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Peak Expiratory Flow Rate and Respiratory Symptoms Following Chronic Domestic Wood Smoke Exposure in Women in Edo, Nigeria

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ABSTRACT

Peak expiratory flow rate (PEFR) of 350 rural women aged (20-70 years) in Edo State, Nigeria who actively used wood as a source of fuel for cooking was measured. The height, chest circumference, weight and blood pressure of the women were also measured. Respiratory symptoms of cough with sputum production, dyspnea, wheezing, chest tightness and chest pain were markedly elevated in the subjects compared to control. The mean PEFR value for the wood exposed women (289 ± 19.6 L/mm) was significantly lower than control (364 ± 17.2 L/mm), $P < 0.05$. The predicted PEFR values for both Africans and Caucasians were significantly higher than the measured values. The PEFR decreased with increase in years of exposure to wood smoke and the fall was neither accounted for by age nor height. The increase in respiratory symptoms and the low PEFR values observed for women exposed to wood smoke, the severity of which is related to exposure time indicate that prolonged exposure to wood smoke is capable of impairing lung functions.

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INTRODUCTION

Wood smoke is a complex mixture of substances produced during combustion of wood. The major emission from wood smoke are carbon monoxides and organic gases, particulate matter, oxides of nitrogen and sulphur. Toxic compounds as well as carcinogenic substances such as benzopyrenes, aldehydes, phenols and cresols are also produced. (Kleeman et al 1999). Irritants of the lungs like oxides of nitrogen and sulphur cause inflammation of the air passage inevitably leading to obstruction of the airways and other more severe effects (Dost et al 1991).

Exposure to wood smoke is as old as humanity itself. Biomass in the form of wood and agricultural waste is a significant source of energy worldwide, constituting more than 10% of total fuel usage. Of these, about 90% is used in its traditional forms as household heating and cooking fuel in developing countries particularly in rural areas which depend almost exclusively on wood as source of fuel. (UNDP, World Energy Assessment 2004).

It is now well established that wood smoke contains significant quantities of health damaging pollutants, including carcinogenic and other toxic organic compounds such as poly aromatic compounds, benzene, and aldehydes. Respirable particulate matter with diameters allowing it to penetrate into the deep lung: carbon monoxide (CO), nitrogen oxides and free radicals like semi-quinone type radicals among many other pollutants. These constituents change sometimes rapidly with time, temperature, sunlight, interaction with other pollutants, water vapour and surfaces (Tuthill R 1984, Traynor G et al 1987).

Wood smoke particles are generally smaller than 1µm and efficiently evade mucociliary defence system and are deposited in the peripheral airways where they may exert irritant and toxic effect (Kleeman et al 1999)

The association between domestic wood smoke exposure and lung function index and respiratory disease in African women has hardly been studied in the rural areas where wood is used as major source of domestic fuel and household

heaters.

Most literature have documented the effect of smoke exposure in forest fire fight and with demonstrable short term changes in their pulmonary function such as a gradual reductions in spirometric parameters, increased airway reactivity, and long term changes such as accelerated declines in spirometric parameters. (Rothman et al 1991, Liu et al 1992). Investigations also among charcoal production workers showed reduction in PEFR and increased respiratory symptoms (Tzanakis et al 2001). Much earlier, Alakija et al (1990) showed similar reduction in lung functions of cement workers, but very little have been documented regarding exposure to wood smoke and its effect on PEFR and respiratory disease in our environment.

In this study we investigated the effect of wood smoke on PEFR in rural women along with its respiratory symptoms. To the best of our knowledge, there has been no study in the literature investigating Cardio-respiratory effects of domestic wood smoke exposure in our environment hence the need for this study.

Respiratory symptoms, PEFR value and its relation to age, years of exposure, chest circumference, height, weight and blood pressure is highlighted.

MATERIALS AND METHODS

350 subjects who used wood actively as source of fuel for cooking at least 2-3 times a day and 5-7 days per week, for at least one year and with age range between 20 and 70 years were randomly selected from three different villages using the cluster sampling method. The study was carried out in the dry season. Informed consent of each subject was obtained after which a demographic questionnaire was administered to obtain information on age, weight, height, number of years of use of wood as source of fuel for cooking, number of times of such cooking per day, possible number of hours per day and place where the cooking normally takes place. 95 of the total study population used

kerosene stove as alternative source of fuel and 36% of them were in the 21-30 age group.

Any history of cough, sputum production, chest pain, breathlessness, other respiratory symptoms, drug usage and previous surgical operation were noted.

PEFR was measured with the standard Wright's peak flow meter with the subject relaxed in sitting position. Subjects were made to practice and perfect the required breathing maneuvers before recorded measurements of PEFR were taken. At least three measurements of PEFR were taken and the best selected. The height and chest circumference were measured using a meter rule. Weight was measured using a calibrated beam scale placed on a firm surface.

The blood pressure was measured using the auscultatory method with a standardized calibrated mercury column type sphygmomanometer and an appropriate size cuff (12x22cm) encircling at least 80% of the arm and in the seated position. Subjects who had elevated B.P were measured more than twice and the closest of such readings was recorded. This procedure was repeated two weeks later to confirm the initial measurements. A control group of 300 female subjects not exposed to wood smoke were selected from urban areas in Benin- City. The subjects were divided into groups based on age.

Results were analyzed using the student's t-test and chi square and presented as means and standard deviation and values of P<0.05 were considered statistically significant.

RESULTS

Mean PEFR \pm S.D of the entire subjects was 289 ± 19.6 L/min as against that of the control which was 364 ± 17.2 L/Min (P<0.05)

The PEFR of the exposed subjects decreased with increased length of exposure to wood smoke from 364.6 ± 19.6 L/Min in the 21-30 year age group with mean years of exposure of 5.5 ± 3.0 to 234.0 ± 27.7 L/Min in the 61-70 year age group which has mean years of exposure of 47.5 ± 9.3 . For the control, PEFR was 428.0 ± 20.5 L/Min in the 21-30 year age group and 340.0 ± 25.5 L/Min in the 61-70 year age group for the control (P<0.05). The PEFR of those in the 21-30 year age group who cooked with wood was lower than those of control in the same age group (p< 0.05), Similarly, the PEFR of those in the 61-70 year age group who cooked with wood was lower than those of control in the same age group (P<0.01).

Bivariant analysis of the Anthropometric characteristics and respiratory function index of the exposed subjects showed that PEFR decreased linearly (r= 0.6, P< 0.05) with decrease in chest circumference and height with PEFR values of 364.6 ± 21.2 L/Min in the 21-30 year age group with corresponding CC values of 73.6 ± 2.9 cm and height of 161.0 ± 5.7 cm . PEFR values of 234.0 ± 27.7 L/Min in the 61-70 age group corresponded with CC values of 68.2 ± 3.2 and height of 147.0 ± 5.8 cm.

TABLE 1:
General characteristics of the study population. (Mean \pm S.D)

AGE (YEARS)	LENGTH OF EXPOSURE (YEARS)	PEFR L/MIN	CC (Cm)	HT (cm)	B.P (mmHg)	WT (Kg)	KNOWLEDGE OF EFFECTS
46.7 \pm 13.8	24.8 \pm 17.8	289 \pm 19.6	70.1 \pm 3.5	159.3 \pm 20.7	<u>130.2\pm7.1</u> 74.1 \pm 12.7	59.2 \pm 14.9	YES 75 NO 100 DON'T KNOW 175

TABLE 2 :

Comparison of PEFR of subjects with control.

AGE GROUP	MEAN PEFR ± S.D (L/MIN)	
	SUBJECTS	CONTROLS
GENERAL	289 ± 19.6	364 ± 17.2
21 – 30	364.6 ± 21.2	428.0 ± 20.5
31 – 40	325.7 ± 23.3	380.4 ± 25.4
41 – 50	295.4 ± 30.0	338.3 ± 16.8
51 – 60	253.0 ± 16.8	320.6 ± 28.7
61 – 70	234.0 ± 27.7	280.9 ± 25.5
OVERALL MEAN	289 ± 19.6	364 ± 17.2

TABLE 3:

Anthropometric characteristics, PEFR and BP of Women exposed to wood smoke.

Age (Years)	No Of Subjects	Length Of Involvement (Years)	PEFR L/MIN	CC (Cm)	HT (Cm)	WT (Kg)	MEAN B.P ±S.D mmHg
21 – 30 (26±3.2)	65	5.5 ± 3.0	364.6 ± 21.2	73.6 ±2.9	161.0 ±5.7	57.5±12.5	112.9± 13.0 69.8 ± 9.6
31 – 40 (35.7±3.1)	75	12.2 ± 5.7	325.7 ± 23.3	72.0 ±3.7	160.8 ±3.8	68.2±16.1	118.7 ± 7.1 70.9 ± 8.6
41 – 50 (46.6±3.6)	65	17.9 ± 10.0	295.4 ± 30.0	70.8 ±5.0	157.3 ±8.3	65.6±18.8	133.2 ± 9.8 74.5 ± 10.6
51 – 60 (56.1±2.8)	65	35.6 ± 11.5	253.0 ± 16.6	70.0 ±2.6	155.8 ±7.2	55.6±9.7	133.7 ± 10.8 76.1 ± 13.4
61 – 70 (65.1±3.0)	80	47.5 ± 9.3	234.0 ± 27.7	68.2 ±3.2	147.0 ±5.8	51.8±10.1	166.4 ± 3.8 97.0 ± 3.1

TABLE 4:

Mean years of exposure and reactive symptoms

AGE GROUP	Mean Exposure ± S.D	SYMPTOMS / NO OF AFFECTED SUBJECT					
(/TOTAL NO OF SUBJECTS)	Years	Nasal Catarrh	Eye irritation/ discharge	Skin Irritation	Wheezin g	Chest tightness	Chest pain
21 - 30 (65)	5.46±3.0	25	20	12	6	4	5
31 - 40 (75)	12.2±5.7	43	40	20	7	8	15
41 - 50 (65)	17.9±10.0	46	50	30	15	15	30
51 - 60 (65)	35.6±11.5	15	10	30	15	5	10
61 – 70 (80)	47.5±93.3	40	25	30	15	5	15

TABLE 5:
Knowledge Of Harmful Effect of Wood Smoke/other Source of Fuel

AGE GROUP	YES	NO	DON'T KNOW	OTHER SOURCE (KEROSENE STOVE)
21 – 30	10	35	15	35
31 – 40	25	25	25	25
41 – 50	30	5	25	10
51 – 60	15	25	25	5
61 – 70	20	20	40	20

It was observed that the BP of the exposed subjects increased linearly with age, (r=0.5) from 112.9 ± 13.0 mmHg systolic BP and 69.8 ± 9.6mmHg diastolic BP in the 21-30 year age group to 134.6 ± 6.5 mmHg systolic BP and 74.9 ± 12.8 mmHg diastolic BP in the 61-70 year age group.

There were incidences of high blood pressure (HBP), i.e BP greater than 140 mmHg systolic BP and 90 mmHg diastolic BP. The number increased from 10 in the 41-50 year age group with mean systolic BP of 152.5 ± 4.5 and diastolic BP of 80.5± 6.3 to 32 in the 61-70 year age group with mean systolic BP of 166.4 ± 3.8 and mean diastolic BP of 97.0 ± 3.1.

It was observed that the prevalence and severity of pulmonary symptoms, eye, nasal and skin reactions increased from the 21-30 year age group to a peak in the 41-50 year age group. Cough, sputum production, nasal catarrh, eye irritation and discharge, wheezing, dyspnea were all reported.

It was observed that less than 50% in all the age group were aware of the several harmful effects of wood smoke. The level of awareness was more in the 31-40 and 41-50 year age group (i.e 33% and 46% respectively) though about 75% of the entire subjects were without formal education.

DISCUSSION

The largest domestic exposure to wood smoke occurs in the household through the use of wood and other forms of biomass as sources of cooking. Such use accounts for the majority of

human exposure to respirable particulates worldwide because of the continued high dependence on such household fuels especially in rural areas and also because their poor combustion efficiency create high emission factors.(Smith KR 1993, Smith et al 2004).

Most of the cooking in our study were normally done outdoors in kitchens that are usually enclosed and situated just at the back of the house. Apart from the poorly ventilated kitchens, the women were without any form of respiratory protective devices. Total meal cooking time per day in our study varied between 4&7 hours, and our subjects were almost continuously exposed throughout this period.

This study show that chronic wood smoke exposure is associated with reduction in PEFR and increased incidences of self reported respiratory symptoms, including cough, sputum production, wheezing, dyspnea and chest pain.

PEFR of the exposed subjects decreased with increased exposure time to wood smoke and this is consistent with the findings of Ellegard (1994) and Tzanakis et al (2001) who reported decrease in PEFR among charcoal workers, and Alakija et al (1990) who reported similar decreases among workers who inhaled cement dust particles.

Women who cook with wood like charcoal workers are exposed to several vegetative resinous combustion products, including carbon monoxides, aldehydes, acids, respirable particulates and semi volatile and volatile organic agents (Pierson et al 1989, Ellegard A 1994). Moreover exposure patterns and work practices have remarkable similarities in both.

Our findings are in accordance with the

PEFR decline seen in the studies of Ellegard 1994 and Tzanakis et al 2001 on exposure of charcoal workers. However, the magnitude of the decline in PEFR of the population in our study is generally greater than in the studies of charcoal workers and this could be explained by the observation that the women in our study were more continuously exposed to wood smoke in the long term than charcoal workers and the women did not use any respiratory protective equipment at any time during cooking.

An increase in the incidence of high blood pressure from 10 women in the 41-50 age group to 32 women in the 61-70 was observed raising the question of possible relationship between developing high blood pressure and chronic wood smoke exposure. However that, BP increases with age is also well documented (Oviasu et al 1980, Iyawe et al 2000). Thus the increase in BP in this study may be age-related with smoke probably an additional factor.

An increase in reports of respiratory symptoms accompanying the decrease seen in lung function (PEFR) was observed in this study. Similar studies on wood smoke exposure in women (Pierson et al 1989, Dennis et al 1996) and in charcoal workers (Ellegard A 1994, Tzanakis et al 2001), also showed increased prevalence in one or more respiratory symptoms especially cough, sputum production, and nasal catarrh. Also non-respiratory symptoms like eye irritation and discharge, and skin irritation were widely observed in this study population and prevalence of such conditions were found to increase with increased exposure to wood smoke. Exposure to and inhalation of CO in combination with combusted particulates produce cough, eye irritation, discharge and nausea. A study by Rao et al (1990) suggested that wood smoke could cause metabolite-induced opacification of the eye lenses and could therefore lead to cataract formation and eventually blindness.

The mechanism underlying the decreased lung function index (PEFR) and increased respiratory symptoms following exposure to wood smoke are uncertain. It may be related to the chemicals emitted in the smoke, namely, the variety of respiratory irritants and noxious

agents, such as Carbon monoxide, aldehyde, acids, SO₂, NO₂, respirable particulate and semi volatile and volatile organic agents. (Dost 1991). Extended cooking demands leading to longer time of exposure and increased breathing rate enhance the toxic effect of the noxious agents with consequent bronchial reactivity. High CO and COHb levels of between 5-9% have been detected in wood smoke (Ellegard 1994).

It was also reported (Dost et al 1991) that aldehydes and acids reduce the ciliary activity of the respiratory tract, interfering with the ability of the airway epithelium to clear mucus and remove particles and micro-organisms. This further explains the increased cough and sputum expectoration seen in these women. Moreover several air pollutant components of wood smoke, such as SO₂, NO₂ and particulates have been reported to adversely affect lung function and increase respiratory symptoms even in low concentrations (Gong 1992). Also, long term increase of airway responsiveness has been reported by Ellegard (1996) amongst women who cook with wood as source of fuel.

Consequently, it is plausible to suggest reactive airways dysfunction syndrome (RADS) in some of our study population with large PEFR decrease. Unfortunately, Metacholine challenge was not applied in this study in order to assess airway hyper-responsiveness. Hence, it is uncertain if these women had RADS.

In conclusion, both worsening of lung function as shown by decrease in PEFR and increased respiratory symptoms found in this study indicate the deleterious effects associated with domestic wood smoke exposure through the use of wood as cooking fuel. Therefore cleaner sources of fuel for domestic cooking and the need for properly ventilated kitchens should be emphasized. The increase in BP found in this study may be related to age and the stress of the cooking rather than the smoke.

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