

## NOISE-INDUCED HEALTH RISKS AND ENVIRONMENTAL DISRUPTIONS: THE PROTECTIVE ROLE OF EAR PROTECTION IN SAWMILL OPERATIONS

AULIA ASMAN<sup>1\*</sup>, SITI FATIMAH<sup>2</sup> AND INDANG DEWATA<sup>2</sup>

<sup>1</sup>Department of Nursing, Faculty of Psychology and Health, Universitas Negeri Padang, 25171 North Padang, Padang City, West Sumatra, Indonesia. <sup>2</sup>Environmental Science Program, Graduate School, Universitas Negeri Padang, 25171 North Padang, Padang City, West Sumatra, Indonesia.

\*Corresponding author: [aulia.asman@fjk.unp.ac.id](mailto:aulia.asman@fjk.unp.ac.id)

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**Abstract:** This research aims to evaluate the effect of noise on workers' cardiac and diastolic blood pressure and explore the role of ear protection in mitigating the impact of noise in Taratak Kampung Baru, Pariaman City. The research used a cross-sectional observational design with 20 respondents from a sawmill. Data was collected through questionnaires and blood pressure measurements before and after noise exposure. In addition, this research also examined the impact of noise pollution on wildlife habitats around the sawmill location, including bird species and small mammals that are indicators of environmental quality. Bivariate analysis was conducted using the Fisher Exact Test to test the relationship between noise intensity, ear protection uses, and blood pressure. The results showed that workers who did not use ear protection experienced a significant increase in cardiac and diastolic blood pressure after exposure to noise > 85 dB. In contrast, workers who used ear protection showed lower blood pressure. These findings also indicate a correlation between high noise and a decrease in local bird populations, which is an early sign of ecosystem disturbance. This research suggests that high-intensity noise not only contributes to increased blood pressure in workers but also affects environmental quality more broadly.

Keywords: Noise pollution, blood pressure, ear protection, ecosystem disturbance, sawmill workers.

### Introduction

Unwanted noise plays a significant role in public health issues, leading to physiological, pathological, and communication disorders. Defined as sound that occurs at certain levels and frequencies hazardous to human health and environmental comfort, it is regulated by the Decree of the Minister of State for the Environment No. 48/1996 (Loe, 2023; Cahyadi *et al.*, 2023; Ferdyan *et al.*, 2023). According to the Regulation of the Minister of Manpower No. 51/MEN/1999, ACGIH® (2018), and SNI 16-7063-2004, the permissible noise limit is 85 dB for workers exposed for eight hours daily or 40 hours weekly. A notable source of harmful noise is logging machinery, with its operation frequently contributing to noise levels above acceptable thresholds (Ranga *et al.*, 2014; Butkus *et al.*, 2015; Lie *et al.*, 2016).

Sawmill environments are typically noisy due to the heavy machinery used for logging and cutting wood, which is often sourced from nearby forests or plantations. The specific type of wood processed in this sawmill comes from forests located upstream in the 2X11 Kayu Tanam Sub-district in Padang Pariaman Regency. The transportation route to the sawmill involves cross-district roads in Padang Pariaman Regency, contributing to the overall environmental impact of the operation. This increases health risks, particularly through excessive noise exposure. Environmental factors such as proximity to residential areas, minimal vegetation, and inadequate infrastructure can exacerbate noise levels (Ferrini *et al.*, 2020). Additionally, poor spatial planning and the absence of physical barriers such as sound-absorbing walls, allow noise to spread to

work areas and nearby communities (Lercher, 2019). This continuous, uncontrolled noise can lead to sleep disorders, stress, and increased risks of cardiovascular disease in workers and surrounding residents (Stansfeld *et al.*, 2000).

Noise-related health risks depend on the intensity, frequency, and duration of exposure (Basner & McGuire, 2018). Research has demonstrated that noise exposure, particularly in industrial environments like sawmills, significantly impacts health, with high blood pressure being a common outcome (Yousif & Ali, 2017). Over 70% of industrial workers are exposed to dangerous noise levels, facing both auditory and non-auditory health impacts, including elevated blood pressure and mental illness (Omari *et al.*, 2013; Idrobo-Avila *et al.*, 2018; Themann & Masterson, 2019; Sheppard *et al.*, 2020; Pretzsch *et al.*, 2021).

Noise is perceived by the brain as a stressor, triggering the release of hormones like adrenaline and cortisol, which affect heart rate and blood pressure (Westman & Walters, 1981; Lusk *et al.*, 2004). Prolonged noise exposure increases the risk of cardiovascular disease. Workers exposed to high noise levels for less than five years have tripled the risk of stroke and a 60% higher chance of dying from cardiovascular disease within 10 years compared to those not exposed (Lie *et al.*, 2016). Studies at Ahmad Yani Airport and in Semarang also linked noise levels to increased blood pressure and a higher prevalence of hypertension (Rosidah, 2004; Siswati & Adriyani, 2017; Sutiningsih *et al.*, 2020).

This research aims to evaluate the effect of noise on workers' cardiac and diastolic blood pressure and explore the role of ear protection in mitigating the impact of noise in Taratak Kampung Baru, Pariaman City. The novelty of the research lies in understanding the impact of noise on workers' health, particularly heart rate and diastolic blood pressure, in the sawmill industry. The research highlights the critical importance of using hearing protection to mitigate the effects of noise while also exploring how environmental conditions surrounding

the workplace contribute to noise exposure. By addressing factors such as machine layout, sound-dampening technologies, and vegetation planting, this research contributes to environmental science by proposing solutions to reduce noise risks for both workers and the surrounding community.

## Research Methods

This type of research is a cross-sectional observational research design (Delaney *et al.*, 2017; Vreman *et al.*, 2020; Kooshanfar *et al.*, 2022). Cross-sectional observational research or cross-sectional study is a type of research conducted by observing variables over a certain period to understand the relationship between different factors in a population (Mann, 2003). This method was used to evaluate the relationship between noise and pressure in blood vessels in the sawmill at the research location, Pariaman City. The research was conducted from May to June 2023 at the location. The research sample consisted of 20 respondents of sawmills with inclusion criteria, who worked the morning shift from 09:00 to 18:00 WIB.

A calibrated Sound Level Meter (SLM) was used to ensure accurate and consistent noise level measurements. The SLM was positioned one meter from the wood-cutting machine to record noise levels at 10-minute intervals during both the heating (80 dB) and operating (90 dB) stages. The precision of this equipment is  $\pm 1.5$  dB, ensuring reliable data for analysis. The noise level in the research area was 80 dB when the wood-cutting machine was heated and 90 dB when the machine was operating (Loe, 2023), with the research population being workers working at the location. Samples were taken based on fulfilling the inclusion and exclusion criteria and filling out the questionnaire.

Inclusion criteria included workers between 20 and 45 years of age who were non-smokers and had no pre-existing cardiovascular or hearing conditions. Exclusion criteria included workers who used ear protection or worked night shifts, as this could interfere with noise exposure comparisons. The research variables

consist of: (1) Independent variables, namely Unwanted Sound (measured at 80 dB when the wood-cutting machine is heated and 90 dB when the machine is working) and (2) Dependent variables, namely blood vessel pressure (heart contraction and diastolic) before and after noise exposure (Salameh, 2005).

Types of data and data collection included: (1) Primary data collected through questionnaires and blood vessel pressure measurements before and after work and (2) Secondary data obtained from related data at the research location. Blood pressure was measured using a validated digital sphygmomanometer at the beginning and end of each workday, ensuring accuracy in pre- and post-exposure readings. Each worker’s blood pressure was measured three times, with the average value recorded for analysis. The questionnaire was designed to collect information on the characteristics of respondents and the impact of noise on their health. More clearly, it can be seen in Table 1.

The data analysis technique in this research consists of univariate analysis used to assess the characteristics of respondents individually. This technique analyses each variable separately to provide a basic statistical description of the

frequency distribution, percentage, average, median, and range of values of the variable (Gnanadesikan, 2011). This analysis helps in understanding the profile of respondents and the variables observed. The following is Table 2 for univariate analysis of respondent characteristics.

Fisher Exact Test (Fernández-Cásseres & Russi-Pulgar, 2023) is used to test the relationship between two categorical variables in small samples. This test is applied when the Chi-Square assumption cannot be met, especially in data with very small frequencies or limited samples. Fisher Exact Test provides a p-value to determine whether there is a significant relationship between the variables being tested. More clearly, it can be seen in Table 3.

**Results and Discussion**

**Research Results**

Based on the results of univariate analysis, this research describes the characteristics of respondents, including their ages, duration of work each day, use of ear protectors, and systolic blood pressure before noise exposure. Table 4 and Figure 1 provide details of the distribution of respondent characteristics.

Table 1: Questionnaire for respondents

No.	Questions	Answer Options
1	Ages	20-30 years
		31-40 years
		41-50 years
		> 50 years
2	Duration of work each day	≤ 8 hours
		> 8 hours
3	Use of ear protection	Using
		Not using
4	Systolic blood pressure before exposure to noise	< 120 mmHg
		120-129 mmHg
		130-139 mmHg
		≥ 140 mmHg

Source: Skogstad et al. (2016); Li et al. (2019)

Table 2: Univariate analysis of respondent characteristics

Characteristics	Category	Frequency (N)	Percentage (%)
Ages	20-30 years	5	25.0
	31-40 years	8	40.0
	41-50 years	5	25.0
	> 50 years	2	10.0
<b>Total</b>		<b>20</b>	<b>100.0</b>
Duration of work each day	≤ 8 hours	0	0.0
	> 8 hours	20	100.0
<b>Total</b>		<b>20</b>	<b>100.0</b>
Use of ear protection	Using	5	25.0
	Not using	15	75.0
<b>Total</b>		<b>20</b>	<b>100.0</b>
Systolic blood pressure before exposure to noise	< 120 mmHg	5	25.0
	120-129 mmHg	8	40.0
	130-139 mmHg	5	25.0
	≥ 140 mmHg	2	10.0
<b>Total</b>		<b>20</b>	<b>100.0</b>

Source: Skogstad *et al.* (2016); Li *et al.* (2019)

Table 3: Fisher’s exact test results

Variable 1	Variable 2	Frequency (N)	Percentage (%)	p-value
Systolic blood pressure before exposure to noise	Use of ear protection	≤ 85 dB, using	10	50.0
		≤ 85 dB, not using	2	10.0
		> 85 dB, using	7	35.0
		> 85 dB, not using	1	5.0
<b>Total</b>		<b>20</b>	<b>100.0</b>	<b>0.045</b>

Source: Skogstad *et al.* (2016); Li *et al.* (2019)

Table 4: Distribution of ages, duration of work each day, use of ear protectors, and systolic blood pressure before noise exposure

Ages (Years)	N	Duration of Work Each Day	Use of Ear Protection	Systolic Blood Pressure Before Exposure to Noise (mmHg)	Percentage (%)
20-30	5	> 10 hours	Using	110	25.0
31-40	8	> 10 hours	Not using	120	40.0
41-50	5	> 10 hours	Using	130	25.0
> 50	2	> 10 hours	Not using	140	10.0
<b>Total</b>	<b>20</b>	<b>100%</b>	<b>-</b>	<b>-</b>	<b>100.0</b>

Source: Data analysis results (2024)

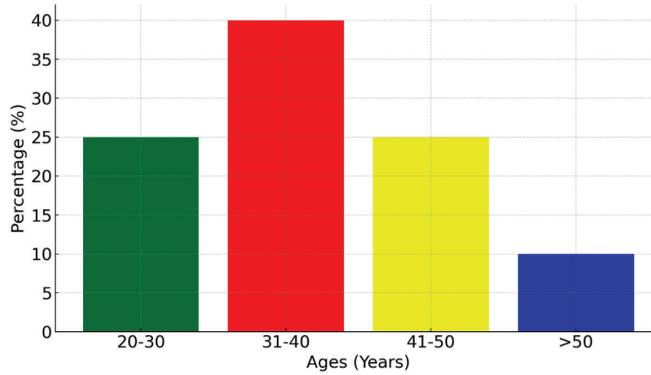


Figure 1: Distribution graph of respondent characteristics by age group

Based on Table 4 and Figure 1, most of the sawmill workers in Taratak Kampung Baru, Pariaman City are aged between 31-40 years, with a percentage of 40%. All respondents work more than 10 hours each day, indicating long and intense working hours. In this noisy working environment, only a few workers use ear protection while the majority, especially those aged 31-40 years, do not use protection. Systolic blood pressure measured before noise exposure ranged from 110 mmHg to 140 mmHg. As many as 10% of respondents had the highest systolic blood pressure at 140 mmHg, indicating a significant health risk due to noise exposure. This condition is exacerbated by the long working hours and the low use of ear protection, which should be the main protective equipment in a high-noise working environment.

A working environment without adequate protective facilities and a lack of awareness and

obligation to use ear protection puts workers at high risk of developing health problems such as hypertension and hearing loss. This underlines the importance of interventions such as restructuring the work environment, increasing awareness of the importance of ear protection, and stricter health monitoring to reduce the negative impacts of continuous noise exposure.

In this research, the distribution of systolic blood pressure after noise exposure was analysed based on the intensity of noise faced and the use of hearing protection by workers. Table 5 and Figure 2 provide an overview of the relationship between the use of hearing protection and noise levels on systolic blood pressure after noise exposure.

The results of Table 5 and Figure 2 show that the highest systolic blood pressure, which is 150 mmHg, occurred in respondents who were exposed to noise of more than 85 dB and did not

Table 5: Distribution according to the use of hearing protection and systolic blood pressure after noise exposure

Systolic Blood Pressure Before Exposure to Noise (mmHg)		Noise Intensity				Use of Ear Protection	
		≤ 85dB	%	> 85dB	%	N	%
High	150	-	-	10	50.0	10 (Not using)	85.0
	140	2	10.0	7	35.0	7 (Not using)	
Normal	130	1	25.0	3	15.0	3 (Using)	15.0
	120	12	65.0	-	-	-	
<b>Total</b>	<b>540</b>	<b>15</b>	<b>100.0</b>	<b>20</b>	<b>100.0</b>	<b>20</b>	<b>100.0</b>

Source: Data analysis results (2024)

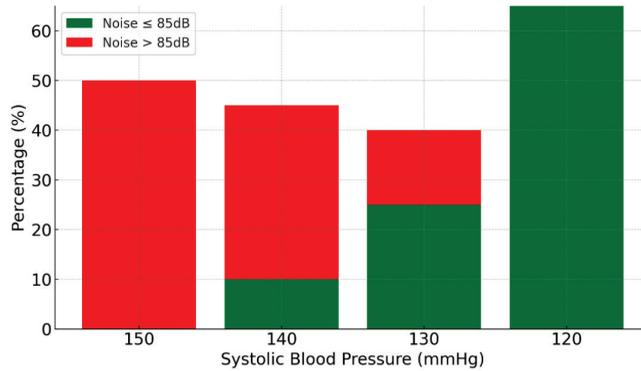


Figure 2: Graph of systolic blood pressure and noise intensity after exposure

use ear protection. Of the total 20 respondents, 10 people (50%) who did not use ear protection experienced systolic blood pressure of 150 mmHg. In addition, seven respondents (35%) from the same group had a systolic blood pressure of 140 mmHg. In contrast, respondents who used ear protection showed lower systolic blood pressure. Only three people (15%) who used ear protection had a systolic blood pressure of 130 mmHg and no respondents reached a systolic blood pressure of 120 mmHg or less after being exposed to noise.

The woodworking environment in Taratak Kampung Baru, Pariaman City faces varying levels of noise, with high noise intensity (> 85 dB) especially when the wood-cutting machine is operating. The results showed that high systolic blood pressure was more common in workers who did not use ear protection, indicating that high noise exposure can cause physiological stress that contributes to increased blood pressure. A high-noise work environment without adequate protection can significantly affect workers' health. Workers who do not use ear protection are at greater risk of increased blood pressure, which can lead to serious health problems such as hypertension and cardiovascular disorders.

This finding is consistent with previous studies showing that high noise exposure is associated with increased blood pressure (Chen *et al.*, 2017). Münzel *et al.* (2018) reported that noise causes increased blood pressure

through stress mechanisms, especially through activation of the sympathetic nervous system. Babisch (2003) emphasised that acute noise can increase blood pressure, heart rate, and cardiac output through the release of stress hormones such as catecholamines. In the context of the woodworking environment in Taratak Kampung Baru, the importance of using ear protection becomes very clear. Workers exposed to noise without protection are at higher risk of increased blood pressure, reflecting physiological stress due to noise. Mitigation measures such as providing ear protection and reducing noise intensity are essential to protect workers' health and prevent long-term health impacts.

## Discussion

Bivariate analysis was conducted to explore the relationship between the independent variable (noise intensity) and the dependent variable (systolic and diastolic blood pressure) using cross-tabulation. The Fisher Exact Test was chosen because the sample size was less than 40 and the expected value was less than 5, so, the Chi-Square test could not be applied. The results of the Fisher Exact Test showed a significant relationship between noise intensity and systolic and diastolic blood pressure. Noise exposure triggers a brain response that considers it as stress so that stress hormones such as adrenaline, norepinephrine, and cortisol are produced. These hormones affect the nervous system, which has an impact on variations in heart rate

and blood pressure (Dart *et al.*, 2002). This is in line with Poiseuille's law, where the diameter of the narrowed arteries due to vasoconstriction reduces blood flow and causes the heart to work harder, thereby increasing blood pressure (Faber & Stouffer, 2017). The research involved 20 respondents who were woodworking workers in Taratak Kampung Baru, Pariaman City. The majority of respondents were aged 31-40 years (40%) and only 10% were over 50 years old. The average working hours each day were 10 hours, exceeding the noise threshold set by the Decree of the Minister of Manpower No. Kep. 51/MEN/1999, which regulates working hours of eight hours each day or 40 hours each week (Stansfeld *et al.*, 2000).

Of the 20 respondents without a history of hypertension, only 15% used ear protection while 85% did not. The data showed that 85% of workers exposed to noise > 85 dB experienced an increase in systolic blood pressure while 15% did not. In addition, 65% of respondents reported an increase in diastolic blood pressure while 35% did not report an increase. At noise < 85 dB, 10% of respondents experienced an increase in systolic blood pressure, 5% reported an increase in diastolic blood pressure and 95% did not experience an increase. The results of the Fisher Exact Test showed a significant relationship between noise intensity and systolic and diastolic blood pressure. This finding is consistent with research by Yuliyatin and Ismayatun (2021) on employees of PT. Muroco Jember found a relationship between noise and increased blood pressure.

Noise-related blood pressure increases occur through stress mechanisms. According to Münzel *et al.* (2018), noise-induced stress activates the sympathetic nervous system, causing an increase in blood pressure. Continuous noise exposure affects vascular autoregulation and can lead to hypertension. This research provides a novel approach by examining both the effects of noise on human health, specifically systolic and diastolic blood pressure, and the impact of noise on local ecosystems, offering a more integrated perspective on the broader consequences of industrial noise.

In addition to its direct impact on worker health, high-intensity noise also has an impact on local ecosystems. According to Kok *et al.* (2023), continuous noise in industrial areas can disrupt wildlife communication, changing the migration and reproductive patterns of some species. This is also supported by Bahía *et al.* (2024), who explain that anthropogenic noise can reduce biodiversity, especially in birds and small mammals that are very sensitive to changes in environmental acoustics. Meira *et al.* (2024) added that natural acoustic ecosystems serve as markers of environmental balance and industrial noise disrupts predator-prey interactions, thus, negatively impacting the food chain.

Noise mitigation, according to Tang and Cheng (2024) can be achieved through rearranging the layout of machines in industrial areas and the use of effective noise-reducing technology. In addition, planting vegetation around the work area can also help reduce the impact of noise on the ecosystem. Mahapatra *et al.* (2023) suggested that increasing awareness and compliance with noise regulations in the industry is an important step to protect both workers' health and the overall environmental balance. This research also offers practical insights into noise mitigation strategies that consider both human and ecological factors, enhancing the significance of noise management in industrial settings.

## Conclusions

This research found that exposure to high-intensity noise (> 85 dB) in the work environment of the research location, Pariaman City had a significant impact on the increase in systolic and diastolic blood pressure of workers. Respondents who did not use ear protection experienced a higher increase in systolic blood pressure, with 50% of them recording systolic blood pressure of 150 mmHg. In contrast, respondents who used ear protection showed lower systolic blood pressure, with only 15% experiencing systolic blood pressure of 130 mmHg. The work environment with high noise levels, especially during wood-cutting machine

operations showed that unprotected workers experienced more frequent increases in blood pressure. These findings indicate that high noise can cause physiological stress, which contributes to increased blood pressure. The lack of use of ear protection is associated with higher health risks, including the potential for hypertension and cardiovascular disorders. In addition to impacting workers' health, excessive noise also affects the ecosystem around the research location, disrupting the balance of local fauna such as birds and small animals, which are indicators of environmental quality. Continuous noise can cause stress to wildlife, change their behaviour, and disrupt the balance of local ecosystems.

Mitigation measures are essential to reduce the impact of noise on workers and ecosystems. Suggested interventions include providing ear protection, rearranging machine layouts to reduce noise, installing sound-dampening technology, and planting vegetation around production areas as natural sound barriers. In addition, reducing noise intensity in the workplace not only protects workers' health but also maintains the balance of the ecosystem in the surrounding environment so that the risk of ecosystem damage can be minimised. This research emphasises the importance of noise mitigation in the workplace to protect workers' health and maintain local ecosystems that are sensitive to acoustic changes. Awareness of the use of ear protection and noise control efforts needs to be increased to reduce long-term negative impacts on workers and the environment.

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### Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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