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Respiratory function of sawmill workers and their relationship to duration of exposure to wood dust seen in Nigeria

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ABSTRACT

Background and Objective: Sawmill workers are exposed to considerable amounts of wood dust which may compromise their respiratory function.

Objective: This study aimed to determine the effects of wood dust by comparing pulmonary parameters between workers in the sawmill industries and their aged matched controls. In addition, to determine the relationship between the respiratory function of sawmill workers and their exposure time.

Materials and Methods: This was a descriptive, cross-sectional study conducted in the south western part of Nigeria. One hundred and two non-smoking male workers were recruited from the sawmill industries while the same number made up the control group (non-smoking). The controls were comprised of members of staff and student of the University of Ibadan who had no history of wood dust exposure. All participants had no chest deformities. Selected lung function tests were performed using a spirometer. Data were analyzed using appropriate statistical tests with alpha set at $p < 0.05$.

Results: There was a significant reduction of forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC) of workers in the sawmill industries when compared with the control group ($p \leq 0.05$). Sawmill workers exposed to wood dust exceeding 10 years were found to have a significant decrease in their FEV_1 ($F = 10.802$, $p = 0.001$). In addition, there was a negative but moderate relationship between FEV_1 and exposure time to wood dust ($r = -0.489$, $p = 0.001$). However, there was no significant relationship between FVC and exposure time to wood dust ($r = -0.17$, $p = 0.241$).

Conclusion: Sawmill workers have increased risk of compromised respiratory function. Furthermore, prolonged exposure to wood dust resulted in decreased respiratory function. Workplace education in terms of the risk of wood dust inhalation and provision of protective devices is recommended.

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Introduction

Occupational hazards are witnessed in workers from different walks of life with industrial workers facing the most of its effects [1,2]. The cumulative effects could in turn affect their respiratory system leading to occupational respiratory disease [3]. Factors predisposing industrial workers to respiratory diseases include heavy, short or prolonged exposure to different gases, chemicals such as pesticides and even dust such as wood dust [4]. Respiratory symptoms including nasal congestion, cough, chest tightness, and wheezing due to constant prolonged unprotected inhalation of wood smokes have been recorded [5,6].

In Nigeria, the numbers of sawmill industries have risen in the last decade and this is partly due to an increase in the demand for timber for both local consumption (growing population) and foreign

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exportation [7,8]. The constant availability of timber has made the industry to thrive with more sawmill industries opening at new locations every year [9] and the more branches are created yearly, the more the number of workers that are likely to be exposed to occupational health hazards including respiratory diseases. Wood dust is the side product of wood with varied chemical compositions of cellulose, hemicelluloses, lignin, and small amounts of extraneous materials [10]. Industrial wood operations like peeling, slicing, milling, drilling, and sawing give out fine wood dust which becomes airborne and may result in respiratory health challenges [11]. Unfortunately, the sawmill industry in Africa has been plagued with a number of short comings ranging from the poor political will to implement comprehensive health care policy, little knowledge of occupational hazards, higher rates of unqualified safety inspectors, meager funding, and poor infrastructure [12]. As a result, sawmill industrial workers are exposed to considerable amounts of the chemical composition of wood dust [13,14].

Bislimovska et al. [15] from their study showed that wood workers exposed to wood dust from oak and beech had significantly lower selected respiratory parameters than their counterparts working in the offices. Sawmill workers exposed to a variety of wood dust have also been shown to exhibit occupational asthma, lung function deficits, and elevated levels of respiratory symptoms [11,16]. Mandryk et al. [17] in their study showed that sawmill industrial workers had a significant drop in their respiratory function despite the fact that they were young workers. Schlunssen et al. [18] in a different study reported that wood dust exposure might cause respiratory symptoms in sawmill workers despite being exposed to relatively low levels of chemical particles. This work therefore was directed toward evaluating the effects of wood dust on selected respiratory parameters of workers in the sawmill industry in Nigeria.

Materials and Methods

Participants

This was a cross-sectional, descriptive study design. A total of 204 male participants took part in this study. This consisted of a 102 consenting male employees from three sawmill industries in Ibadan and a 102 willing male participants who are members of staff of the College of Medicine and students of the University of Ibadan whose age groups matched those of the workers from the sawmill industries. The Ibadan timber markets are located in different parts of the city. Each timber market is comprised of open sheds which are a small-scale factory with less than 10 employees in each shed. The male workers are involved in slicing, peeling, sawing, carving, and timber sales. The type of wood the Ibadan sawmill factory mostly deal with are samba, iroko, mahogany, teak, and obeche. Each sawmill worker worked 6 days in a week, 8 hours daily. Participants that were recruited for this study had no history of cardiopulmonary disease, no history of smoking, no physical chest deformities and were all within the age range of 20–59 years. Furthermore, only machine operators and laborers who had worked for a minimum of 1 year were selected from the sawmill industry to participate. This was to ensure getting sawmill workers who were directly exposed to wood dust.

Procedure

Ethical approval for the study was obtained from the joint University of Ibadan/University College Hospital (UI/UCH) Institutional Review Board. Chairmen of the selected sawmill industries were approached and the purpose of the study was explained to them who in turn assisted to mobilize and disseminate the information to both machine operators and laborers. An informed consent was obtained from each participant before they were allowed to participate. Each consenting participant was interviewed individually. Information obtained included: present age, anthropometric parameters, socioeconomic status, educational background, years of experience (for saw mill workers); smoking status (non-smoker, smoker, or ex-smoker); previous history of exposure to wood fumes; living near any wood plant/sawmill factory; past medical history; and alcohol status. Respiratory measurements taken were forced expiratory volume in the first second (FEV_1) and forced vital capacity (FVC). However, the respiratory function testing was performed in the early hours of the day, specifically between 9:00 AM and 12 noon to reduce diurnal discrepancies.

All recruited sawmill participants were non-smokers. However, some indicated that they were exposed to wood fumes from the burning of sawmill waste at work and from the burning of wood to serve as fuel for cooking at home. Participants in the age-matched controls were either students or lecturers whose works did not involve exposure to wood fumes, non-smokers (ex-smokers and smokers were excluded from this study), and did not reside near any wood plant or factory.

Socioeconomic status of both sawmill workers and their age-matched controls were calculated using the Ogunlesi et al. [19] classification of social class which is a modification of an earlier classification done by Oyedeji [20]. The previous classification did not take into account the monthly wages to assign socioeconomic scores, therefore the need for a modification. Hence, socioeconomic scores were assigned to both educational qualification and occupation based on the equivalents of each participant's mean wages using their percentile wages [19]. Socioeconomic class was scored as 1, 2, 3, 4, and 5 with the social class represented as I, II, III, IV, and V respectively. Socioeconomic status was then further sub-divided as:

1) An aggregate score of 1 or 2 which represent the social classes of I and II were sub-classified as upper class.
2) An aggregate score of 3 which represent a social class of III was sub-classified as middle-class.
3) An aggregate score of either 4 or 5 representing social classes IV and V were sub-classified as lower class.

The height of each participant was measured in meters to the nearest centimeters. Participants with shoes off were instructed to stand erect on a stadiometer and allowing their occiput to touch the meter vertical rod while the adjustable horizontal projection from the stand is placed at the highest point of the head. Two readings were taken and the average value was recorded. A portable bathroom weighing scale (Hanson) calibrated in kilograms from 0 to 120 kg was used to measure participants' weight. Participants were instructed to stand erect on the bathroom scale with arms by the side and looking forward as the measurement was taken in kilograms. It has an adjustable knob that can be used to correct the zero error.

Both the FEV in the first second and FVC were measured using a compact computerized spirometer manufactured by Micro Medical Ltd, calibrated from 0.10 to 9.99 L and measured to the nearest 0.01 L. Before usage of the compact computerized spirometer, it was pre-calibrated and programed to measure for both FEV_1 and FVC.

Each participant was asked to relax for three minutes on a chair to stabilize all vital signs. After which, each participant was instructed to take a full breath in, then locking their lips around the mouth piece of the spirometer and blowing out as hard and fast as possible. Inspiration was full, unhurried and expiration was continued forcefully without a pause. This procedure was repeated three times for each participant with a rest period of 1 minute in between effort to ensure that the participant had enough rest before performing another maneuver with the highest value recorded. The forced expiratory ratio (FER), which is a calculated ratio, was derived by dividing the each participant's FEV_1 by their FVC. This was used to determine the possible presence of a restrictive or obstructive lung disease [21].

Data analysis

Continuous variables such as age, height, weight, FEV_1, FVC, and FER were summarized using mean and standard deviation (SD) while categorical variables such as socioeconomic status and educational background were summarized using proportions and percentages. Chi-square was used to determine association between categorical variables and the research groups. Inferential statistics of independent "*t*" test was used to compare age, weight, height, body mass index (BMI), FEV_1, FVC, and FER between workers in the sawmill industries and their age matched controls. One-way analysis of variance (ANOVA) was used to compare each respiratory parameter across the three different exposure times to wood dust and this was further analyzed using the Post hoc analysis of Fisher's least significant difference (LSD) to identify the exact location of statistical difference. In addition, Pearson product moment correlation coefficient was used to determine the relationship between respiratory parameters and exposure time to wood dust in sawmill workers. Data were analyzed using Statistical Programme for Social Sciences (SPSS) version 22.0 (SPSS Inc., Chicago, IL). Alpha level was set at 0.05.

Results

A total of 204 consenting male participants took part in this study. The age range of workers in the sawmill industries was 20–59 years while that of the control group was 20–58 years. The mean age, weight, height and BMI of all participants were 29.34 ± 9.07 years, 65.70 ± 8.65 kg, 1.72 ± 0.08 m and 22.35 ± 2.69 kg/m^2, respectively. Table 1 shows the independent *t*-test comparison of the anthropometric parameters of the participant by group. The comparison of age and anthropometric parameters between the two groups showed no significant difference.

Table 1. Independent *t*-test comparison of the anthropometric and respiratory parameters of sawmill workers and their age-matched controls.

Variable	Sawmill workers' Group ($n = 102$) Mean ± SD	Control Group ($n = 102$) Mean ± SD	*t*-test	*p*-value
Age (years)	29.53 ± 9.08	29.16 ± 9.10	0.293	0.770
Weight (kg)	66.35 ± 8.68	65.12 ± 8.62	1.019	0.309
Height (m)	1.71 ± 0.07	1.72 ± 0.08	−1.072	0.285
BMI (kg/m^2)	22.60 ± 2.19	22.10 ± 3.10	1.319	0.189
FEV_1 (L)	2.47 ± 0.43	3.10 ± 0.55	−9.002	0.001
FVC (L)	2.73 ± 0.53	3.14 ± 0.57	−5.304	0.001
FER (%)	91.86 ± 12.67	98.36 ± 3.80	−4.966	0.001

*Significance level = $p < 0.05$.

Table 2. Independent *t*-test comparison of respiratory parameters of various age groups between sawmill workers and their age-matched controls.

Variable	Sawmill workers' Group ($n = 102$) Mean ± SD	Control Group ($n = 102$) Mean ± SD	*t*-test	*p*-value
Group 1 (20–29 years) ($n = 68$)				
FEV_1 (L)	2.57 ± 0.34	3.26 ± 0.64	−6.245	0.001*
FVC (L)	2.68 ± 0.33	3.27 ± 0.39	−5.057	0.001*
FER (%)	95.86 ± 3.89	99.08 ± 2.74	−3.378	0.001*
Group 2 (30–39 years) ($n = 19$)				
FEV_1 (L)	2.45 ± 0.41	3.21 ± 0.36	−4.283	0.001*
FVC (L)	2.73 ± 0.72	3.22 ± 0.63	−2.346	0.030*
FER (%)	92.55 ± 13.50	98.26 ± 3.27	−1.067	0.046*
Group 3 (40–49 years) ($n = 9$)				
FEV_1 (L)	2.07 ± 0.44	3.08 ± 0.56	−6.284	0.001*
FVC (L)	2.58 ± 0.23	3.14 ± 0.60	−2.766	0.007*
FER (%)	79.54 ± 12.55	98.11 ± 4.17	−4.401	0.002*
Group 4 (50–59 years) ($n = 6$)				
FEV_1 (L)	1.77 ± 0.53	2.86 ± 0.29	−4.598	0.002*
FVC (L)	2.38 ± 0.81	2.89 ± 0.26	−1.778	0.099
FER (%)	76.98 ± 16.58	98.06 ± 3.24	−3.190	0.002*

*Significance level = $p < 0.05$.

Table 2 shows the mean scores of the respiratory function for both the sawmill workers and their age-matched control group of various age groupings. The independent *t*-test showed that the mean values of FEV_1, FVC, and the calculated FER were all significantly higher (across the various age grouping) in the control group compared with sawmill workers.

Table 3 shows the socioeconomic status and educational background of the study participants. More than half of the sawmill workers and their age-matched controls were from a lower social class and statistical analysis showed no significant difference between the two groups. Significantly, more of the apparently healthy controls were from the upper class as compared to the sawmill workers (28.4% *vs.* 2.9%; $p = 0.001$). 23.5% of the sawmill workers had only primary education as compared to none of the apparently healthy controls ($p = 0.001$).

One way ANOVA was used to compare the mean value of FEV_1, FVC, and FER across the four age groups in the sawmill workers' and control groups as shown in Table 4. The respiratory function of participants from the sawmill workers' group showed a significant difference, except for the FVC while those in the control group showed no significant changes in all respiratory parameters. *Post-hoc* analysis of Fisher's LSD was used to identify the exact location of statistical difference in the sawmill workers group.

Again, one-way ANOVA was used to compare the mean values of FEV_1, FVC, and FER across the three different exposure times (in years) as shown in Table 5. Fisher's LSD *post-hoc* analysis was also used to identify the exact location of statistical difference. The results showed that wood dust exposure time exceeding 10 years has a significant decline in the respiratory parameters of sawmill

Table 3. Comparison of socioeconomic status and educational background of sawmill workers and their age-matched controls.

Variables	Sawmill workers	Controls	χ2	*p*-value
	n = 102 (%)	*n* = 102 (%)		
Socioeconomic status				
Upper class	3 (2.9)[a]	29 (28.4)[b]	31.657	0.001*
Middle class	23 (22.5)[a]	6 (5.9)[b]		
Lower class	76 (74.5)[a]	67 (65.7)[a]		
Educational background				
Primary	24 (23.5)[a]	0 (0)[b]	28.336	0.001*
Secondary	52 (51.0)[a]	60 (58.8)[a]		
Post-secondary	26 (25.5)[a]	42 (41.2)[a]		

*Significance level = $p < 0.05$.
[a, b]For a particular variable, mode means with different superscript are significantly different. Mode means with the same superscript are not significantly different.

Table 4. One-way ANOVA comparison of the respiratory parameters across the various age groups of both sawmill workers and their control.

Variable	Group 1 (20–29 years)	Group 2 (30–39 years)	Group 3 (40–49 years)	Group 4 (50–59 years)	*F*	*p*-value
	n = 68	*n* = 19	*n* = 9	*n* = 6		
Sawmill workers' group						
FEV_1 (L)	2.57 ± 0.34[a]	2.45 ± 0.41[a]	2.07 ± 0.44[b]	1.77 ± 0.53[c]	11.919	0.001*
FVC (L)	2.68 ± 0.33	2.73 ± 0.72	2.58 ± 0.23	2.38 ± 0.81	1.014	0.390
FER (%)	95.86 ± 3.89[a]	92.55 ± 13.50[a]	79.57 ± 12.54[b]	76.99 ± 16.59[b]	17.497	0.001*
Control group						
FEV_1 (L)	3.26 ± 0.64	3.21 ± 0.36	3.08 ± 0.56	2.86 ± 0.29	1.223	0.305
FVC (L)	3.27 ± 0.39	3.22 ± 0.63	3.14 ± 0.60	2.89 ± 0.26	0.799	0.497
FER (%)	99.08 ± 2.74	98.26 ± 3.27	98.11 ± 4.17	98.06 ± 3.24	0.376	0.77

*Significance level = $p < 0.05$.
[a, b]For a particular variable, mode means with different superscript are significantly different. Mode means with the same superscript are not significantly different.

Table 5. One-way ANOVA of respiratory parameters (sawmill workers' group) at different levels of exposure time to wood dust.

Variable	Exposure time	*N*	Sawmill workers Group (*n* = 102)	*F*	*p*-value
			Mean ± SD		
FEV_1	From 1 to 5 years	38	2.64 (0.35)[a]	10.802	0.001*
	From 6 to 10 years	31	2.50 (0.31)[a]		
	Above 10 years	33	2.21 (0.51)[b]		
FVC	From 1 to 5 years	38	2.75 (0.33)	1.061	0.350
	From 6 to 10 years	31	2.62 (0.31)		
	Above 10 years	33	2.61 (0.65)		
FER (%)	From 1 to 5 years	38	96.27 (4.06)[a]	11.588	0.001*
	From 6 to 10 years	31	95.13 (3.65)[a]		
	Above 10 years	33	86.30 (15.42)[b]		

*Significance level = $p < 0.05$.
[a, b]For a particular variable, mode means with different superscript are significantly different. Mode means with the same superscript are not significantly different.

workers—FEV_1 ($F = 10.802$; $p = 0.001$) and FER ($F = 11.588$; $p = 0.001$). Finally, Pearson's correlation between respiratory function and exposure time to wood dust showed a negative but significant relationship (FEV_1: $r = -0.489$, $p = 0.001$; FER: $r = -0.544$, $p = 0.001$).

Discussion

The study was carried out to determine the association of wood dust exposure with pulmonary functions of workers in the sawmill industries. Comparison of the age and anthropometric characteristics between the two groups (sawmill workers and their age matched control) revealed no significant difference. Most of the study participants were from the lower socioeconomic class with no significant difference between the two study groups. Studies done have shown that people from lower socioeconomic status are at a higher risk of generating respiratory health challenges due to exposure to air pollutant [22,23].

This study showed that employees from selected sawmill industry had a significantly lower respiratory function compared with their age-matched control group. These findings are in agreement with previous studies [17,24,25]. This significant decline in respiratory parameters of sawmill workers maybe as a result of direct inhalation of wood dust which is made up of chemical substances and airborne microflora such as molds, bacteria or fungi as a result of secondary infection of the wood dust [26].

These chemical substances are easily absorbed into the body through the lungs or skin, though the lungs are more susceptible to airborne threats [27]. The wood dust created by the sawmill workers especially during sawing, carving, and drilling are made up of tiny particles of sub-5 μm which easily gets trapped in the upper respiratory system. Some of these small particles by-pass the defence mechanism of the upper respiratory tract and penetrate into the lower respiratory system where they remain for a while, long enough to cause minute wounds and scarring to the lungs which if it persists for a period of time results in a significant reduction in lung function with additional health challenges [28,29].

The FEV_1, from this study showed a decline with increasing age. Studies have shown that the efficiency of the lungs (lung elasticity, chest wall compliance, brachial hyper-responsiveness) declines as we get older [30,31]. However, exposure to wood dust at any age from various studies have proven to be hazardous to the lungs and the entire respiratory system [11,15,17,18,27]. Besides the adverse respiratory symptoms that wood dust exposure causes like chest pain, cough, dyspnea, malaise, and wheezing [11,14,32], the respiratory parameters of exposed industrial workers are also compromised [17,32]. Hence, there is a likelihood that sawmill workers have a greater rate of decline in their respiratory function when compared with individuals not exposed to sawdust or any other harmful airborne chemicals.

This study also looked at the respiratory parameters (FEV_1 and FVC) of sawmill workers in relation to their exposure time to sawdust. The result revealed that FEV_1 had a significant decline with exposure time of above 10 years. This result implies that sawmill workers who have worked in the industry for more than 10 years were more likely to have their FEV_1 significantly compromised. Some studies done have shown that the longer a sawmill worker is exposed to sawdust the greater the concentration levels that would be absorbed through the lungs [24,33,34]. A study done in the south–southern part of Nigeria by Tobin et al. [35] as regards the concentration levels of sawdust in the sawmill industries revealed that sawmill workers were exposed to inhalable wood dust at a higher level. The FVC of sawmill workers from this study did not show any significant change across the age groups. Berry and Wise [36] in their study showed that both the FEV_1 and FVC values reduced as one ages. However, the decline of FEV_1 was seen to be greater than that of FVC. This they explained resulted in a decline in the FER which is an important diagnosis of obstructive lung disease. From the result of this study, we see that the FVC actually decreases but this decline is not significant enough across the age ranges. This could imply that a person with obstructive respiratory disease will have a relatively normal FVC while their FEV_1 will be significantly reduced. The possible reason for this may have to do with the maneuver to get both the FVC and FEV_1 readings. The FVC procedure requires an expiratory air to be delivered forcefully and completely into the spirometric device while FEV_1 is the expiratory air delivered in the first second of an FVC maneuver [37].

The findings of this study shows the importance of industrial hygiene which aims to diminish the amount of exposure first with technical improvements, including sharp cutting edge and local and general industrial ventilation systems like exhaust ventilation device and high efficiency particulate filters. Protective clothing, goggles, and gloves are needed to reduce skin exposure to sawdust. Dust mask is also helpful in providing some form of protection against inhalation of wood dust. In addition, sawmill industries should be encouraged to purchase a gravimetric air sampling device in order to assess the concentration of sawdust within their work place. Finally, education of employers and employees concerning the effects of wood dust on health and safety measures are essential for the success of occupational health programs.

Study Limitations

Although this study looked at both respiratory parameters and exposure time of sawmill workers, we did not measure the amount of sawdust each worker is exposed to during their work period.

Conclusion

Sawmill workers have increased risk of compromised respiratory function. Furthermore, prolonged exposure to wood dust resulted in decreased respiratory function. Workplace education in terms of the risk of wood dust inhalation and provision of protective devices is recommended.

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Conflict of Interests

None declared.

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