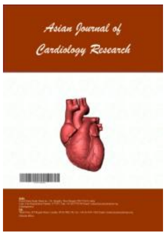

Asian Journal of Cardiology Research

5(3): 22-34, 2021; Article no.AJCR.73702

Assessment of Occupational Noise Exposure Effects on Cardiovascular Functions of Saw-Mill Workers

Ezeani Emmanuel Ifeakandu[1], Maduka Stephen Ozoemenam[1], Dimkpa Uchechukwu[1*], Chukwukaeme Chidinma Winifred[1] and Okwuonu Ifeoma Frances[1]

[1]Human Physiology Department, Faculty of Basic Medical Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Sam Said, Hospital Group Twente, Netherlands.
Reviewers:
(1) Mohammad Saad Ahmad Khan, Aligarh Muslim University, India.
(2) Ekta Damani (Malvania), AMC Dental College and Hospital, India.
Complete Peer review History: https://www.sdiarticle4.com/review-history/73702

Original Research Article

Received 03 July 2021
Accepted 12 September 2021
Published 14 September 2021

ABSTRACT

Aim: We aimed at assessing the effects of occupational noise exposure on cardiovascular functions of saw-mill workers in Nnewi metropolis, Anambra State, Nigeria.
Study Design: This is a cross-sectional study comparing saw-mill workers occupationally exposed to intense noise levels with unexposed control.
Place and Duration of Study: Department of Human Physiology, Nnamdi Azikiwe University, between February, 2019 and March 2020.
Methodology: Fifty saw-mill workers (26 males, 24 females), of mean age 30.84 ± 6.26 years and 50 controls (18 males, 32 females; mean age, 26.32 ± 6.32 years) participated in the study. The mean ambient noise level for each site was obtained with a sound meter measurement prior to cardiovascular function test for each participant. The noise level, blood pressure (BP) and heart rate (HR) measurements were done for the saw-mill workers when the machines were in operation. Other parameters such as mean arterial pressure (MAP), pulse pressure (PP), rate pressure product (RPP), cardiac output (CO) and oxygen consumption (VO_2) were determined using appropriate scientific equations.

**Corresponding author: Email: u.dimkpa@unizik.edu.ng;*

Results: Saw-mill workers indicated significantly higher ($p<0.05$) mean systolic BP, diastolic BP, MAP, RPP and PP, but lower ($p<0.05$) mean CO, and VO_2 compared with the control. No significant difference was observed in HR between the two groups. Incidences of both systolic and diastolic hypertension and abnormally high MAP were greater in sawmill workers compared to the control. The risk of systolic hypertension, abnormally high MAP, among sawmill workers was higher compared to the control.

Conclusion: Our study revealed that hypertension and other abnormal cardiovascular outcomes were more prevalent in the noise-exposed saw-mill workers compared to unexposed control. These findings may serve to increase workers' awareness about effects of occupationally noisy environments on their health and suggest the need to reduce workplace noise levels in order to improve their cardiovascular health.

Keywords: Noise; cardiovascular functions; blood pressure; heart rate; rate pressure product; pulse pressure; oxygen consumption; sawmill.

1. INTRODUCTION

The role of noise as an environmental pollutant and its impact on health is being increasingly recognized. The World Health Organization (WHO) considers noise as the third dangerous pollutant of megacities [1], and acute noise exposure has been shown to interfere with communication, concentration, and relaxation; it also disturbs sleep, impairs cognitive performance and causes annoyance [2]. Long-term exposure to noise has been previously associated with negative cardiovascular health outcomes such as arterial hypertension, acute myocardial infarction, arteriosclerosis, ischemic heart disease and stroke [2].

Occupational noise is one of the major sources of environmental noise pollution in mega cities. General awareness of the effects of occupational noise such as the one experienced in saw mill industries has led to promulgation of several legislations which prescribe permissible noise level at workplaces. For example, occupational standards specify a maximum allowable daily noise dose of 85 dBA (National Institute for Occupational Safety and Health - NIOSH) over an 8-hour work shift [3]. However, there is low knowledge of environmental laws and utter disregard to noise pollution limits by most of the noise-producing industries operating in Nigeria. Similarly, precautionary measures such as the use of hearing protectors, machinery noise propagation control and occasional hearing status tests and health checks are not practiced by the industry operators and their workers. Unfortunately, most of these workers are daily exposed to these industrial noise pollutions and for a long period of time without being aware of the health hazards associated with them.

The health impact of noise in several industrial workplaces has been extensively studied in literature. However, there is paucity of information on the health impact of noise pollution from sawmill activities within the cities in Nigeria. With a harvest of more than 100 million cubic meters of wood annually, Nigeria is considered as Africa's largest wood producer [4]. It is therefore not surprising that saw-mills account for about 93.32% of the total wood-based industries and it is common to find them domiciled in major cities in Nigeria [5]. The saw-mills have been identified as major sources of environmental noise pollution and an extreme acoustic environment for workers [6]. Job tasks of workers who work in saw-mills include the breakdown of logs into cants, slabs, processing the cants and slabs into functional lumber sizes, grading, sorting, drying and processing the lumber for industrial specific uses with preservatives, fire retardants or surface protection [7,8]. These activities expose the sawmill workers to a high level of noise generated from cutting, shaping, milling and sawing of timber and from machine engine operations for long periods of time, everyday [7,9]. Exposure to noise in sawmills is perhaps one of the most intense and prolonged level of noise experienced daily [10]. The level of noise experienced by individuals in these saw-mills could either be short or varied in some instances, but are generally harmful to their physical, sociological, and psychological well-being [10,11]. Traditionally, this industry is known as one of the most labor-intensive, dangerous repetitive work settings and production-oriented industries [12,13]. Its labor-intensive nature could result in highly physical activities which could be at variance with health and safety procedures, thereby leading to increased health risks for sawmill workers [14].

The present study therefore investigated the effect of noise exposure on cardiovascular functions of a cross section of sawmill workers in Nnewi metropolis, Anambra state, Nigeria and also proffered mitigation strategies to protect the workers from any resultant adverse cardiovascular health effects of the occupational noise pollution.

2. MATERIALS AND METHODS

2.1 Study Population

A total of 50 saw-mill workers (26 males, 24 females), aged between 18 - 40 years (30.84 ± 6.26 years) and 50 apparently healthy controls (18 males, 32 females; mean age, 26.32 ± 6.32 years) voluntarily participated in the study. The sawmill workers included machine operators, saw technicians, dust packers, overseers, wood loaders, machine off loaders and administrative staff randomly selected from sawmills located in Timber market in Nnewi metropolis. The control subjects were randomly selected from civil servants residing in rural Okofia community of Nnewi North Local Government Area, who were not occupationally exposed to high level of noise pollution. Information regarding the participants' demographic characteristics, health condition and lifestyle were obtained through a structured health and lifestyle questionnaire. The inclusion criteria of the study were: subjects within the age range of 18 to 40 years, spending at least six months in continuous employments in the sawmill, being physically and psychologically healthy, not smoking, not using alcohol, not taking drugs that can affect cardiovascular function, and not working in shifts. The exclusion criteria included; sawmill workers who had spent less than six months on the job, history of cardiovascular and respiratory diseases; sawmill workers who are part time workers; and those who did not give consent to participate in the study.

2.2 Sample Size Calculation

The sample size for the study was calculated based on the formula for comparison between two groups when endpoint is quantitative data: $n = 2SD^2 (Z_\alpha + Z_\beta)^2 / d^2$ [15]. Where: n = the sample size (sawmill workers who participated in the study); SD = 3.41 dBA (standard deviation from mean sawmill noise level of a previous study [16]); Z_α = 1.96 (Z score corresponding to 95% confidence interval); Z_β = 0.84 (Z score corresponding to 80% confidence interval); d = 2 dBA (the margin error that was accepted in this study). On applying; $\frac{2SD^2 (Z_\alpha + Z_\beta)^2}{d^2}$

$$n = \frac{2\,(3.4)^2 \times (1.96 - 0.84)^2}{2^2} = \frac{23.12 \times 7.84}{4} = \frac{181.26}{4} = 45.31$$

n = 45 + 5 (considering 10% drop out of study participants) = 50 participants

2.3 Sawmill Noise Measurements

A designed noise exposure evaluation questionnaire was used to retrieve data from the participants. The mean ambient noise level for each site was obtained using a sound meter (Model No. TA8152; Suzhou TASI Electronic Co. LTD, Suzhou City, China), prior to cardiovascular function test for each participant. For the sawmill workers, the measurements were done when the machines were in operation. The sound meter was hand-held such that the microphone attached to the sound meter faced the source of the sound and was also very close to the workers. The maximum and the minimum mode were chosen and the sound pressure level displayed their respective readings on the noise meter. The average reading was then taken for the different sites.

2.4 Anthropometric Measurements

Each participant's height was measured with the use of standiometer (SECA, Hamburg, Germany) with the shoulders in a relaxed position and the arms hanging freely. Weight was measured with the participant in light clothing without shoes using a standard scale. Body mass index was calculated as weight (kg) divided by the square of the height (m^2).

2.5 Measurement and Determination of Cardiovascular Parameters

2.5.1 Blood pressure and heart rate measurements

The subjects' blood pressure (BP) and heart rate (HR) were measured twice when the machines were in operation with the subject in a sitting position using the mercury-column sphygmomanometer and Omron electronic heart rate monitor (HEM-712C, Omron Health Care Inc., Vietnam) respectively. The average of the blood pressure and heart rate measurements were used for the data analysis.

2.5.2 Mean Arterial Pressure (MAP)

The mean arterial pressure was calculated as [(2 x diastolic blood pressure (DBP) + systolic blood pressure (SBP)]/3 [17].

2.5.3 Pulse Pressure (PP)

The Pulse pressure is the difference between systolic and diastolic blood pressures i.e. SBP - DBP [18].

2.5.4 Rate Pressure Product (RPP)

The rate pressure product provides an accurate reflection of the myocardial oxygen demand and workload [19]. In other words, it is a direct indication of the energy demand of the heart and thus a good measure of the energy consumption of the heart and calculated as HR x systolic blood pressure [20].

2.5.5 Cardiac Output

Cardiac output was calculated using the equation 4.3 × absolute VO2 + 4.5 [21].

2.6 Determination of Cardiorespiratory Fitness Parameters

2.6.1 Resting Absolute VO_2

Resting absolute VO2 (L/min) a measure of cardiovascular fitness was determined using the formula: Rate of energy expenditure at rest (kcal/min) / Caloric Equivalent per oxygen (kcal/L) [22]. The rate of energy expenditure at rest is calculated using Harris Benedict's equation for all adults [males: 66.47 + (13.75 x body weight (kg)) + (50 x Height (cm)) – (6.76 x Age (yrs)); Females: 655.1 + (9.56 x body weight (kg)) + (1.86 x Height (cm)) – (4.68 x Age (yrs)] [23]. Caloric equivalent per liter of oxygen consumed is expressed as respiratory exchange ratio for mixed diet = 0.82 equivalent to 4,825 kcal/liter of oxygen).

2.6.2 Resting Relative VO_2

Relative VO_2 was determined using the formula: (Absolute VO_2 x 1000) / body weight in kg.

2.7 Definition of Outcomes

High blood pressure was defined as systolic pressure equal to or higher than 140 mmHg and/or a diastolic pressure equal to or higher than 90 mmHg [24]. High MAP was defined as >100 mmHg, while low MAP was defined as <60 mmHg [25]. Normal range for PP was defined as 40 – 60 mmHg, thus values >60 mmHg were considered as high PP and values <40 were considered as low PP [26]. Normal RPP was defined as ≤12 mmHg.bpm, while abnormal RPP was defined as values >12 mmHg.bpm [27]. Slow HR (bradycardia) was defined as HR <60bpm, while fast HR (tachycardia) was defined as HR >100 bpm [28].

2.8 Data Analysis

Descriptive data were expressed as mean and standard deviation for continuous variables and percentages for categorical data. Comparative analysis between two groups was done using independent sample t-test, while that of multiple groups was done using one-way analysis of variance involving the Bonferroni post hoc multiple comparison test. Statistical significance was set at $P \leq 0.05$. All statistics were performed using SPSS for windows (version 20.0).

3. RESULTS

Table 1 shows the demographic and occupational characteristics of the study population. A total of 100 subjects were recruited for this study including 50 unexposed controls and 50 sawmill workers. The mean age of the participants was 28.58 years (ranged from 18 to 40 years) with a SD of ± 6.65 years. The mean age of the sawmill workers (30.84 ± 6.26 yrs) was significantly higher (p = 0.001) compared with that of the control (26.32 ± 6.32 yrs). Majority of the control, 62% were of age group 21-30 yrs; while most of the sawmill workers, 58% were of the age group 31-40 years. The Chi-square test of association indicated that the difference between the two groups with respect to percentage distribution of age groups was statistically significant (p = 0.001). Independent sample t-test indicated that there were no significant differences in mean height and weight between the two groups. However, the sawmill workers indicated significantly greater (p = 0.007) body mass index compared with the control (24.30 ± 3.01 vs. 22.09 ± 4.76 kg/m^2). In both groups most of the respondents (control, 86%; sawmill workers, 62%) had body mass index less than 25kg/m^2; the observed difference in BMI was statistically significant (p = 0.006) across the groups. Majority of the participants in the control group (64%) were females, while in the sawmill workers, majority (52%) were males. There was no significant difference in the sex distribution of the participants across study groups. Half of the respondents in the sawmill workers group (50.0%) had completed their secondary education, while majority (72%) of the control group had completed their tertiary education. All the respondents in both groups had one form of education or the other, however those with primary education were the lowest (2%) among the control, while those with tertiary education were the lowest (16%) among the sawmill workers. The observed difference between the two groups with respect to their level of education was statistically significant ($p < 0.001$).

The participants who had spent equal and less than 10 years in employment made up a greater proportion of the control (96%) and test (64%) groups respectively. Four percent of the control group and 36% of the sawmill workers had spent greater than 10 years duration of employment. The observed difference between participants with respect to duration of employment was statistically significant ($p < 0.001$). The mean number of years spent in employment was significantly higher ($p < 0.001$) in the sawmill workers (9.06 ± 1.80 yrs) compared with the control group (3.60 ± 2.92 yrs). A greater proportion (94%) of the control group worked ≤10 hours daily compared to those who worked >10 hours (6%). On the other hand, majority (64%) of the workers worked for >10 hours daily compared to those who worked ≤10 hours (36%). The difference observed across the two groups with respect to their daily working hours was significant ($p < 0.001$). The mean number hours spent at work by the sawmill workers (9.92 ± 1.80 hrs) was significantly greater ($p < 0.001$) compared with that of the control group (5.16 ± 2.21 hrs).

Fig. 1 shows the assessment results of the noise level in sawmill sites and control sites. The average noise level in the sawmill sites was 90.40 dB (range, 79 – 105 dB) compared with 50.30 dB (range, 41 – 59 dB) in control sites. Independent sample t-test indicated significantly higher ($p < 0.001$) mean noise level in the sawmill sites compared with the control sites.

Table 2 shows the cardiorespiratory indices of the control and sawmill workers. Independent sample t-test indicated significantly higher ($p < 0.05$) mean SBP, DBP, MAP, RPP and PP in sawmill workers compared with the control. On the other hand, significantly lower ($p < 0.05$) mean cardiac output, relative VO_2 and absolute VO_2 were observed in sawmill workers compared with the control. In contrast, no significant difference was observed in HR between the two groups.

Table 3 shows the cardiovascular health statuses of sawmill workers and control groups. Majority of the participants had normal SBP (94%), normal DBP (97%), normal mean arterial pressure (82%), normal PP (80%), normal rate pressure product (91%), normal HR (91%) and normal cardiac output (100%). There were no significant differences in the percentages of sawmill workers with normal SBP, DBP, PP, RPP, HR and CO when compared with the control group. In contrast, a significantly greater ($p = 0.029$) percentage of the control (96%) had normal MAP compared with the sawmill workers (68%). The incidence of systolic hypertension (12%) and diastolic hypertension (6%) were seen among the sawmill workers, but none in the control group. Abnormally high MAP was more frequent ($p < 0.001$) among the sawmill workers (32%) compared with the control (4%). The percentage of the control group 13 (26%) with abnormally low PP was significantly higher ($P < 0.05$) compared with the sawmill workers 2 (4%). The incidence of abnormally high PP among the sawmill workers was higher (8%, n = 4), but not statistically significant ($p = 0.058$) when compared with the control group (2%, n = 1). No significant difference was seen in the percentage of the sawmill workers whose values fell within the 'risk zone' of the RPP (6%, n = 3) compared with that of the control (12%, n = 6). The incidences of tachycardia and bradycardia were 10% (n = 5) and 8% (n = 4) respectively among the control group, but none was observed among the sawmill workers. Interestingly, none of the control and sawmill workers indicated abnormal cardiac output. The risk of sawmill workers experiencing SBP hypertension, abnormally high MAP, and lower incidence of abnormally low pulse pressure was at least 6, 13 and 9 times higher ($p < 0.05$) compared to the control respectively. Data also indicated a zero risk ($p < 0.05$) of the sawmill workers experiencing tachycardia or bradycardia compared with the control.

Table 4 shows the assessment of sawmill environment, noise preventive measures and some common complaints by sawmill workers. Data indicate that majority (58%) of the respondents rated the sawmill environment as very noisy, followed by those who rated it as noisy (42%). As expected, none rated it as quiet. All the respondents reported that there was no availability of hearing protectors and machinery noise control measures in their workplace. Of the workers, only 4 (8%) made use of hearing protectors, which they provided by themselves. A greater percentage complained they feel headache occasionally (42%), followed by those who felt headache often (34%) and always (24%). None of the respondents indicated not feeling headache at all. Majority (84%) of the workers complained of feeling annoyed and irritated by the noise in the sawmill. Most workers complained that they find it difficult to concentrate (78%) and that they feel physically and mentally stressed and exhausted after each day's job.

4. DISCUSSION

The present study indicated that the sawmill workers were exposed to higher mean noise level of 90.40 dB compared with the control who were exposed to an average noise level of 50.3 dB. The sawmill noise intensity was above the permissible noise levels of 85 dB stipulated for industries and factories over an 8-hour work shift and the stipulated limit of 70 dB for general environment [29]. This level of noise in the sawmills located in Nnewi metropolis constitutes a nuisance and threat to public health as it can result in several physiological and psychological disorders in workers as well as those living within the vicinity of the sawmills.

Our findings also indicated higher systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP) and pulse pressure (PP) levels in sawmill workers compared with the control group. This is in agreement with previous studies, which showed that occupational exposure to noise increases blood pressure [30-33]. The current study is however at variance with a previous study that found no significant relationship between blood pressure and noise exposure [34]. To the best of our knowledge, no previous studies have shown the effect of occupational noise pollution on MAP and pulse pressure. Mean arterial pressure is a measure of the pressure necessary for adequate perfusion of the organs of the body, and often considered a better indicator of perfusion to vital organs than systolic blood pressure [35]. A high MAP >100 mmHg indicates that there's a lot of pressure in the arteries. Elevated MAP has been reported to contribute to increased oxygen demand by the heart, ventricular remodeling, blood clot, vascular injury, end organ damage, and stroke [36]. Furthermore, pulse pressure, defined as the difference between SBP and DBP has been shown to be an easily measurable correlate of arterial stiffness and pulsatile hemodynamic load [37,38] as reflected in the disproportionate gap between SBP and DBP. It is reported to be a significant risk factor in the development of heart disease [39] and has even been shown to be more of a determinant of cardiovascular outcomes than the mean arterial pressure [39]. In fact, as little as a 10 mmHg increase in the pulse pressure increases the cardiovascular risk by as much as 20% [40]. Our data therefore support the hypothesis that increase in occupational noise is associated with increase in blood pressure and its components and may be an important predictor of cardiovascular outcomes.

In this study, the incidence of hypertension among the sawmill workers was low (systolic, 12%, diastolic, 6%), compared to a previous study that reported 32% prevalence of hypertension among sawmill workers in British Columbia [41]. The observed prevalence of hypertension among sawmill workers was also higher compared to the control who indicated no presence of both systolic and diastolic hypertension. In addition, abnormally high MAP was more prevalent among the sawmill workers (32%) compared with the control (4%). Unexpectedly, the sawmill workers indicated lower incidence (2%) of abnormally low PP compared with the control (26%). It is not clear the reason behind the lower incidence of this abnormal outcome among the sawmill workers compared to the unexposed control. It is however noteworthy that we used a lower range of 40 mmHg, whereas a previous study [39] has reported the use of a lower cut-off of <25% of SBP, which if used, would have completely removed the presence of abnormally low PP from both control and sawmill workers. Furthermore, the risk of sawmill workers experiencing SBP hypertension and abnormally high MAP, was at least 6 and 13 times higher compared to the control respectively. Previous studies have implicated noise as a risk factor of arterial hypertension [42-44]. Other studies have also showed that occupational noise exposure is associated with a higher risk of hypertension or with a sustained elevation of blood pressure [45,46].

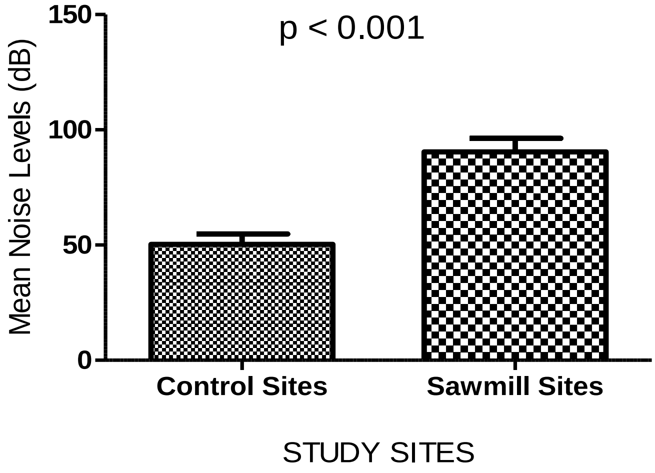

Fig. 1. Mean noise levels in the sawmill and control sites

Table 1. Demographic and occupational characteristics of the study population

Characteristics	Control N = 50 n (%) or Mean ± SD	Sawmill Workers N = 50 n (%) or Mean ±SD	Total N = 100 n (%) or Mean ±SD	Test Statistics	p - Value
Age (years)					
≤20	8 (16.0)	4 (8.0)	12 (12.0)		
21 – 30	31 (62.0)	17 (34.0)	48 (48.0)	X^2, 13.52	0.001
31 – 40	11 (22.0)	29 (58.0)	40 (40.0)		
Mean Age (years)	26.32 ± 6.32	30.84 ± 6.26	28.58±6.65	t-test, -3.59	0.001
Mean Height (meters)	1.77 ± 0.51	1.65 ± 0.07	1.71 ± 0.37	t-test, 1.74	0.084
Mean Weight (kg)	65.50±12.72	66.30 ± 9.12	65.90±11.02	t-test, -0.36	0.719
Body Mass Index					
<25 kg/m^2	43 (86.0)	31 (62.0)	74 (74.0)	X^2, 7.48	0.006
≥25 kg/m^2	7 (14.0)	19 (38.0)	26 (26.0)		
Mean Body Mass Index (kg/m^2)	22.09 ± 4.76	24.30 ± 3.01	23.20±4.11	t-test, -2.77	0.007
Gender					
Males	18 (36.0)	26 (52.0)	44 (44.0)	X^2,2.59	0.079
Females	32 (64.0)	24 (48.0)	56 (56.0)		
Educational Status					
Primary	1 (2.0)	17 (34.0)	18 (18.0)		
Secondary	13 (26.0)	25 (50.0)	38 (38.0)	X^2,35.96	<0.001
Tertiary	36 (72.0)	8 (16.0)	44 (44.0)		
Duration of Employment					
≤10 yrs	48 (96.0)	32 (64.0)	80 (80.0)	X^2,16.0	<0.001
>10 yrs	2 (4.0)	18 (36.0)	20 (20.0)		
Mean Duration of Employment (years)	3.60 ± 2.92	9.06 ± 3.85	6.33 ± 4.36	t-test, -7.98	<0.001
Daily Working Hours					
≤10	47 (94.0)	18 (36.0)	65 (65.0)	X^2, 36.96	<0.001
>10	3 (6.0)	32 (64.0)	35 (35.0)		
Mean Daily Working Hours	5.16 ± 2.21	9.92 ± 1.80	7.54 ± 3.12	t-test, -11.77	<0.001

Table 2. Baseline Cardiorespiratory function parameters of the study groups

Parameters	Control	Sawmill Workers	t – Statistics	p – Value
Systolic Blood Pressure (mmHg)	116.52 ± 11.23	130.44 ± 11.43	-6.14	<0.001*
Diastolic Blood Pressure (mmHg)	72.28 ± 9.20	77.92 ±8.29	-3.22	0.002*
Mean Arterial Pressure (mmHg)	87.08 ± 9.27	95.14 ± 9.04	-4.40	<0.001*
Pulse Pressure (mmHg)	44.24 ± 7.98	52.52 ± 7.61	-5.30	<0.001*
Rate Pressure Product (x 10^3 mmHg.bpm)	8.88 ± 1.99	9.55 ± 1.46	-1.92	0.05*
Heart Rate (bpm)	76.08 ± 14.23	73.14 ± 8.58	1.25	0.214
Cardiac Output (L/min)	5.14 ± 0.11	5.09 ± 0.10	2.05	0.043*
Relative VO_2 (ml/kg/min)	2.32 ±0.44	2.11 ± 0.42	2.41	0.018*
Absolute VO_2 (L/min)	0.15 ± 0.02	0.13 ± 0.02	2.05	0.043*

*****_Significant (p ≤ 0.05)_

Table 3. Distribution of subjects based on classification of their cardiovascular health statuses

Parameters	Control N = 50 n (%)	Sawmill Workers N = 50 n (%)	Total N = 50 n (%)	X^2	RR (CI)	P – Value
SBP						
Normal	50 (100)	44 (88.0)	94(94.0)	6.38	2.13 (1.06-2.13)	0.012
Hypertension	0 (0)	6 (12.0)	6 (6.0)			
DBP						
Normal	50 (100)	47 (94.0)	97 (97.0)	3.09	2.06 (0.62-2.06)	0.079
Hypertension	0 (0)	3 (6.0)	3 (3.0)			
MAP						
Normal	48 (96.0)	34 (68.0)*	82 (82.0)	13.28	2.14 (1.42-2.49)	<0.001
High	2 (4.0)	16 (32.0)*	18 (18.0)			
PP						
Normal	36 (72.0)	44 (88.0)	80 (80.0)			
Low	13 (26.0)	2 (4.0)*	15 (15.0)	8.78	0.24(0.04-0.78)	0.003
High	1 (2.0)	4 (8.0)	5 (5.0)	1.19	1.45 (0.52-1.84)	0.274
RPP						
Normal	44 (88.0)	47 (94.0)	91 (91.0)	1.09	0.64 (0.17-1.41)	0.295
Risk Zone	6 (12.0)	3 (6.0)	9 (9.0)			
HR						
Normal	41 (82.0)	50 (100)	91 (91.0)			
Tachycardia	5 (10.0)	0 (0)	5 (5.0)	5.73	0 (0 – 1.0)	0.017
Bradycardia	4 (8.0)	0 (0)	4 (4.0)	4.64	0 (0 – 1.14)	0.013
CO						
Normal	50 (100)	50 (100)	100 (100)	-	-	-
Low	0 (0)	0 (0)	0 (0)			

*****_Significant at p ≤ 0.05. Abbreviations: SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; MAP, Mean Arterial Pressure; PP, Pulse Pressure; RPP, Rate Pressure Product, HR, Heart Rate, CO, Cardiac Output_

The elevated level of blood pressure and its components among sawmill workers may be attributed to the activation of the sympathetic nervous system resulting in the release of epinephrine, as well as the release of stress hormones when the workers are exposed to the high intensity sawmill noise [47]. Our results indicated that symptoms such as headache, noise-induced annoyance and stress were much more prevalent among noise exposed subjects than in their unexposed counterparts. These findings may suggest that the increase in blood pressure (BP) is attributable to the headache, stress and noise annoyance experienced by majority of the workers. Headaches are one of the most common neurological problems which are painful and debilitating, and cause a substantial health and social burden on the society [48]. Noise induced annoyance causes stress characterized by increased levels of stress hormones such as cortisol and catecholamines [48]. Stress may in turn cause a pathophysiological adaptation, such as increased blood pressure, which may ultimately manifest as arterial hypertension [48]. A previous study has also reported that there was a positive and significant relationship between the annoyance caused by exposure to traffic noise and the increased risk of high blood pressure [49].

Contributory to the higher prevalence of noise annoyance, headache and stress could be the failure of majority (92%) of the workers to use personal protective device such as ear muffs and the unavailability and lack of usage of machinery noise control measures in the sawmill workplaces. These measures, if put in place, are expected to mitigate the impact of the noise on the workers. The low usage of hearing protectors and lack of machinery noise control measures could be linked to the inability of the employers to provide these safety gadgets due to poor economic condition of the country, which has played a major role in the availability and affordability of these important protective devices. In addition, majority of the workers (64%) worked longer hours in which they are exposed to noise pollution for more than 10 hours daily and under very poor working conditions. Traditionally, this industry is known as one of the most dangerous repetitive work settings, labor-intensive and production-oriented industries [50]. Its labor-intensive nature could result in highly physical activities which could lead to exhaustion, increased level of stress and feeling of headache.

Table 4. Assessment of sawmill environment, noise preventive measures and some common complaints by sawmill workers

Parameters	Number	Frequency (%)
Rating of Sawmill Environment		
Quiet	0	0
Noisy	21	42
Very Noisy	29	58
Availability of Hearing Protectors		
Yes	0	0
No	50	100
Usage of Hearing Protectors		
Yes	4	8
No	46	92
Availability of Machinery Noise Control Measures		
Yes	0	0
No	50	100
Feeling of Headache		
Always	12	24
Often	17	34
Occasionally	21	42
Not at all	0	0
Feeling of Noise Annoyance		
Yes	42	84
No	8	16
Difficulty in Concentration		
Yes	39	78
No	11	22
Feeling of Stress/Exhaustion		
Yes	37	74
No	13	26

The sawmill workers also indicated significantly higher rate pressure product (RPP), lower resting cardiac output (CO) and oxygen consumption (VO_2); and no significant difference in heart rate (HR) when compared with the control. The lack of significant difference in mean HR between the two groups is in contrast with previous studies which have shown higher HR values among workers exposed to high occupational noise [13,45,51]. Rate pressure product gives an accurate reflection of the myocardial oxygen demand [19]. To our knowledge, no previous study has reported the effect of occupational noise pollution on RPP or compared RPP between sawmill workers and their unexposed control. The higher RPP observed among sawmill workers is therefore a reflection of the increase in their mean arterial pressure and the resultant cardiac oxygen demand compared with the control. Surprisingly, the sawmill workers indicated a lower resting cardiac output and VO_2 despite the expected greater level of cardiac oxygen demand as suggested by the higher RPP level. These findings suggest that the lower CO and VO_2 may not be a function of their metabolic demands, but a reflection of their poor cardiorespiratory fitness. Traditionally, HR, BP, CO and VO_2 are included among the indicators of cardiovascular fitness [52]. Thus, a cardiovascular fit individual is expected to have a decreased HR, lower BP, increased CO, increased SV, and increased VO_2 at rest compared to a non-cardiovascular fit person. The present findings which indicated higher BP, lower CO and lower VO_2 at rest suggest that the sawmill workers may have lower cardiovascular fitness compared with the unexposed control. It is noteworthy that although lower mean CO and VO_2 were observed among sawmill workers exposed to noise; these values were within the normal resting range of CO and VO_2.

Some of the limitations of our study include; the relatively low sample size from the sawmill factories when compared with other previous studies, hence the need for further studies with larger sample sizes. The measurements used to classify some of the sawmill workers as hypertensive were based on two blood pressure measurements taken at one single occasion. Such approach may have created a selection bias and misclassified healthy individuals into hypertensive workers. Furthermore, we could not adjust for factors traditionally associated with blood pressure during the comparative analysis between the two groups. This calls for caution in hasty interpretation of some of the outcomes of our study which may not actually be due to the effect of sawmill noise exposure.

5. CONCLUSION

The present study indicated higher SBP, DBP, MAP, PP and RPP, but lower resting cardiac output and VO_2 levels in workers who were exposed to an intense sawmill noise level compared with the unexposed control group. Similarly, the incidences of both systolic and diastolic hypertension and abnormally high MAP were greater in sawmill workers compared to the control. Furthermore, the risk of SBP hypertension and abnormally high MAP, by sawmill workers was higher compared to the control. Our study helped in revealing the adverse effects of noise not only on blood pressure, but other blood pressure components and cardiovascular parameters. Understanding the harmful effects of noise pollution on cardiovascular health will help sawmill workers and their employers to take all the appropriate measures to prevent or to reduce the possible health risks. These measures will include increasing workers' awareness about the occupational effects of noise on health, enlightening the workers on the need to wear hearing protectors, to enforce laws guiding occupational noise levels in such industries like sawmills and enlightening the operators of the need to provide machinery noise propagation control measures to reduce the noise coming from these machines. Furthermore, worksite health programs including monitoring of BP and other cardiovascular parameters should be adopted as a health management strategy for worker where high noise level exposure is unavoidable.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

Before the commencement of the study, subjects were informed (written and oral) of the experimental procedures and their consents were obtained before participation.

ETHICAL APPROVAL

The Experiments and Ethics Committee of the College of Health Sciences of the University approved the study. The guidelines and recommendations for studies involving humans were strictly adhered to, in accordance with the ethical standards laid down in the 1964 declaration of helsinki."

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Nasiri P, Esmaeelpour MM, Foroushani AR, Ebrahimi H, and Salimi Y. Occupational noise exposure evaluation in drivers of bus transportation of Tehran City. IranianJournal of Health & Environment, 2009;2:124–131.
2. Münzel T, Gori T, Babisch W, Basner M. Cardiovascular effects of environmental noise exposure. Eur Heart J. 2014;35(13):829–836. doi: 10.1093/eurheartj/ehu030.
3. Center for Disease Control. National Institute for Occupational Safety and Health Review on 'Reducing noise exposure – Guidance and Regulations'. Available:https://www.cdc.gov/niosh/topics/noise/reducenoiseexposure/regsguidance.html. Assessed on 01/08/ 2021.
4. Aruofor RO. The Nigerian Forestry Outlook Study. 2001. Available at http://www.fao.org/forestry/FON/FONS/outlook/Africa/AFRhom-e.stm. Assessed 01/08/2021
5. Fuwape JA. Developments in wood-based industries in Nigeria. Foresea Miyazaki. 1998;2:575-585.
6. Davies HW, Teschke K, Kennedy SM., Hodgson MR, Demers PA. Occupational noise exposure and hearing protector use in Canadian lumber mills. Journal of Occupational and Environmental Hygiene, 2008;6(1):32-41.
7. Aremu AS, Aremu AO, Olukanni DO. Assessment Of Noise Pollution From Sawmill Activities In Ilorin, Nigeria. Nigerian Journal of Technology (NIJOTECH), 2015;34(1):72-79.
8. Alamgir H, Tompa E, Koehoorn M, Ostry A, Demers PA. Cost and Compensation of work related injuries in British Columbia saw mills. Occup Environ Med, 2006; 64: 196-201.
9. Owoyemi JM, Falemara BC, Owoyemi AJ. Noise pollution and control in mechanical processing wood industries. Biomedical Statistics and Informatics, 2017;2(2):1–11.
10. Ajayeoba AO, Olanipekun AA, Raheem WA, Ojo OO,Soji–Adekunle AR. Assessment of Noise Exposure of Sawmill Workers in Southwest, Nigeria. Sound and Vibration. 2021; 55(1): 69-85.
11. Uzorh AC. Analysis of industrial noise in a manufacturing company. International Journal of Engineering and Sciences, 2014;3(3):45–46.
12. Top Y, Adanur H, Öz M. Comparison of practices related to occupational health and safety in microscale wood-product enterprises. Safety Science, 2016;82:374–381. DOI 10.1016/j.ssci.2015.10.014.
13. Mong'are RO, Mburu C, Kiiyukia C. Assessment of occupational safety and health status of sawmilling industries in Nakuru County, Kenya. International Journal of Health Sciences, 2017; 5(4):75–102.
14. Thepaksorn P, SiriwongW, Neitzel RL, Somrongthong R, Techasrivichien T. Relationship between noise-related risk perception, knowledge, and the use of hearing protection devices among para rubber wood sawmill workers. Safety and Health at Work, 2017;9(1): 25–29.
15. Charan J and Biswas T. How to calculate sample size for different study designs in medical research. Indian Journal of Psychological Medicine, 2013;35(2):121–126.
16. Ugbebor JN and Yorkor B. Assessment and Evaluation of Noise Pollution Levels in Selected Sawmill Factories in Port Harcourt, Nigeria. International Journal on Emerging Technologies. 2015;6(2):01-08.
17. Iaizzo PA. Blood pressure, heart rate and diagnosis. Handbook of Cardiac Anatomy, Physiology, and Devices. Totowa, New Jersey: Humana Press, 2005;182.
18. Levanovich PE, Diaczok A, Rossi NF. Clinical and Molecular Perspectives of Monogenic Hypertension. Curr Hypertens Rev. 2020;16(2):91-107

19. Nagpal S, Walia L, Lata H, Sood A, Ahuja GK. Effects of exercise on rate pressure product in premenopausal and post-menopausal women with coronary artery disease. Indian Journal of Physiology & Pharmacology. 2007;51(3):279-83.
20. Ansari M, Javadi H, Pourbehi M, Mogharrabi M, Rayzan M, Semnani S, Jallalat S, Amini A, Abbaszadeh M, Barekat M, Nabipour I, Assadi M. The association of rate pressure product (RPP) and myocardial perfusion imaging (MPI) findings: a preliminary study. Perfusion. 2012; 27(3): 207-13.
21. Agostoni P, Vignati C, Gentile P, Boiti C, Farina S, Salvioni E, Mapelli M, Magrì D, Paolillo S, Corrieri N, Sinagra G, Cattadori G. 2017. Reference values for peak exercise cardiac output in healthy individuals. Chest 2017;151:1329-1337.
22. Laboratory #5. Fuel consumption and resting metabolic rate -Indirect Calorimetery.
Available:https://leap.aacu.org/toolkit/wp-content/uploads/2014/06/Engaging-Contingent-Faculty-with-Assignment-Design.pdf. Assessed on 01/08/2021.
23. Harris JA, Benedict FG. A biometric study of basal metabolism in man. Washington DC: Carnegie Ins. 1919;266.
24. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, et al. Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. Hypertension. 2003;42(6):1206–52.
25. Null R. Understanding Mean Arterial Pressure. Healthline Publications; 2018. Available at https://www.healthline.com/health/mean-arterial-pressure
Assessed on 01/08/2021.
26. Seladi-Schulman J. Pulse Pressure Calculation Explained. Healthline Publications; 2018.
Available:https://www.healthline.com/health/pulse-pressure.
Assessed on 01/08/2021.
27. White WB. Heart rate and rate pressure product as determinants of cardiovascular risk in patients with hypertension. Am J Hypertens. 1999;S-5:12-50.
28. All About Heart Rate (Pulse). American Heart Association; 2015.
Available:https://www.heart.org/en/health-topics/high-blood-pressure/the-facts-about-high-blood-pressure/all-about-heart-rate-pulse.
Assessed 21/08/2021.
29. NESREA. National Environmental (Noise Standards and Control) Regulations, 2009. Federal Republic of Nigeria Official Gazette. S.I. No. 35, FGP 104/102009/1,000 (OL 60), National Environmental Standards and Regulations Enforcement Agency, Federal Government Printer, Nigeria, 2009;96:67.
30. Lee JH, Kang W, Yaang S, Choy N, Lee C. Cohort study for the effect of chronic noise exposure on blood pressure among male workers in Busan, Korea. Am J Ind Med, 2009; 52:509-517.
31. Chang TY, Su TC, Lin SY, Jain RM, Chan CC. Effects of occupational noise exposure on 24-hour ambulatory vascular properties in male workers. Environ Health Perspect, 2007;115:1660-1664.
32. Lusk SL, Gillespie B, Hagerty BM, Ziemba RA. Acute effects of noise on blood pressure and heart rate. Arch Environ Health. 2004;59(8):392-399
33. Sakata K, Suwazono Y, Harada H, Okubo Y, Kobayashi E, Nogawa K. The relationship between shift work and the onset of hypertension in male Japanese workers. J Occup Environ Med. 2003;45:1002-1006
34. Hessel PA, Sluis-Cremer GK. Occupational noise exposure and blood pressure: longitudinal and cross-sectional observations in a group of underground miners. Arch Environ Health, 1994; 49:128-134.
35. DeMers D and Wachs D. Physiology, Mean Arterial Pressure. StatPearls Publishing, Treasure Island (FL); 2021.
PMID: 30855814.
Available:https://www.ncbi.nlm.nih.gov/books/NBK538226.
36. Wehrwein EA and Joyner MJ. Autonomic Nervous System in *Handbook of Clinical Neurology*; 2013.
37. Franklin SS, Gustin WIV, Wong ND. et al. Hemodynamic patterns of age-related changes in blood pressure. Circulation.1997;96:308-315.
38. Smulyan H and Safar ME. Systolic blood pressure revisited. J Am Coll Cardiol. 1997;29:1407-1413.
39. Travis D. Homan; Stephen Bordes; Erica Cichowski. Physiology, Pulse Pressure. In:

StatPearls [Internet]: Treasure Island (FL); *StatPearls Publishing;* 2021.
PMID: 29494015.
Available:https://www.ncbi.nlm.nih.gov/books/NBK482408.

40. Blacher J, Evans A, Arveiler D, Amouyel P, Ferrières J, Bingham A, Yarnell J, Haas B, Montaye M, Ruidavets JB, Ducimetière P., PRIME Study Group. Residual cardiovascular risk in treated hypertension and hyperlipidaemia: the PRIME Study. J Hum Hypertens. 2010;24(1):19-26.
41. Sbihi H, Davies H W, Demers P A. Hypertension in noise-exposed sawmill workers: a cohort study. Occupational and Environmental Medicine; London 2008;65(9):643.
DOI:10.1136/oem.2007.035709
42. McCunney RJ, Meyer JD. Occupational exposure to noise. In: Rom WN, ed. Environmental and Occupational Medicine. 3rd ed. Lippincot-Raven, Philadelphia, New York, USA, 1998;1345-57.
43. Jovanović J, Jovanović M. The effect of noise and vibration on the cardiovascular system in exposed workers and possibilities of preventing their harmful effects. Med Pregl. 1994;47:344-7. [7565325]
44. Lang T, Fouriaud C, Jacquinet- Salord MC. Length of occupational noise exposure and blood pressure. Int Arch Occup Environ Health 1992;63:369-72. [1544682]
doi:10. 1007/BF00386929
45. Tomei G, et al. Occupational exposure to noise and the cardiovascular system: a meta-analysis [J]. Sci Total Environ 2010;408(4):681–689.
46. Wu X, Yang D, Fan W, Fan C, Wu G. Cardiovascular risk factors in noise-exposed workers in china: Small area study[J]. Noise Health, 2017;19(91):245–253.
47. Kelsey RM, Blascovich J, Tomaka J, Leitten CL, Schneider TR, Wiens S. Cardiovascular reactivity and adaptation to recurrent psychological stress: effects of prior task exposure. Psychophysiology, 1999;36:818-831.
48. NICE. Diagnosis and Management of Headaches in Young People and Adults. Clinical Guideline 150, National Institute for Health and Clinical Excellence, United Kingdom, 2012.
49. Münzel T, Sørensen M. Noise Pollution and Arterial Hypertension. European Cardiology Review. 2017;12(1):26–9.
50. Ndrepepa A, Twardella D. Relationship between noise annoyance from road traffic noise and cardiovascular diseases: A meta-analysis. Noise Health. 2011;13: 251–9.
51. Kristal-Boneh E, Melamed S, Harari G, Green MS. Acute and chronic effects of noise exposure on blood pressure and heart rate among industrial employees: the Cordis Study. Arch Environ Health. 1995; 50(4):298–304.
52. Dimkpa U. Post-exercise heart rate recovery: An index of cardiovascular fitness. JEP online 2009;12(1):19-22.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/73702