkey. Biomass exposure was found to be a contributing factor in the development of chronic airway diseases in non-smoking women. They concluded that the presence of acute respiratory symptoms during cooking in women in rural areas should suggest to general practitioners the possibility of chronic airway diseases.[4]

Pérez-Padilla et al examined women living in rural areas where they used mainly wood (70%) in the stoves as fuel, and found that 73% of those who were exposed to biomass smoke had chronic bronchitis and obstructive airway diseases. There was a positive correlation between the duration of biomass exposure and the airway diseases.[26]

Kurmi et al found that exposure to wood smoke while performing domestic work presents a greater risk of development of COPD and chronic bronchitis than other fuels.[27] Ozbay et al concluded that biomass fuels had deleterious effects on lungs, leading to airway diseases in non-smoking women with COPD and biomass exposure.[28] Similarly, Master reported respiratory illness in 63% of the patients who were exposed to biomass smoke.[29]

Jindal et al showed increased bronchial hyper-responsiveness in asymptomatic women who were exposed to biomass and cigarette smoke, and this situation was correlated with biomass exposure duration.[30] Behera et al evaluated the relationship of biomass use and spirometric values in women who used biomass as fuel in their kitchens. In women who used animal dung, FVC values were below 75% of the predicted value (mean ± SE 73.42 ± 0.90%). FEV_1, FEV_1/FVC, and peak expiratory flow measurements were within the normal limits. There was a negative correlation between the exposure time of biomass and lung function test parameters.[31]

Several limitations of our study should be addressed. The main limitation was the lack of a control group including subjects without biomass exposure and cigarette

smoke. The study was carried out in a state hospital that admitted patients from various regions of the country, and we aimed to document the clinical and functional findings in women with biomass exposure. Another limitation was that 44% of the study population was composed of passive smokers. We performed a statistical analysis and showed that passive smoking was not a covariant factor. There were no statistically significant differences between the subjects who were exposed to biomass smoke only, and those who were exposed both to biomass and cigarette smoke.

There is increasing evidence that biomass smoke is a causative or contributory factor for developing COPD. This global problem is often neglected, though it affects a substantial proportion of the world's population. There are still missing data and little is known about the prevalence, morbidity, and mortality of COPD in developing countries.[32] Making the diagnosis of COPD relies on clinical judgment based on a combination of history, physical examination, and confirmation of the presence of air-flow obstruction using spirometry, as stated in COPD guidelines.[14] Substantial air-flow obstruction may be present before the individual is aware of it. In the present study we aimed to assess clinical and functional findings and exposure index and to evaluate their relationship in subjects who used biomass products as fuel. COPD cases could be hidden among these cases. When biomass exposure is determined in the history, and presence of air-flow obstruction confirmed spirometrically, the COPD cases in this group can be diagnosed and their treatment can be arranged.

Healthcare workers and professionals should take the responsibility to raise the awareness of hazards associated with biomass exposure primarily in people living in rural areas. We have to develop technologies for reducing biomass exposure, such as a separate kitchen with ovens for bread cooking, improve the poor design of stoves and ventilation, and switch to better, clean energy sources such as natural gas and solar energy. Interventional studies are required to provide detailed data about biomass exposure related disease outcomes, and their associations. Longitudinal studies should be planned, involving larger sample sizes and longer follow-up period.

Conclusions

Biomass fuels can affect lung function tests parameters in women who used biomass fuels for cooking and heating. The highest risk of having $FEV_1/FVC < 70\%$ was observed in the presence of animal dung use. Distribution of animal dung and wood use for cooking and heating was significantly higher in subjects at severe and very severe GOLD-FEV_1 stages. We conclude that we should assess the risks in areas where biomass exposure is intense and take protective health measures.

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