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Research Article

Occupational Exposure to Wood Dust and Respiratory Health Status of Sawmill Workers in South-South Nigeria

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Abstract

Ill-health from wood dust inhalation results in decreased work output and increased morbidity. Despite the potentially hazardous nature of the work, there has been little attention given to the state of health and safety of the workers in this industry in Nigeria. The study sought to investigate the prevalence of respiratory symptoms and lung function abnormalities from occupational exposure to wood dust among sawmill workers, and assess wood dust concentration in sawmills in Egor Local Government Area of Edo State. A cross-sectional analytical survey involving 227 workers from 17 sawmills recruited through a one stage cluster sampling technique and matched for age and height with 227 workers in water bottling companies in the same locality was carried out. Structured questionnaires and spirometry were used for data collection. Dust monitoring in the both study and comparison sites was carried out with the aid of a gravimetric dust sampler. Data analysis was done using SPSS version 15 and PEPI version 10. Ethical clearance was obtained from the University of Benin Teaching Hospital. Prevalence of respiratory symptoms in the study group was: cough 46.7%, phlegm expectoration 50.2%, wheeze 5.3%, chest tightness 10.1%, chest pain 5.7% and breathlessness 7.5%. Respiratory symptoms were of significantly higher prevalence among the study than the comparison group. Mean value for total and inhalable dust was significantly higher (p = 0.00 and p =0.01 respectively) higher in the study than in the comparison sites. There was no significant difference (p = 0.16) between both sites for mean values of respirable dust.

Sawmill workers had a high prevalence of respiratory symptoms particularly cough and phlegm production, and a higher exposure to total suspended and inhalable dust compared to suitably matched respondents. The results have strong implications for improved dust control in the wood industry.

Keywords: Air sampler; Respiratory symptoms; Spirometry; Wood dust

Introduction

Wood dust is produced when machines or tools are used to process wood and is basically a by-product of the process, not produced for any specific purpose [1,2]. Airborne, wood dust is the most prevalent occupational exposure hazard in the wood industry [3,4]. Wood dust inhalation has been associated with upper and lower respiratory symptoms in humans including cough, wheezing, sputum production and shortness of breath [5,6]. Syndromes that may arise include mucus membrane irritation syndrome, extrinsic allergic alveolitis, organic dust toxic syndrome, occupational asthma, non-asthmatic chronic airflow obstruction, simple chronic bronchitis (mucus hypersecretion), cryptogenic fibrosing alveolitis, adenocarcinoma of the nasal and paranasal sinuses, cancer of the larynx and pharynx [7,8]. Ill-health from wood dust inhalation results in the inability of the worker to meet the demands of his job, increased incidences of sickness absenteeism and eventually early retirement [9]. Despite the potentially hazardous nature of the work, there has been little attention given to their state of health and safety in Nigeria by government health departments. In the academia, few studies have focused on their morbidity pattern with limited evidence of published data on dust exposure monitoring in the face of an ever increasing number of sawmills operating within the country in less than optimal conditions. The present study was designed to investigate the prevalence of respiratory symptoms and lung function among sawmill workers in Edo state, and measure particulate dust concentration in sawmills as an index of exposure. It is envisaged that the results of this study will add to the body of knowledge about wood dust exposure in sawmills in Nigeria, and provide data useful both for advocacy to government and for the planning and design of interventions targeted towards dust control in the wood industry.

Materials and Methods

Study location

The study was carried out in Egor local government area of the ancient town of Benin City, the capital of Edo state in the South – south region of Nigeria. The city is noted for her age long tradition of woodcraft and furniture making, with the sale of timber contributing significantly to the economy of the state. A typical sawmill is a large shed with a roof made of old corrugated zinc supported by wooden poles. The floor is earth, and covered with several layers of sawdust. The open shed houses one or more giant electrically driven band saw and circular saw mounted on a fabricated metal table. Sawdust piles surround the machines and may also be kept in a waste dump on the premises, awaiting disposal, usually by burning. There are about 10-20 workers in each mill, depending on the number of sawing machines, and the volume of work at hand. The main activities in sawmill are debarking and cutting of timber logs into planks. Both processes generate wood dust, some of which is visible to the naked eye.

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Study population and design

The study which was carried out between August and December 2011 utilised a cross sectional analytical study design. The study group comprised sawmill workers within the local government area who had been in continuous employment in the industry for at least one year preceding the study. The comparison group comprised junior staff of various water packaging and bottling companies located in the same local government area. They belonged to similar socio-economic class as the study group and included those who had never worked in sawmill or other wood –related industry. They were primarily involved in the distilling, packaging, labelling and distribution of sachet and bottle water. Sample size was calculated using the formula for comparative studies with p_1 and p_2 taken as 4% and 0% respectively, being the proportion of ventilatory dysfunction among sawmill workers in Benin city and matched controls, in a study to assess the effect of wood dust on the respiratory system, a minimum sample size of 227 in each group was taken. Ethical approval for the study was obtained from the ethical committee of the University of Benin Teaching Hospital, Benin. Written informed consent was obtained from each participant.

Sampling method

A one stage cluster sampling technique was used to select participants in the study group. A list of registered sawmills was obtained from the Forestry department of the State Ministry of Agriculture. A preliminary survey gave the average number of workers in sawmill as 15. The minimum number of sawmills required to yield the sample size was calculated as 14 (calculated by dividing the sample size by the average number of workers in each mill). A table of random numbers was used to select 17 out of 32 registered sawmills. In all selected sawmills, eligible respondents were invited to participate in the study. Workers in Water bottling factories within the LGA were matched for age (within a 10-year range), and height (within 10-cm range) with sawmill workers on a group basis using frequency-matching technique [10] similar to that used in an earlier study in the country [11], to ensure that they were compatible and thus avoid the confounding effect of height and age. All sawmill workers were male, so matching for sex was not done.

Data collection techniques

Data was collected by trained research assistants, Community health extension workers in the local government health department. An interviewer-administered structured medical and occupational questionnaire adapted from the British Medical Research Council (MRC) questionnaire on respiratory symptoms [12], which has been validated and used for studies in the country [13,14] was applied to assess the prevalence of symptoms among respondents. The questionnaire was pre-tested in sawmill in another local government area within the state. Cough and sputum were said to be present when the subject had the symptoms either during the day or at night for 5 or more days each week; breathlessness was defined as getting short of breath when walking hurriedly with other people of same age on level ground or when climbing up a low hill; chest tightness was defined as feeling tight in the chest ,without a cold, on the first days back at work on more than 50% of occasions; wheeze was defined as whistling breathing; Chest pain was assessed as a positive response to the questions "Do you experience any pain or discomfort in your chest when hurrying on level ground or climbing up a hill?" Cough with phlegm was implied with a positive answer to the question "Have you had a period of increased cough with phlegm in the last 3 months? To improve recall, questions on presence of symptoms were limited to occurrence within 3 months prior to the conduct of the study. To control for smoking as a confounder, respondents were further classified based on smoking history. A non-smoker was one who had never smoked or who never smoked as much as one cigarette a day for as long as 1 year; an ex-smoker was one who smoked regularly as above, but has since stopped for at least 1 month preceding the survey. A current smoker was one still smoking as defined even as of the time of the survey.

The occupational section of the questionnaire sought information on current job description, duration and a history of previous employment. Physical examination of all participants involving measurement of height and weight was undertaken. Standing height was measured using a stadiometer with measuring range up to 78 inches (207 cm) and graduations in 1/8 inch (1 mm) and standard procedure [15]. Weight was determined using a digital scale with maximum capacity of 150 kg in divisions of 100 grams. The respondent stood in the centre of the scale, with hands by his side, with light clothing and without shoes. Peak expiratory flow rate was determined on the study and comparison groups in accordance with American Thoracic Society (ATS) guidelines [16] using an electronic spirometer (Micro-GP by Micromedical Ltd UK). Spirometric testing was carried out from Tuesday to Friday and between the hours of 12.00 and 17.00, during which time it was expected that sawmill participants had reasonably been exposed to wood dust.

Area dust sampling was with the aid of a portable SKC Air check XR5000 high volume gravimetric sampler model 210-5000, serial No. 20537 with technical assistance provided by the Department of Physics, University of Benin, Nigeria. The sampling unit consisted of a gas pump (which creates a flow of air that allows the contaminants in the air to be captured), an in built flow rate meter (having a rating of 1000 ml/min -5000 ml/min of air) and an I.O.M (Institute of Occupational medicine) Multi dust sampler Batch no 221442/1 connected to the sampling pump by a Teflon tube. Sampling was done twice in all selected locations; the first time to determine total suspended particulates, and the second for inhalable and respirable dust (particle selective sampling). Samples of total suspended particles were collected on a pre-weighed 2.5cm Whatman glass fibre filter with pore size of 1.0 micron by pumping 2000 ml/min (2 L/min) volume of air through it for eight hours, between 8.00 and 16.00 hours without interruption. After sampling, the filter was transported to the laboratory in a filter case. Dust concentration in mg/m^3 was calculated from the changes in weight of the filter (before and after sampling) divided by the volume of air sampled [17-20]. For particle selective sampling, a Multi dust foam disc batch #225772 was used in the I.O.M sampler cassette. In all 10 samples were collected: one sample each from 5 sawmills and 5 from 5 purposively selected locations within the factory premises. The 5 sites in the latter were presumed to be areas with high human and/or dust generating activity and included: the reception, factory floor, loading area, storage unit and office. In the sampled sawmills, the dust sampler was mounted on a supporting pole at a height of 1.5meteres, and at a distance of 3 feet away from the band saw in use.

Data analysis

Data was analysed using Statistical packages for social sciences (SPSS) version 15.0 and "Computer Programs for Epidemiologists" (PEPI), version 10.0 [21]. Discrete data were presented as diagrams and proportions (percentages) while continuous variables that were normal in distribution (such as age and height) were expressed as means $\pm$ standard deviation. Statistical comparisons of the arithmetic means of the study and comparison groups were carried out using the unpaired student's t-test (two –tailed). Statistical analysis of difference between proportions was done by the use of the χ^2-test. Where the expected frequency in more than 20% of cells was less than 5, or any cell had an expected cell count less than 1, Fishers' exact test was used to test for association between the variables.

Results

Socio-demographic characteristics

From Table 1, in all, 227 out of a total of 246 eligible all male workers in 17 sawmills agreed to participate in the study, giving a response rate of 92.3%. A total of 227 respondents in the comparison group participated as well. Subjects in both groups were generally comparable in terms of age, height, the Body Mass Index (BMI) (p=0.63, p=0.36 and p=0.17 respectively). The majority in both study and comparison groups were of Benin origin (37.9% and 55.1% respectively) and secondary level of education was the highest level attained for the majority (57.5% and 73.6% respectively). There was no significant difference in marital status between the groups (p=0.64).

Symptom	Study group (N=227) n (%)	Comparison group (N=227) n (%)	χ^2 test	p value
Cough	106 (46.7)	18 (7.9)	85.92	0.00*
Phlegm	114(50.2)	11(4.8)	117.12	0.00*
Breathlessness	18 (7.5)	3 (1.3)	11.23	0.00*
Wheeze	14 (6.0)	3 (2.6)	6.08	0.00*
Chest pain	13 (5.7)	2 (0.9)	8.34	0.00*
Chest tightness	23 (10.1)	0 (0.0)	24.23	0.00*
Cough with phlegm	20 (8.8)	2 (0.9)	15.48	0.00*

*Significant at p < 0.001

Table 1: Prevalence of respiratory symptoms in study and comparison groups.

Symptom	Study group n = 115	Comparison group n = 156	p value
Cough	47 (41.2)	7 (4.5)	0.00*
Phlegm	43 (37.4)	0 (0.0)	0.00*
Breathlessness	3 (2.6)	0 (0.0)	0
Wheeze	1 (0.9)	0 (0.0)	0.00*
Chest tightness	3 (2.0)	0 (0.0)	0.00*
Cough with phlegm	4 (3.5)	0 (0.0)	0.00*

*significant at p < 0.001

Table 2: Prevalence of respiratory symptoms among non-smokers in study and comparison groups.

Self-reported prevalence of respiratory symptoms in studied groups was as follows: cough 46.7%, phlegm production 50.2%, breathlessness 7.5%, wheeze 5.3%, chest pain 5.7%, chest tightness 10.1% and cough with phlegm 8.8%. There was also a significantly higher prevalence of all symptoms among current and ex-smokers than among non-smokers. In relation to the comparison group, respondents in the study group had a significantly (p=0.00) higher prevalence of all symptoms.

Cough had the highest percentage of 41.2% in the study group of Prevalence of respiratory symptoms among non-smokers in study and comparison groups as shown in Table 2.

From Table 3, one hundred and fifty five (68.3%) respondents in the study group reported at least one respiratory symptom compared with 23 (10.1%) in the comparison group. Non-smokers in the study group had significantly (p=0.00) higher proportion of all symptom. The presence of at least one respiratory symptom among sawmill subjects was significantly associated with duration of work (p=0.04). There was no relationship between job category and history of previous employment in a dusty occupation with occurrence of at least one respiratory symptom. The FEV_1/FVC ratio also called Tiffeneail-pinelli [22] index, is a calculation ratio used in the diagnosis of obstructive and restrictive lung disease [23,24], it represent the proportion of Person's vital capacity that are able to respire in the first second of forced respiration [25]. The mean values of all parameters Forced Expiratory Volume in first second (FEV_1), Forced Vital Capacity (FVC), FEV_1/FVC and PEFR) were significantly (p=0.00, 0.01, 0.00 and 0.00 respectively)

Variable	Sawmill group (n= 227)			Comparison group (n = 227)		
	No symptom n (%)	At least one symptom n (%)	Total	No symptom n (%)	At least one symptom n (%)	Total
History of previous dusty job						
Yes	15 (41.7)	21 (58.3)	36 (100.0)	24 (70.6)	10 (29.4)	34(100)
No	57 (29.8)	134 (70.2)	191 (100.0)	180 (93.3)	13 (6.7)	193(100)
Total	72 (31.7)	155 (68.3)	227 (100.0)	204(89.9)	23 (10.1)	227(100)
	χ^2 = 1.96, df 1, p = 0.162			**χ^2 = 16.32, df 1 , p = 0.000**		
Duration of work (years)						
≤ 4	37 (33.0)	75 (67.0)	112 (100.0)	96 (77.4)	28 (22.6)	124(100)
5 – 9	12 (21.1)	45 (78.9)	57 (100.0)	41 (89.1)	5 (10.9)	46(100)
10 – 14	9(29.0)	22 (71.0)	31 (100.0)	28 (90.3)	3 (9.7)	31(100)
≥ 15	14 (51.9)	13 (48.1)	27 (100.0)	20 (76.9)	6 (23.1)	26(100)
Total	72 (31.7)	155 (68.3)	227 (100.0)	185 (81.5)	42(18.5)	227(100)
	χ^2 = 8.24 df 3 , p = 0.041			**Fisher's exact test p = 0.137**		
Job category						
Operator	22 (36.1)	39 (63.9)	61 (100.0)			
Drawer/Table boy	21 (24.1)	66 (75.9)	87 (100.0)			
Jack man	9 (25.7)	26 (74.3)	35 (100.0)			
Maintenance	9 (50.0)	9 (50.0)	18 (100.0)			
Manager	4 (40.0)	6 (60.0)	10 (100.0)			
Loader/Packer	7 (43.8)	9 (56.2)	16 (100.0)			
Total	72 (31.7)	155 (68.3)	227 (100.0)			
χ^2 = 7.59, df = 5, p = 0.18						

Table 3: Factors associated with the presence of at least one respiratory symptom among study and comparison groups.

Parameter	Sawmill workers Mean ± SD N = 115	Control group Mean ± SD N = 156	p value
FEV_1 (L)	3.07 ± 0.51	3.30 ± 0.53	**0**
FVC (L)	3.60 ± 0.70	3.79 ± 0.69	**0.01**
FEV1/FVC	77.64 ± 4.32	79.48 ± 6.26	**0**
PEFR (L/min)	404.11 ± 88.80	457.40 ± 84.45	**0**

Table 4: Comparison of lung function among non-smokers in study and comparison groups.

	Sampling location		
Type of particulate	**Study site (n = 5)**	**Comparison site (n = 5)**	**t test (p value)**
Total suspended particulates (mg/m³)			
mean ± SD	1.39 ± 0.28	0.52 ± 0.07	6.77
(Range)	(0.94 – 1.67)	(0.83 -1.67)	0
Inhalable suspended particulates (mg/m³)			
mean ± SD	1.07 ± 0.34	0.44 ± 0.09	4.07
(Range)	(0.60 – 1.66)	(0.31 – 0.53)	-0.01
Respirable suspended particulates (mg/m³)			
mean ± SD	0.33 ± 0.12	0.23 ± 0.08	1.57
(Range)	(0.17 – 0.57)	(0.10 – 0.31)	-0.16

Table 5: Assessment of mean particulate concentration in study and comparison sites.

higher in the comparison than among the study group as shown in Table 4. Total suspended and inhalable dust levels were significantly (p=0.000 and 0.012 respectively) higher in study than comparison sites. Respirable dust was higher in concentration, though not significantly (p = 0.156), in the study compared to comparison sites as shown in Table 5**.**

Discussion

The higher prevalence of respiratory symptoms in the study group gives the impression that occupational exposure to wood dust may expose workers to a higher risk of developing pulmonary disorders. This finding is in agreement with results from other comparative studies [26-28]. Respondents in the study group reported a higher prevalence of cough, and phlegm expectoration compared to chest pain, chest tightness, wheeze or breathlessness. The implication is that upper respiratory tract involvement was more likely compared to lower respiratory tract involvement, the latter presenting with wheeze, chest pain, breathlessness and tightness. This finding, which has been similarly reported by other investigators [29-31] might be as a result of the fact that wood dust, made up of cellulose and other soluble chemicals including acetic acid and resins, is largely of large diameter fibres that irritate the cough receptors in the trachea and cause mucostasis in the upper respiratory tract, leading to cough and phlegm production. This is supported by area sampling of the study sites which showed concentrations of total particulates clearly in excess of that obtained from control sites with a clear absence of any form of dust control mechanism in place. It may possibly also be due to the fact that sawmill workers represent a 'survival population' that have experienced less debilitating symptoms which otherwise would have sent them out of the establishment.

About 68% of the study group and 10% of the comparison group in the study reported at least one respiratory symptom, which was lower than what was obtained in an earlier study conducted in the same geopolitical region (87.6% in study group and 18.5% in the comparison) [32,33] and comparable to what was obtained (62%) among wood workers in Jos, Nigeria [34,35]. Respondents in the study group who had put in less than 10 years in the trade had a significantly higher proportion of respiratory symptoms than those who had put in more than 10 years. Correspondingly, the mean age of the former workers was 41.2 ± 7.7 years compared to the mean age of those who had put in less than 10 years (29.0 ± 7.1 years). This may be explained by considering that in the course of their work, as symptoms develop, those who are worse affected tend to leave or change jobs leaving the 'apparently healthier' ones behind. A comparison of non-smokers in both groups showed prevalence of symptoms higher in the study compared to comparison group, indicating that wood dust acts on the respiratory tract independent of smoking. Similarly, when comparison was made among non-smokers, spirometric readings and peak expiratory flow readings were significantly better in the comparison than the study groups, though for both groups, the ratio of forced expiratory volume in first second and forced vital capacity (FEV_1/FVC) was essentially normal. This has been reported in previous studies outside the country [36] and contrary to what was obtained in an earlier study carried out in Tanzania [37].

The study sites had significantly higher levels of total and inhalable dust than control sites. Similar results have been documented in earlier studies [38]. The higher concentration of dust might possibly explain the high prevalence of upper airway irritation symptoms among sawmill workers. Similar findings have been documented in other studies [39,40]. This can be explained by the fact that operations such as debarking, sawing and cutting produce relatively coarse (rather than fine) dust that is largely in the thoracic fraction [41,42] with diameter greater than 10 microns, and are thus outside the respirable range. The processing of fresh (rather than dried) timber, as is the case with sawmills in the study area, may also be responsible for production of large diameter wood dust. Respirable wood dust (<5.0 to 0.5 microns in size and designated $PM_{2.5}$), made up a small proportion (31%) of inhalable dust concentration in the sawmills, and not significantly different from what was obtained in comparison sites. Thus only a small portion of wood dust generated actually penetrated the deeper lung tissue to provoke pathological changes. However, because of the irritant and allergic properties of wood dust, this small proportion is responsible for the higher prevalence of lower respiratory symptoms among study than control subjects. Previous employment in a dusty job was not associated with presence of at least one respiratory symptom in the study as against the control group, implying a continued destruction of lung tissue by wood dust exposure in spite of previous assault from other inhaled agent encountered in previous work.

The Time weighted average (TWA) for total inhalable wood dust in the study sites (1.39 mg/m³), fell below the 15 mg/m³ permissible exposure limit (PEL) set by the Occupational safety and health administration (OSHA) for total inhalable wood dust for an 8-hour work- shift. While this finding is obviously not due to the existence of dust extraction systems in the sawmills, the most likely explanation may be the fact that the study sites, being open sheds, have a good supply of natural ventilation, which serve to readily disperse the dust. Moreover, the gravimetric sampler used measures airborne dust, and since wood particles generated during debarking and planning are to an extent of large diameter, they settle quickly to the ground and may not be measured. Also, the limits specified by these regulatory bodies apply mainly to personal exposure sampling, whereas, the value obtained in this study was based on area sampling, which may give lower values, and therefore be an underestimation of worker exposure to wood dust. The value obtained for total inhalable dust in this study was higher than what was obtained in sawmill in Canada [43] (0.2 mg/m^3), probably because the Canadian mills may have dust extraction systems in use. The value obtained was comparable to that obtained from the sawmill section of a wood furniture factory in Thailand [44,45], a developing country like Nigeria.

The TWA for respirable dust obtained in this study (0.33mg/m^3) was also well below the PEL set by OSHA (5 mg/m^3), and the 1 mg/m^3 recommended exposure limit set by National Institute of Occupational Safety and Health (NIOSH). The value was lower than what was obtained in a study in Calabar (31.75 mg/m^3) [46] possibly because of the difference in air sampling equipment's used in both studies. The value for respirable dust in this study was similar to what was obtained in sawmill in Sweden (0.3 mg/m^3) [47]. A limitation of the study is that assessment of respiratory symptoms was made based on self-report, and was not validated using medical records.

Conclusion

Sawmills in a developing country like Nigeria face the challenge of providing work environments where hazards such as wood dust are poorly controlled. Sawmill workers in Nigeria are like their counterparts elsewhere therefore at an increased risk of developing respiratory symptoms from occupational exposure to wood dust. Symptoms from this study were predominantly from affectation of the upper airway, and showed a significantly higher prevalence in smokers than non-smokers. Area sampling of sawmills showed higher concentrations of particulate dust than in control sites. It is needful for dust control mechanisms to be put in place in sawmills, and sawmill workers educated on the need to use protective devices while at work. Standards for permissible dust exposure levels should be set for sawmills in Nigeria to guide monitoring.

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