Lung function impairment among charcoal workers in an informal occupational setting in Southern Nigeria

I P Obiebi, R U Ibekwe, and G U Eze

Abstract

The production of charcoal is characterised by marked exposure to wood smoke which contains an array of harmful substances capable of causing irreparable damage to the respiratory system. This study was conducted to highlight the effect of inhaling wood smoke on the respiratory function of charcoal workers. This cross-sectional comparative study carried out in Sapele, Nigeria involved 296 participants: 148 wood charcoal workers and 1480 age, sex and height-matched controls. Lung function indices were measured and compared between groups. Analysis was done using SPSS version 22. Differences in lung function between charcoal workers and controls were compared using Student's paired t test for differences in means, McNemar's test and odds ratios. Multivariate analysis controlled for the effect of smoking, biomass use, height and agme. For the charcoal workers, mean forced expiratory volume in 1 second (FEV_1) was 1.99± 0.83 L which was 75% of predicted; mean forced vital capacity (FVC) was 2.39±0.93 L, about 76% of predicted; while mean FEV_1/FVC was 83.26±12, about 99% of predicted. The mean values of FEV_1 and FVC were significantly lower among charcoal workers. FEV_1/FVC ratio was elevated in the charcoal workers compared with the controls. The prevalence of lung function impairment was higher in charcoal workers than in their controls; restrictive impairment was more prevalent in charcoal workers and the prevalence rate was almost twice that of controls (odds ratio (OR), 1.94). It is concluded that deficits in pulmonary function indices were more prevalent in charcoal workers compared with controls, and restrictive lung impairment was the predominant type. Although individualised exposure measurements were not performed, adoption of new work processes and health education would be beneficial to these workers.

Introduction

The global need for alternative sources of domestic fuel has given rise to an increased demand for charcoal, particularly in developing countries. Consequently there has been a rise in the utilisation of charcoal especially in the last decade.[1–3] This trend is likely to continue, particularly as the world anticipates a depletion in the supply of its major energy sources (namely oil, natural gas, and coal[4]), with an upsurge in the cost of petroleum products driven by peculiarities in Nigeria's oil sector and compounded by population increase.[5] A study conducted in Ibadan, South-West Nigeria reported increased charcoal consumption due to higher costs of kerosene – a common domestic fuel.[6]

Charcoal production involves combustion/burning of wood in kilns. This process routinely takes several days to about a fortnight especially for the traditional methods, and this stage is characterised by the release of wood smoke. Thereafter the kilns are unloaded by workers with shovels or pitchforks. While unloading, workers are exposed to more wood smoke and charcoal dust.[7,8] Toxic substances emitted from burning wood include benzene, polycyclic aromatic hydrocarbons (PAHs), methane, and formaldehyde, together with carbon monoxide and oxides of sulphur and nitrogen. The emissions are particularly severe because the burning process is incomplete and occurs in local kilns with the absence of air (or with insufficient oxygen)[9] to prevent full combustion of the wood and retain the charcoal as the end-product.

Studies have shown that repeated exposure to wood smoke is linked with various forms of pulmonary function deficit in adults and children; and also respiratory diseases such as asthma, chronic obstructive airway disease, and lung cancer.[10–12] Some authors have associated charcoal production with the development of chronic obstructive pulmonary disease (COPD) predominantly[13] and, according to World Health Organization, COPD is the fourth leading cause of death globally, surpassing the mortality rates of HIV/AIDS, malaria, and tuberculosis in sub-Saharan Africa.[14] However, other authors have associated charcoal predominantly with restrictive pulmonary disease.[15,16]

Although there is documented evidence on the effect of wood smoke, assessing the health risks for workers in the charcoal industry in Nigeria has been hampered by paucity of information on the individuals exposed and the degree of exposure; in addition, there is a lack emphasis on improving conditions. Thus, there is a need to determine the effect of wood smoke on the health of charcoal workers in Nigeria; assessing their pulmonary functions would serve a good proxy for identifying its effect on their respiratory system in particular. This study therefore assessed the pulmonary function indices of wood charcoal workers in Sapele, Delta State, Nigeria in a bid to substantiate the need to explore ways to mitigate the hazards of exposure to wood smoke among workers.

Methods

This study was carried out in Sapele, Delta State, Nigeria using a cross-sectional comparative design. Sapele has been known for timber production and sawmilling since the twentieth century.

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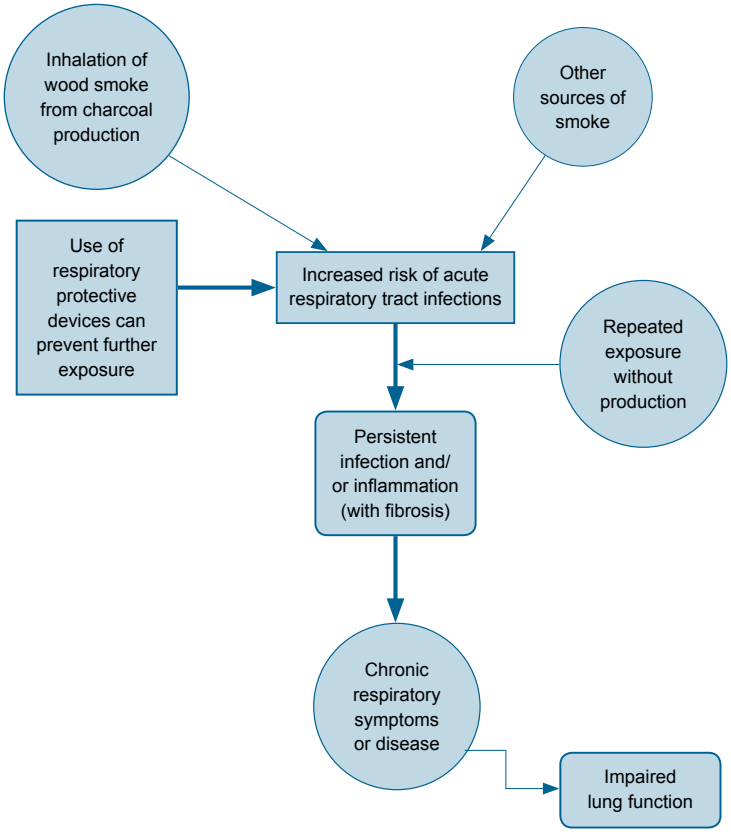

Figure 1 Conceptual framework of lung function deficit due to charcoal production

		Charcoal workers (n=148)	Controls (n=148)	p[2]
Age (years)		39.14±15.22	38.27±14.78	0.614
Height (cm)[1]		1.63±0.09	1.65±0.08	0.070
Weight (kg)[1]		67.01±12.98	79.65±14.64	<0.001
Body mass index[1]		25.23±4.71	29.68±6.53	<0.001
Sex	Male Female	55 (37.2%) 93 (62.8%)	55 (37.2%) 93 (62.8%)	1.000
Smoking status[2]	Smokers Non-smokers	14 (9.5%) 134 (90.5%)	4 (2.7%) 144 (97.3%)	<0.001
Biomass fuel exposure	Yes No	104 (70.3%) 44 (29.7%)	3 (2.0%) 145 (98.0%)	<0.001
Duration of work[3]		3 (1–28 years)	-----	

[1]Data expressed as mean±standard deviation; [2]Two tailed p-values based on paired t-test for continuous data, McNemar's test for proportions; [3]Data expressed as median due to skewed data

Table 1 Characteristics of the study population

Charcoal making is dependent on the availability of timber. Ethical approval was obtained from the Health Research and Ethics Committee at Delta State University Teaching Hospital as part of a larger research project on the respiratory health profile of wood charcoal workers. Written informed consent was obtained from study participants who voluntarily took part in the study.

A total of 296 participants took part in this study. Half of them (148) were the total population of charcoal workers at all 12 production sites in Sapele; excluding those who did not meet the criteria. Controls were drawn from one of the major markets in Sapele which was picked because it was sufficiently far away from the charcoal production site. The controls were 148 traders from the shops/sales points in the market, selected using a simple random sampling technique with a table of random numbers. Traders for whom matches were not found, or who did not consent, were skipped and replaced with traders at further sale points. The study included charcoal production workers who had been consistently involved in charcoal production for at least one year and traders in Sapele market who had not been involved in any occupation with exposure to wood smoke and willingly gave their consent. Charcoal workers who had a long-term history of respiratory symptoms such as productive cough, wheezing and dyspnoea prior to getting involved in charcoal production, as well as traders who lived around charcoal production sites were excluded. The matching criteria were: height ±5cm; age ±2 years; same sex.

Four research assistants (medical doctors in the Department of Community Medicine, Delta State University Teaching Hospital), were recruited and trained for the purpose of this study. A five-day training session covered spirometry training, questionnaire validation, participant information document and consent form review, demonstrations, and role plays. The research assistants were also educated on participant privacy and confidentiality. Training for spirometry was done with the assistance of a spirometry technician, and in accordance with American Thoracic Society and European Respiratory Society Joint Task Force Guidelines on Spirometry.[17]

A portable micro-GP spirometer (Micro Medical, Ltd, Kent, UK) with a flow range of 0.2–15.0 L/s, volume of 0.1–9.99 L, and an accuracy of ±3.5% was used in accordance to the American Thoracic Society and European Respiratory Society Joint Task Force Guidelines on Spirometry.[17] Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and peak expiratory flow rate based on sex-, age- and height-predicted values were calculated. All spirometric indices

Pulmonary indices	Charcoal workers (n=148)	Controls (n=148)	Mean difference	95% CI*	
				Lower limit	Upper limit
FEV_1 (L)	75.18	80.60	-5.42	-10.42	-0.42
FVC (L)	76.32	89.58	-10.26	-18.76	-7.75
FEV_1/FVC (%)	98.96	90.30	8.66	5.39	12.00
PEFR (L/min)	58.40	51.75	6.65	2.17	11.41
*Confidence interval of difference of means.					

Table 2 Lung function indices: percentage of predicted value among participants

Lung function indices	Charcoal workers (n=55)	Controls (n=55)	Mean difference	95% CI*	
				Lower limit	Upper limit
FEV_1 (L)	2.73±0.51	2.79±0.74	-0.06	-0.300	0.180
FVC (L)	3.15±0.79	3.57±0.50	-0.42	-0.670	-0.170
FEV_1 /FVC	86.05±9.91	77.53±8.56	8.42	5.020	12.020
PEFR (L/min)	311.74±96.88	06.5±93.05	5.24	-30.663	41.143
*Confidence interval of difference of means.					

Table 3 Lung capacities of male study participants

Lung function indices	Charcoal workers (n=93)	Controls (n=93)	Mean difference	95% CI*	
				Lower limit	Upper limit
FEV_1 (L)	1.56±0.54	1.93±0.67	0.37	-0.543	-0.193
FVC (L)	1.95±0.70	2.57 ±1.07	0.62	-0.883	-0.350
FEV_1 /FVC	81.59±12.77	76.68±11.00	4.91	1.281	8.181
PEFR (L/min)	192.40±20.63	198.63±85.62	-6.23	-24.247	11.789
*Confidence interval of difference of means.					

Table 4 Lung capacities of female study participants

were adjusted by 10% according to European Respiratory Society Standardised Lung Function Testing, as expected for populations of African origin.[18] The best of three readings was taken for each parameter being assessed. All spirometric readings were taken with the participants seated in a relaxed and upright position facing the spirometer and in loose-fitting clothing. Subjects who had smoked within an hour, or eaten within two hours of the measurement were asked to wait for the appropriate interval before testing. The ventilatory function assessment objective and technique were explained to each participant before testing commenced; each subject was instructed to inspire deeply and blow continuously into the apparatus via a disposable mouthpiece without interruption and as intensely and rapidly as possible; sustaining the blowing for at least six seconds or until the machine indicated a complete blow. Trial efforts were encouraged in a bid to perfect techniques and obtain readings truly reflective of participants' lung function. To ensure compliance, each participant was closely supervised and guided during testing. The heights of the study participants were measured using a mobile stadiometre (Seca 213, USA) with a measuring range of 50–205 cm (1 mm intervals), and weights measured with a bathroom weighing scale (Harrison Emperors, China) with a maximum capacity of 120 kg (100 g divisions). All readings were recorded in appropriate data collection instruments. Spirometric and anthropometric measurements were taken under a shade (some distance away from the kilns) where workers sit and rest at intervals during their workday.

All data were sorted and collated in a spreadsheet from the Statistical Package for Social Sciences (SPSS) version 22 (IBM Corp., Armonk NY, USA) for analysis. Categorical variables were presented in percentages, while continuous variables in means (±standard deviations). Paired t-tests were applied to assess the difference between means. McNemar's test and odds ratio for matched pairs tested the difference in proportions. Multivariate analysis and logistic regression were used to control for potential confounders and other variables that differed between the target population and controls. The level of statistical significance was set at $p<0.05$ for McNemar's and paired t tests.

Results

Charcoal workers and controls did not differ significantly in age (Table 1). The mean height of the charcoal workers was not dif-

Variables	Charcoal workers (n=148)	Controls (n=148)	Controls (n=148)	Effect size*		
				Unadjusted	Adjusted†	95% CI for the adjusted differences
FEV_1 (L)‡	1.99±0.83	2.25±0.74	2.25±0.74	-0.26	-0.26	-0.07 to -0.46
FVC (L)‡	2.39± 0.93	2.94±1.02	2.94±1.02	-0.55	-0.58	-0.31 to -0.85
FEV_1/FVC (%)	83.26±12.00	76.53±10.72	76.53±10.72	6.73	7.22	3.57–10.88
PEF(L/s)‡	236.80± 99.60	238.70±102.50	238.70±102.50	-0.19	-13.55	-14.99 to 42.09
Restrictive patterns	53 (35.8%)	31 (20.9%)	31 (20.9%)	8.33	1.94	1.14–3.30
Obstructive patterns	19 (12.8%)	11 (7.4%)	11 (7.4%)	1.80	1.89	0.65–5.49

*Effect size expressed as simple difference in means for continuous variable and for categorical data, odds ratios for matched pairs.
†Adjusted for age, height, smoking status, biomass fuel exposure using logistic regression for categorical data and multivariate analysis for numerical variable.
‡Data expressed as mean±standard deviation.

Table 5 Lung volume patterns of participants: charcoal workers vs controls

ferent to that of the controls (p=0.070). The proportion of males and females were the same among charcoal workers as among the controls (p=1.00). Females were the higher proportion in both groups. Majority, 278 (93.9%) of all study participants were non-smokers. There were more smokers (14 (9.5%)) among charcoal workers compared with controls (4 (2.7%)) and the difference was statistically significant (p= <0.001). The majority of charcoal workers (104 (70.3%)) used biomass as their domestic fuel compared with controls where there was minimal use (3 (2%)).

Table 2 shows lung function indices. The percentage of predicted values of FVC and FEV_1 were significantly higher among controls than for charcoal workers, however the reverse was true for FEV_1/FVC ratio and peak expiratory flow rate (PEFR). Among male study participants (Table 3), the mean FVC was higher among controls and the difference was significant. Conversely, FEV_1/FVC ratio was significantly higher among charcoal workers. Among female study participants (Table 4), controls had significantly higher values of FEV_1 and FVC than charcoal workers; and FEV_1/FVC was significantly higher among charcoal workers. The mean values of FEV_1 and FVC were significantly higher among controls (Table 5); while FEV_1/FVC was higher among charcoal workers. The mean differences for all indices except PEFR were significant after adjusting for potential confounders. A higher proportion of charcoal workers than controls had restrictive and obstructive lung function impairment; however, only the difference in the prevalence of restrictive impairment was significant after controlling for confounders (OR=1.94).

Discussion

This study compared pulmonary function indices between charcoal workers and matched controls (traders who did not differ significantly in height, age, or sex proportions). The study revealed pulmonary function deficits among the selected charcoal workers as depicted by lower mean FEV_1 and FVC, both below 80% of predicted values. This observation is in agreement with evidence from studies that have shown an association between lowered pulmonary function indices and continuous exposure to wood smoke.[13,19,20] The mean FEV_1 of the charcoal workers recorded in this study is slightly higher than the mean FEV_1 of 1.77±0.49 L recorded among individuals exposed to wood smoke in a previous study conducted in Ekiti State, Nigeria; but lower than the mean FEV1 of 2.35±0.73 L and 2.62±0.6 L reported among charcoal workers in similar studies conducted in Oyo State and Kebbi State respectively.[21,22] The very low FEV_1 recorded in the Ekiti State study among charcoal workers compared with the present study was probably because the study included only women, whereas the higher mean FEV_1 recorded among charcoal workers in the studies conducted in Oyo and Kebbi States may not be unconnected with the male predominance among study participants. The mean FVC recorded among charcoal workers in this study, 2.39±0.93 L, although only about 76% of the normal predicted for age, sex, race, and height, was higher than the 1.96±0.52 L recorded in a previous study conducted in south-western Nigeria,[23] but relatively lower than the mean FVC of 2.81±0.7 L and 3.78±0.7 L recorded in previous studies conducted in Kebbi[21] and Brazil respectively.[24] The marked decline in both FEV_1 and FVC observed among the charcoal workers in this study compared with their predicted values is corroborated by findings from a previous study in Pakistan which reported that charcoal kiln workers exposed to particulate matter from wood smoke had considerably poorer FEV_1 and FVC than expected for their age, sex, race, and height.[25]

The mean FEV_1/FVC ratio recorded among the charcoal workers in this study (83.26±12%) was within normal range and was comparable with the mean FEV_1/FVC ratio of 82.82±9.4% reported from a similar study in Brazil.[24] However, it was rela-

tively lower than the mean FEV_1/FVC ratios of 90±11.5% and 93±9.6% reported from Ekiti and Kebbi respectively.[21,23] The proportionate reduction in both FEV_1 and FVC (both lower than 80% of the predicted value) gives a possible explanation for the normal range of FEV_1/FVC ratios recorded among charcoal workers in this study. It is quite likely that the workers at Ekiti and Kebbi had had longer exposure to wood smoke, unlike the index study where median duration of exposure was three years, and as such they were suffering more restriction which resulted in higher FEV^1/FVC ratios.

The PEFR recorded in this study was 237.00±100.00 L/min. This value was comparatively lower than the values of mean PEFR of 253.72, 286, and 289 L/min recorded in previous studies among subjects exposed to wood smoke in Edo, Ekiti, Ogun and Oyo states.[22,23,26] A similar study conducted in Punjab, India reported a deficit in PEFR among the exposed compared with their controls.[27] The lower PEFR in this study could however be accounted for by the difference in sex distribution of the charcoal workers, as more females participated in this study. Males tend to have better lung function indices than females because of variation in height and physical activity.

Among the controls, both FEV^1 and FVC were above 80% of their predicted values compared with charcoal workers, where they were both below 80%. Charcoal workers in this study had lung function indices that were significantly lower than those of their controls. All pulmonary function indices except for FEV^1/FVC ratio were higher among controls than among charcoal workers. Similar findings were made from previous studies conducted among workers exposed to wood smoke in Oyo and Ogun states, Nigeria and in South Korea where higher deficits in FEV^1 and FVC were reported among those exposed to wood smoke compared with controls who were not exposed.[22,28]

Male charcoal workers showed no significant difference in FEV^1 compared with their controls but the difference in their FVC was significant. This may be because in the absence of infective processes, reduced FVC is the first reflection of the effect of chronic insult on the lungs while FEV1diminishes rapidly after recent or short-range exposure, and as a follow up to diminishing total lung volume when it has begun to affect the parenchyma of the total lung architecture.[29] Females on the other hand, showed a significant difference in FEV^1 alongside FVC. This significant reduction in FEV^1 may be because the females in this study were more closely involved in charcoal production and as such had both acute and chronic processes taking place in their lungs at the same time; the lungs of the female charcoal workers had suffered more impact from wood smoke than their male counterparts who were largely assistants at the local charcoal industries in Sapele. The scenario was different in studies from Kebbi and Oyo where more males were involved in charcoal production than females.[21,22]

It is no surprise that, after controlling for biomass and/or tobacco use, pulmonary function deficits among charcoal workers still remained higher than in controls. This was probably because among charcoal workers, the duration and consistency of exposure to wood smoke surpassed exposure to biomass and cigarette smoke and therefore rendered the effect of those exposures insignificant.

The prevalence of smoking among the charcoal workers (9.5%) was lower than reported in similar studies in north-western Nigeria, Brazil and India where the prevalence of smoking was 45.8%, 31.3%, and 84% respectively.[21,24,30] The higher prevalence of smoking in these earlier studies may not be unrelated to their higher male proportions. Biomass users in this study may have cooked mostly with charcoal and firewood or sawdust due to proximity and availability, as many of the charcoaling sites were close to sawmills and they had access to wood, sawdust and charcoal with which they prepared their meals. The domestic use of biomass further exposed the charcoal workers to wood smoke.

Restrictive lung function impairment was the more prevalent type of lung function impairment among study participants; over a third (35.8%) of charcoal workers showed that pattern. Charcoal workers were nearly twice as likely as controls to have this type of impairment. Obstructive lung impairment was also greater among charcoal workers compared with controls but this difference was not statistically significant. The prevalence of restrictive lung function patterns observed in this study is consistent with results from a study conducted in Malawi.[31] However, the prevalence of obstructive lung function impairment among charcoal workers in this study is far higher than the prevalence of 2.9% and 3.6% reported among individuals exposed to wood smoke from previous studies in Mexico and Nepal respectively.[32,33] Amidst the greater prevalence of lung function impairment among charcoal workers, the fact that a sizeable proportion of participants in the control group also had impairments shows there is a risk of lung function impairment attributable to residing in that host community. The locale is known for its numerous saw mills, wood works, biomass use and even worse, gas flaring activities from oil and gas companies sited there. Since charcoal workers are exposed to vast quantities of particulate matter from wood smoke and the environment, the high prevalence of lung function abnormalities recorded substantiates the inverse relationship between lung function and the concentration of particulate matter identified in a study in Ibadan, Nigeria.[34]

Future studies may need to measure differential exposures to particulate matter among charcoal workers and correlations made with the extent of pulmonary compromise in these workers. The diffusing capacity of their lungs for carbon monoxide (DLCO) may also need to be measured in order to estimate gas exchange in the lungs as subjects with restriction of lung function usually have marked clinical desaturation after exercise.

Conclusion

Charcoal workers had a higher prevalence of lung function impairment than controls. Restrictive lung function impairment was more prevalent among charcoal workers and more common than obstructive impairment. Although no individual exposure measurements were performed, this industry would benefit from changes to work processes to reduce workers' exposure to smoke. Health education on the specific hazard control measures that should be adopted would help mitigate the harmful effects of wood smoke on these workers.

Author Declaration

Competing interests: none.
Any ethical issues involving humans or animals: none.
Was informed consent required: yes - documentation on file.

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