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Research article

Assessing Occupational Noise Exposure and Blood Pressure of Cabin Personnel of an Indonesian Diesel Train

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Abstract

Noise may cause serious health problems, including physiological responses, specifically in the cardiovascular system. This study aims to assess occupational noise exposure and analyze the correlation between occupational noise and blood pressure in cabin and station personnel. The participants were 30 cabin personnel (train drivers) and 30 station personnel. The cabin had a Leq of 90.3 dBA while the noise level at Poncol Station was still below the threshold limit value (TLV), i.e., 75.8 dBA. The noise exposure assessment also included noise exposure profiling. The Chi-square test showed that noise influenced systolic and diastolic blood pressure changes. Furthermore, for train drivers, the t-test showed a difference in systolic and diastolic between before and after the activity. As for station personnel, there was a difference in systolic, but contrarily it was not the case in diastolic. According to the noise profile, the train whistle had the most significant noise level at 120 dBA. Moreover, the use of a train whistle regularly may raise the noise level exposure to cabin staff and even station workers. This study contributes to scientific evidence that occupational noise might affect blood pressure

Keywords: Occupational noise; train; cabin personnel; train driver; blood pressure

1. Introduction

The railway is a land transportation service industry that is relatively more favorable to the public (Hosoya, 1995). Rail services not only positively impact workers and the community but may also negatively impact the noise generated by the train (Eldakdoky and Elkhateeb, 2021; Hosoya, 1995). Train noise may be categorized as either airborne or structure-borne. Steel wheel/rail action, train siren/whistle, aerodynamic noise, power and auxiliary equipment, power units, and engines are all airborne noise sources (Croy et al., 2013). With prominent frequencies below 200 Hz, the structure-borne noise originates from vibroacoustic sources emitted via vibration transmission into the training envelope from bogies and mounted equipment (Choi et al., 2004; Sujarwanto et al., 2014). Noise emitted by trains between wheels and rails is affected by the stability of the track supports, inadequate maintenance, and rail alignment (Evans et al., 2020).

The Indonesian railway is operated by a state-owned company, PT Kereta Api Indonesia (PT KAI). Although Indonesia's railway infrastructure is rapidly developing, PT KAI still operates 10–40-year-old locomotives (Iridiastadi, 2016). That may contribute to the noise level in a cabin which commonly presents from 67 to 101 dBA with frequent train whistles that warn individuals walking along the rail track or reaching a level crossing (Iridiastadi, 2016). The locomotives do not have an air-conditioned cabin, and the cabin's design does not take ergonomics into account (Iridiastadi, 2021), including how to reduce the noise exposure to the cabin personnel. The Indonesian railway safety has been evaluated by previous research (Bambang and Wiwik, 2013; Iridiastadi, 2021, 2016), but the noise-induced health problem is rarely investigated by assessing the continuous noise exposure. This situation may affect the health of workers (cabin and station personnel) both psychologically and physiologically (Vermeer and Passchier, 2000).

People exposed to noise tend to have unstable emotions leading to stress (Budiawan et al., 2016; Hahad et al., 2019). Long-term stress can cause narrowing blood vessels, which leads the heart to work harder to pump blood throughout the body. For a long time, blood pressure will rise, and this is so-called hypertension. Hypertension is a health disorder often found in almost all countries (World Health Organization (WHO), 2013). Hypertension is still one of the leading causes of disease and mortality avoided (James et al., 2014). The existence of a link between occupational noise exposure and hypertension is still up for debate (Chang et al., 2013). The relationship between noise and possible health impacts is influenced by several factors, namely noise level, noise frequency, and the length of time a person is in or near the sound source (either from day to day or throughout life (Passchier-Vermeer and Passchier, 2000). Occupational noise is associated with exposure to a prolonged increase in blood pressure or a greater risk of hypertension (Chang et al., 2013; Lu et al., 2018; Sbihi et al., 2008). Noise can also be associated with hypertension (Chang et al., 2013; Hahad et al., 2019). However, inconsistent results have been reported by other studies (Fogari et al., 2001; Inoue et al., 2005; Kristal-Boneh et al., 1995) that are caused by variations in research design, exposure measurement, the ability to adjust for possible confounders, and levels of hearing-protective device use while working (Chang et al., 2013).

Area Operation IV Semarang, also known as DAOP IV Semarang, is an Indonesian railway operations area operated by PT Kereta Api Indonesia (Persero) (Andarani et al., 2019). The noise levels at Poncol Station were measured by Sutiningsih (2020), while the locomotive CC201 noise levels during the operation were compared by Sujarwanto et al. (2014). There is little information on occupational noise exposure inside the cabin and its impact on cabin personnel, particularly on DAOP IV. It is necessary to continuously measure occupational noise exposure at work so that noise level peaks are not missed. Therefore, this study aims to assess the occupational noise exposure of cabin personnel and to evaluate whether the exposure affects blood pressure. To eliminate confounding factors, this study was undertaken by a case-control approach.

2. Methods

2.1. Subject of Research and Measurement Time

Indonesian Railways Company operates trains with several locomotives, i.e., electric, diesel-electric, diesel-hydraulic, and multipower locomotives (https://www.kai.id/). The selected travel route is Semarang–Tegal and Tegal–Semarang, namely Kaligung train (code: CC201, CC203, and CC206). The locomotive type of Kaligung KA is diesel-electric, with technical data shown in Figure 1.

<table>
<tr><td rowspan="2">L*</td><td>1</td><td>2</td><td rowspan="2">RT</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td rowspan="2">GT</td><td rowspan="2">L*</td></tr>
<tr><td colspan="2">Executive Class</td><td colspan="7">Economic Class</td></tr>
</table>

Figure 1. Schematic layout of the Kaligung train. Abbreviations: L*, Locomotive; RT, Restoration Train; GT, Train Generator/diesel engine

The population of this study was all officers at DAOP IV Poncol Semarang Station who were exposed to noise obtained from secondary data, which was 213 people. The number of participants was 10–15% of the total population at UPT Crew Semarang, namely 30 people, of which 30 cabin personnel for one work service (approximately one week). The research began in July, the first and second week of 2017.

Measurements were carried out for three consecutive days, from Friday to Sunday. The rotation of the work schedule is usually within two months. Control variables in this study were age, gender, and heredity (uncontrollable risk factors), as well as nutritional status (obesity), smoking habits, alcohol drinking habits, coffee drinking habits, disease history, years of service, and use of Personal Protective Equipment (PPE). Thirty station personnel also participated as the control subject.

2.2. Measurement of Occupational Noise Exposure and Blood Pressure

The research stages include sampling and recording data using a noise dosemeter in the driver's cabin and station. Blood pressure measurement (systole and diastole) is carried out at the health post station with a digital sphygmomanometer (Omron 7203) equipped with the Intellisense BPM feature, which aims to determine the optimal level of inflation and deflation when measuring blood pressure. The noise measurement time was on Friday, Saturday, and Sunday. Health checks 45 minutes before and after the driver travels for 15 days. If there is an increase or decrease in blood pressure of ±10 mmHg after the driver and assistant engineer are exposed to noise, it is considered a change in blood pressure.

A noise Dosimeter is a measuring instrument (dosimeter) used to calculate the noise exposure received during working hours. The noise dosimeter used in this investigation was the Lutron DS2013SD, which has the capability of being a noise data logger. Throughout the journey, the noise level exposure was taken every five seconds. This measurement complies with the Ministry of Environment Decree No. 48/1996 on Noise Level Thresholds. Measurements were made in the worker's hearing area, approximately 15 - 30 cm from the worker's ear. The measurement of noise data began at the initial departure station (Semarang Poncol Station) until it arrived at Tegal Station.

The threshold limit value (TLV) for the occupational noise, according to the Indonesian Ministry of Labor No. 13/2011 and NIOSH (NIOSH, 1998), is 85 dB for 8 hours of work per day. Based on the calculation of the Leq value, the modified NIOSH calculation was carried out to determine the recommended duration of noise exposure (Leq). The modified NIOSH equation is as follows:

$$T = \frac{16}{2^{(L-82)/3}} \quad \text{(Eq. 1)}$$

T is the duration (hour), and L is the exposure level (dBA).

2.3. Statistical Analyses

Univariate and bivariate analysis was performed to determine the effect of noise level on changes in blood pressure before and after noise exposure. The chi-square test was used to observe whether there was a relationship between two variables. Furthermore, the comparative statistical analysis used in this study is the paired sample T-test. The T-test was conducted to determine whether there was a difference between blood pressure before and after exposure to noise personnel in a cabin, engine room, and locomotive. The level of significance (p) used is 0.05. The analyses were conducted using Microsoft Office Excel 2010 and SPSS 16.

3. Results and Discussion

3.1. Existing Condition of Rail Track and The Kaligung Train

There are 127 stations in Central Java Province, including 16 significant stations (class 1) and seven minor stations (class 2). These stations are controlled by three railway management institutions, which are under the control of PT KAI. The Kaligung Train (Route: Semarang–Tegal, roundtrip) is one of the trains under the control of DAOP IV Semarang City. In addition to controlling train operations, DAOP also regulates the environment around the station. One of them is a settlement located near the railroad tracks. Settlements must be 100 meters from the railroad tracks. That is to prevent train accidents and the risk of noise caused by railway activities. Based on Railway Law No. 13/1992 with the derivative of Government Regulation No. 69/1998, the area around the 11-meter side of the railroad track is not allowed to carry out any activities other than train travel traffic.

3.2. Occupational Noise Exposure Analysis

In this study, noise measurements were carried out in the cabin of the train driver of the Kaligung Train between Semarang and Tegal (roundtrip). The measurement during the train running on the first to third day had an average travel time of 4 hours 47 minutes, including when the train stops at the station to drop off or pick up passengers. Figure 2 shows measurement results of noise levels in the cabin, which generated 3,458 data points in total. According to the Ministry of Labor Regulation No. 13/2011 that for 4 hours of work, the TLV of noise intensity is 88 dBA. In this study, the average noise in the cabin area is on the first day: 88 dBA, on the second day: 93 dBA, and on the third day: 90 dBA. In the station area, the average noise (Leq) was 75.88 dBA, with L10 (65,4 dBA), L50 (62 dBA) dan L90 (88 dBA).

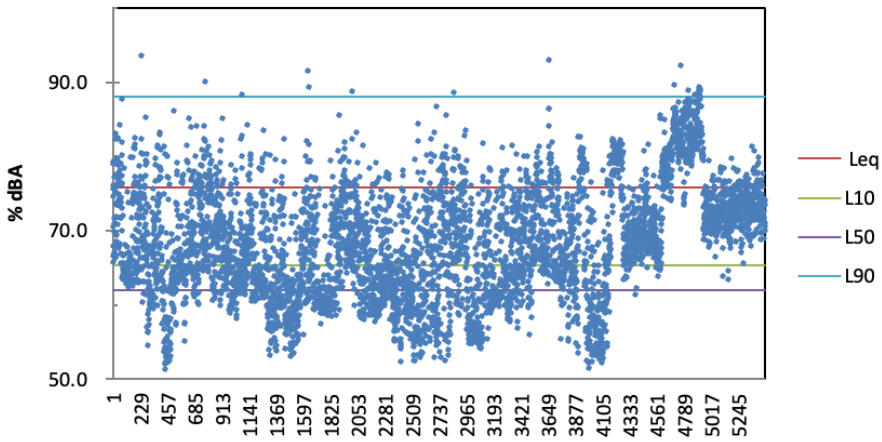


Figure 2. Noise exposure in the cabin (3,458 data points)

According to observation when continuously measuring the noise levels (Figure 2), the source of the noise, which was the most prominent health risk, when the driver used the train whistle because of the noise, according to measurement, greater than 100 dBA, while the train whistle in the locomotive depot when the train stops were ~120dBA. At this level, the allowable duration was only 7 seconds. It noted that 140 dBA is already not acceptable at any duration according to the Regulation of Ministry of Labor No. 13/2011. Another source of the noise was the sound of the train engine, which is ~80dBA, and when the train is braking entering the station area or densely populated region, the noise level was ~70dBA. Sujarwanto et al. (2014) measured the CC201 noise levels inside the train driver's cabin with an open window, which reached 81.8 dBA, and if the door was opened, the noise level was 83.4 dBA. It should also be noted that the position of cabin personnel relative to the engine may also affect the noise exposure as the train moves—the train driver is either behind the engine or in front of the engine.

Figure 3 illustrates descriptive statistics of the noise levels exposed to cabin personnel. It can be seen that 70 to 75 dBA was exposed to the crew at 6.9% of the time on the first day, 2.4% on the second day, and 4.8% on the third day. Furthermore, 34.5% of the time was exposed to 85 dBA on the first, 41.2% on the second, and 40.1% on the third.

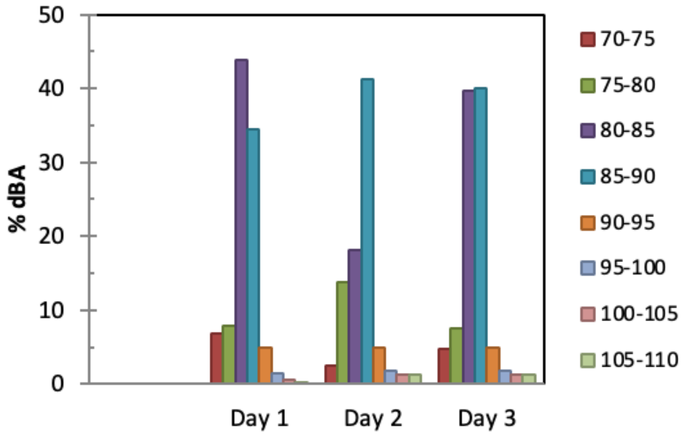


Figure 3. Summarizing diagram of noise levels in the cabin

In Figure 4a, that can be seen that the L10 was greater than the Leq on the first and second days, while the level was the same as the Leq value on the third day. According to FHA (2006), L50 is the average noise level during the measurement. Meanwhile, L10 describes the initial noise level, and L90 is the residual noise level. The L50 values on the first, second, and third days were below Leq, ranging from 84 dBA to 89 dBA, while the L90 value was from 76 dBA to 79 dBA. The noise level in the station area can be seen in Figure 4b. The Leq at the Poncol station was 75.88 dBA with L10 (65.4 dBA) L50 (62 dBA), and L90 (88dBA). That can be interpreted that the noise level at the train station still met the TLV.

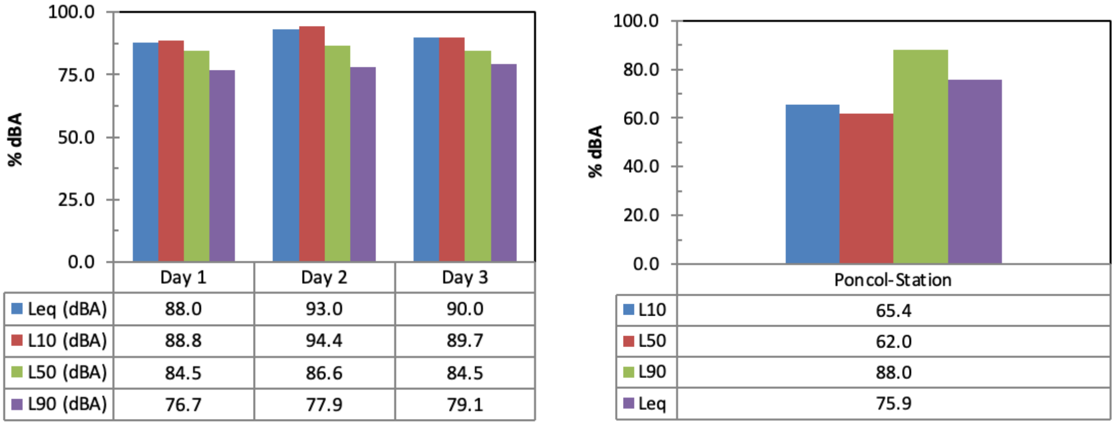


Figure 4. Noise statistics: (a) in the cabin; (b) in the Poncol Station

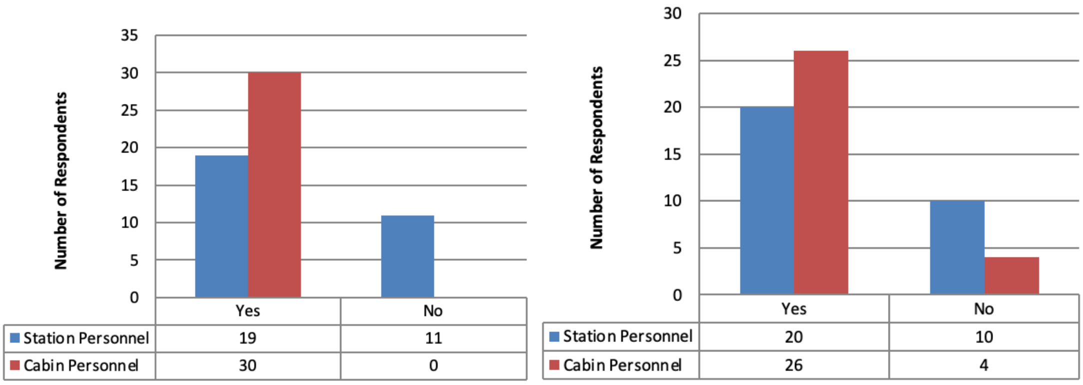
Based on Equation 1, the maximum duration of each Leq was determined. The maximum duration for the noise exposure on days one, two, and three were 4.24, 1.26, and 2.52 hours, respectively. On day one, because the working time was 5 hours, it exceeded the recommended duration at the Leq of 88 dBA (4.24 hours). It even greatly exceeds the maximum duration on the second and third days, as shown in Table 1.

Table 1. The threshold limit value of the maximum exposure.

	Leq (dBA)	T max (hours)	Notes
Day-1	88	4.24	Exceeded the recommended duration
Day-2	93	1.26	Exceeded the recommended duration
Day-3	90	2.52	Exceeded the recommended duration

3.3. Effect of the Occupational Noise on Blood Pressure

Figure 5a shows the increase in systolic blood pressure in cabin personnel after work. All cabin personnel (30 respondents) increased between before and after work. The increase was between 10 and 20 mmHg. Meanwhile, in station personnel, there was an increase in 19 respondents from 30 respondents. The increase in systolic blood pressure was not too significant; only between 5 to 10 mmHg and 11 stations personnel surveyed had blood pressure that remained or even decreased from blood pressure before work. In diastolic blood pressure (Figure 5b), both groups of respondents experienced changes in diastolic blood pressure. The number of respondents who experienced an increase was more evident in-cabin personnel than station personnel. This study used cross-tabulation and chi-square tests to see the relationship between the independent and dependent variables.



(a) (b)

Figure 5. Elevated blood pressure of cabin and station personnel: (a) Systolic; (b) Diastolic

Table 2 showed that in the environment with an intensity above the TLV, 30 people (100%) experienced an increase in systolic blood pressure. While in the group who worked in an environment with noise intensity below the TLV, there were, in 20 respondents, only 19 (63.3%) experienced an increase in systolic blood pressure (p-value <0.05); thus, it can be concluded that there was an effect of noise level on increasing blood pressure.

Table 2. Correlation between noise intensity in the workplace and an increase in systolic blood pressure in the respondents of PT KAI

Noise Level	Elevated blood pressure				Total		p-Value
	Yes		No				
	n	%	n	%	N	%	
Exceed Threshold Limit Value	30	100	0	0	30	100	< 0.05
Below Threshold Limit Value	19	63	11	37	30	100	
Total	49		11		60		

Table 3. Correlation between noise intensity in the work environment with an increase in diastolic blood pressure in the respondents of PT KAI

Noise Intensity	Elevated blood pressure				Total		p-Value
	Yes		No				
	n	%	n	%	N	%	
Exceed Threshold Limit Value	26	86.7	4	13.3	30	100	< 0.05
Below Threshold Limit Value	20	66.7	10	33.3	30	100	
Total	46		14		60		

According to Table 3, from 30 respondents who worked in an environment with an intensity above the TLV, 26 respondents (86.7%) experienced an increased diastolic blood pressure. Although in the group who worked in an environment with noise intensity below the TLV, only 20 out of 30 respondents (66.7%) experienced an increase in diastolic blood pressure (p-value <0.05). Therefore, it is evident that there is an effect of exposure to noise on elevated blood pressure. In this measurement, the blood pressure of cabin personnel (systolic and diastolic) has increased significantly. That may be additional evidence that noise is one factor that increases blood pressure. However, in the measurement of station personnel, there was no significant increase in the cabin personnel. The paired sample t-test shows a significant difference between systolic blood pressure before work and systolic blood pressure after work in cabin personnel (Table 4). However, station personnel did not indicate a significant difference in the diastolic blood pressure. Only the systolic blood pressure differed between before and after work.

Table 4. Paired t-test results on cabin and station personnel

Cabin Personnel (Before-After Work)	Paired Differences			
	Mean	SD	T-test	p
Cabin Personnel				
Systolic	1.134	8.786	-6.822	< 0.05
Diastolic	-6.668	15.967	-3.241	< 0.05
Station Personnel				
Systolic	2.578	9.709	-4.889	< 0.05
Diastolic	-9.010	19.131	-2.098	0.215

Abbreviations: SD, Standard Deviation; p, significance of t-test

This study confirms once again that occupational noise may affect blood pressure. Sutiningsih et al. (2020) also had the same result, although the authors did not reveal the actual noise levels. Weinmann et al. (2012) found that exposure to objective personal noise affected hypertension. A systematic review of articles published after 1999 reported that occupational noise was consistently associated with an elevated risk of the occurrence of hypertension [hazard ratio (HR) = 1.68; 95% confidence interval (CI) 1.10-2.57] (Skogstad et al., 2016).

4. Conclusions

Noise level profiling and blood pressure (before and after work) analysis revealed that a noisy environment above the threshold limit value (TLV) could affect the health of cabin personnel. The noise intensity in the cabin had a Leq of 90.3 dBA. The noise level at Poncol Station was still below the TLV, namely 75.8 dBA, although this level almost reached the TLV (85 dBA for eight working hours). Noise profiling verified that the train whistle had the highest noise level at ~120 dBA. The frequent use of the train whistle can increase the noise level exposure to the cabin crew and even the station personnel. Based on the chi-square test, there is an effect between noise and an increase in systolic blood pressure (p-value < 0.05) and diastolic blood pressure (p-value < 0.05). The elevated blood pressure due to occupational noise was 100% for cabin crews and 63% for station personnel in systolic, while in diastolic, the ratios were 87% for cabin personnel and 67% for station personnel. The paired sample t-test also showed a difference in blood pressure between systolic blood pressure before and after work (p-value < 0.05). The layout of the CC201 train may have different potential noise exposures to the train driver, specifically during running. A further study should be conducted to design an optimal reduction in noise exposure, either by technology or management.

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