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A Critical Assessment of Occupational Noise Exposure and Relevant Variables for Hearing Disturbances: A Study among Watercraft Personnel

Kresna Febriyanto[1,2], Joana Cristina Cardoso Guedes[1], Luis João Rodrigues Das Neves Correia Mourão[3], Nida Amalia[2], Boy Putra Anggara Prasetyo[2], Ferry Fadzlul Rahman[2,*]

[1]Faculty of Engineering, University of Porto, Portugal
[2]Faculty of Public Health, Universitas Muhammadiyah Kalimantan Timur, Indonesia
[3]CIETI/NBIN, Instituto Superior de Engenharia do Porto (ISEP), Polytechnic of Porto, Portugal

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Abstract Noise pollution is one of the newly emerging environmental issues associated with ships. Despite numerous efforts to reduce noise, noise levels on board remain above the threshold limit value (TLV). The aims of present study were to classify levels of occupational noise, hearing disturbances, and identify other factors that impact hearing loss. From July to August 2022, this cross-sectional study was enrolled among speedboat members. We used sound level meter as a noise measurement, and audiometer for assessing hearing problems. The questionnaires were used to support the data with the questions according to age, job position, Body Mass Index (BMI), years of working, work duration in a day, smoking and alcohol consumption, physical activities, and hobbies during leisure time. Chi-Square test was used to find out the relationship between the variables. The captain's position does not exceed the TLV (average noise level was 85.45 dBA). In contrast, six speedboats in the crew's location exceeded TLV based on the length of exposure duration. A total of 109 participants (83.8%) had hearing loss, with the majority suffering from mild (40.8%), moderate (39.2%), and severe (3.8%) levels. Except for job position, all independent variables were related to hearing impairment. Due to prolonged exposure to noise, high decibel levels, and other factors, members of speedboats are susceptible to hearing loss. Age, BMI, and other lifestyle factors such as smoking, alcohol consumption, recreational activities, and daily exercise will also contribute to their hearing problem.

Keywords Workplace Noise, Assessment, Monitoring, Hearing Impairment, Speedboat, Ship, Vessel, Seafarers, Sailors

1. Introduction

Noise-induced hearing loss (NIHL), one of the most prevalent forms of sensorineural hearing loss among individuals working in noisy environments, is the world's most pervasive industrial disease [1]. There are three fundamental forms of hearing loss: conductive loss, sensorineural loss, and mixed loss. Once the hair cells in the cochlea are damaged, sensorineural hearing loss is usually permanent [2].

The NIHL has been studied in a variety of industrial and nonindustrial activities, including the transportation

industry. In the era of globalization, transport is a crucial need for the community to support all activities and daily rituals. Each mode of transportation has its function and capacity for passenger service. Maritime transport is the mode of public transport that assists the government in its genuine development efforts. Sea transport is essential for connecting islands so that the distribution of products and passengers from one island to another can run smoothly and development can be distributed equitably rather than being concentrated in a single region or island [3].

Noise exposure in the workplace is one of the primary causes of NIHL [4]. Because they are exposed to noise daily, the sailors and crew members are susceptible to NIHL. There are several sources of noise on a boat, including engines, wind, waves, and entertainment on board. Oldenburg et al. [5] mention that high levels of noise on board are caused by ship operation, loading and offloading (especially on container ships), port stay, port facilities (such as cranes), and environmental noise (wind and sea).

Noise pollution is a new emerging environmental issue caused by ships [6] and also as one of the most prevalent occupational risk factors associated with hearing loss. Hearing impairment can be detected early before permanent hearing loss results from continued exposure [7].

According to the most recent estimates, 1.59 billion persons worldwide, or 20.3% of the global population, are affected by hearing loss, with 430 million (5.5%) suffering from moderate or severe hearing loss [8]. By 2050, it is anticipated that the number of persons with hearing loss will approach 2.5 billion, with 700 million requiring intervention. Hearing loss was classified as the third leading cause of years lived with a disability globally in 2019, according to statistics [9]. Globally, hearing loss is estimated to cause an annual economic burden of over $750 billion [10]. In a study conducted on five distinct Brazilian vessels, approximately 56.5% of the crew suffered from NIHL. At 78.8%, engine room personnel had the highest incidence of NIHL [11]. Such damage to the hearing system makes it challenging to communicate with the encompassing environment and comprehend the verbal communication of others, especially in noisy environments. As a result, it can also increase the likelihood of occupational accidents [7], [12]–[14].

The International Maritime Organization's (IMO) Maritime Safety Committee, the primary international body regulating safety at sea from hazardous noise pressure levels in vessels, has issued a warning to ship operators: acceptable noise levels are 85 dBA in work environments, 75 dBA in motor control rooms, 65 dBA in command and navigation spaces, and 60 dBA in common areas [15]. As for the ship type, the noise threshold value is not expressly stated but was modified according to exposure duration. According to the regulations, employees may be exposed to 85 dBA for no more than eight hours daily. Even though the threshold value for noise on ships has been defined, many research investigations on noise intensity were above the limit.

Various factors contribute to health issues among seafarers, including noise exposure, duration of exposure at work, years of experience in maritime work, age, lifestyle choices like smoking and alcohol consumption, and engaging in activities involving loud sounds, such as attending concerts or clubs and listening to loud music [16]. Previous studies conducted on seafarers only examined hearing loss resulting from shipboard noise. They measured the noise level on the vessels and the workers' hearing thresholds. Hearing loss is not caused exclusively by noise but also by non-occupational factors such as age, work experience, body mass index (BMI), and non-infectious chronic diseases [7]. Therefore, this study was conducted to classify levels of occupational noise, hearing disturbances, and identify other factors that impact hearing loss.

2. Materials and Methods

2.1. Study Design

The present research was designed as a cross-sectional study to investigate hearing disturbances experienced by workers due to noise in operating the speedboat and to determine other factors that correlate to their hearing problems.

2.2. Place and Time of Study

The study was conducted from July to August 2022. Study data were collected within working hours of the day at Tengkayu II, port of Tarakan City. Tarakan is an island in North Borneo province, Indonesia that has a vital role in advancing equitable development in this province.

2.3. Study Population and Sample

There were 168 speedboat workers included in this survey, with 56 speedboats operating at the port and each speedboat containing three to four workers. The researcher used the Slovin formula to calculate the sample size from N = 168.

The calculation results indicate 118 respondents, but to avoid errors in data acquisition or loss, the researchers added 10%, bringing the total number of samples in this study (n) to 130 respondents. The sampling technique utilized in this study was simple random sampling, specifically sampling of respondents who could be in a location that corresponds with the research context [17].

2.4. Instruments of Research

2.4.1. Occupational Noise Monitoring

Noise measurements in speedboats have been carried out

on 12 speedboats. Using the Sound Level Measurement (SLM) type Lutron SL 4001, each speedboat was measured at two locations (the skipper's and the crew's positions) while in operation. The SLM was placed parallel to the worker's ear for two to three minutes to measure the continuous noise generated by the ship's engine that entered the worker's ears. As shown in Figure 1, the type of vessel operating in the Tarakan region is a speedboat with a capacity of 15 to 60 passengers.

2.4.2. Hearing Assessment

To determine the air conduction threshold, pure tone audiometry was performed. The subjects were not exposed to occupational noise for at least 14 hours prior to the audiometric threshold testing to recover from temporary threshold shift [18]. The result of hearing impairment was classified into four categories: normal (< 25 dB), mild (26–40 dB), moderate (41–55 dB), and severe (> 55 dB). They were evaluated in a soundproof chamber using a pure-tone audiometer. Hearing levels at 500, 1,000, 2,000, 4,000, and 8,000 kHz were determined using the ascending threshold technique.

2.4.3. Questionnaire

The questionnaire included queries regarding occupational and non-occupational risk factors for hearing impairment (Table 1). This included questions about personal identification (such as age and BMI), the current job (job position, years of working, work duration in a day), and health habits (smoking and alcohol consumption, exercise activities, hobbies).

2.5. Statistical Analysis

SPSS (version 22) was used to calculate descriptive statistic (mean, min, max, SD, frequency, and percentages) and bivariate analyzed among the variables. Chi-Square test was used to measure association between each independent variables (noise level, age, job description, body mass index, smoking consumption, years of working, work duration in a day, drinking alcohol, exercise activities, and hobbies related to loud sound) against dependent variable (hearing disturbance). The significant association was defined as p value < 0.05.

2.6. Ethical Approval

Since the use of humans in research necessitates the protection of individual rights, the "informed consent" condition was implemented as a code of ethics, and each employee's verbal permission was obtained. This research has also passed the health research ethics test, as stated in the Letter of Agreement for Ethical Consideration No. 91/KEPK-FK/VII/2022 issued by the Health Research Ethics Commission, Faculty of Medicine, Mulawarman University on July 5, 2022.

Figure 1. The Speedboat

Table 1. Demographic and General Information of Speedboat Workers

Variable		Frequency (n=130)	Percentage (%)
Age	Late tens (17-25)	10	7.7
	Young adults (26-35)	40	30.8
	Old-aged adults (36-45)	58	44.6
	Young elderly (46-55)	21	16.1
	Late elderly (56-65)	1	0.8
	Min: 19; Max: 59; Mean: 36.99		
Job position	Skipper	20	15.4
	Speedboat Crews	110	84.6
Body mass index	Normal weight	74	56.9
	Pre-obesity	3	2.3
	Obesity class I	24	18.5
	Obesity Class II	29	22.3
Smoking consumption	No	19	14.6
	Yes	111	85.4
	Min: 0; Max: 32; Mean: 14.53 (bars in a day)		
Years of Working	≤ 7 years	67	51.5
	> 7 years	63	48.5
	Min: 1; Max: 20; Mean: 7.42		
Work duration (in a day)	1 – 5 hr	82	63.1
	> 5 hr	48	36.9
	Min: 2; Max: 6; Mean: 3.86		
Drinking alcohol	No	43	33.1
	Yes	87	66.9
	Min: 0; Max: 4; Mean: 1.26		
Physical activities	Yes	21	16.2
	No	109	83.8
Time to do exercise	Never do exercise	109	83.8
	Daily	4	3.1
	Weekly	13	10
	Monthly	4	3.1
Hobbies	Not related with high sound	54	41.5
	Related with high sound	76	58.5
Hearing status	Normal	21	16.2
	Disturbances	109	83.8
Hearing Disturbances	Normal	21	16.2
	Mild	53	40.8
	Moderate	51	39.2
	Severe	5	3.8

3. Results

The majority of speedboat employees are between the ages of 36 and 45, with an average age of 37 years old, as indicated by Table 1 as primary characteristics. The classification of age groups refers to the Republic of Indonesia's Department of Health [19]. Despite being classified as the old-aged adult age group, the majority of workers have worked less than seven years (51.5%). Most employees have a normal body mass index, with an average of 15 cigarettes smoked daily. However, more than 80% of workers were cigarette smokers. Only 43 respondents did not drink alcohol, and only 21 participated in physical activities outside their profession. Over fifty percent of employees have noise-related hobbies. According to the findings of interviews, employees engage in noise-related activities such as: going to nightclubs, listening to music through loudspeakers or headphones, concert attendance, and hunting/shooting.

Therefore, each speedboat has between three and four crew members, and the majority of respondents in this study (84.6%) are also speedboat personnel. A total of 109 respondents out of 130 research samples had hearing problem, the majority of whom had mild (53 respondents) and moderate (51 respondents) levels.

The measurements of noise using the SLM were showed in Table 2. The number of engines per speedboat ranges from one to five. Each speedboat typically makes two round journeys per day with travel time one to four hours per way. There were two types of speedboats: closed (speedboat walls cover the entire speedboat body, as shown in Figure 1) and open (speedboat walls cover only half or three-quarters of the ship).

In this study, researchers measured the noise of four speedboat routes (round trip for each route), centered on the port of Tengkayu II, Tarakan City (where A is Tarakan). In accordance with international regulations and the decision of the Indonesian Minister of Manpower, the noise threshold limit value (TLV) for four hours of work is 88 dBA; for two hours, it is 91 dBA; and for one hour, it is 94 dBA [17]. Noise measurements results showed that overall the skipper position did not exceed the TLV. In contrast, in the crew's place, six speedboats exceeded the threshold value according to the length of exposure (speedboat no: 1, 2, 5, 6, 7, and 8). The captain's position does not surpass TLV because the captain's place is in front of the speedboat, and the distance between the captain and the engine is quite large. Especially in enclosed speedboats, the commotion generated by the machine will be automatically reduced by the walls surrounding the speedboat's body. However, the personnel will be directly exposed to the engine noise because they are on a ship. Consequently, it is not remarkable that the noise level in this location exceeds the TLV and is higher.

The results of statistical analyses for each independent variable and dependent variable are displayed in Table 3. Consequently, almost all independent variables are associated with hearing impairments, with the exception of job position (p-value > 0.05). Independent variables that are associated with the dependent variables have their own corresponding odds ratio values. The smoking status variable has the greatest OR value. This data indicates that a crew that smokes has a 227.3 times higher risk of hearing damage than a crew that does not smoke. Although OR (odds ratio) is the lowest for the BMI variable, it might be concluded that a ship crew with an abnormal BMI has a 5.6-fold higher risk of hearing problems than those with a normal BMI.

Table 2. Results of Noise Assessment

No	Length of journey	Kind of boat	Engine (pcs)	Route	Pos.1 (skipper)	Pos.2 (crew)
1	1.5-2 hr	closed	5	A – B	85.4	91.6
2	1.5-2 hr	open	5	B – A	86.9	92.1
3	1.5-2 hr	open	4	A – B	85.7	87.4
4	1.5-2 hr	closed	4	B – A	83.9	87.6
5	3.5-4 hr	closed	5	A – C	87	92
6	3.5-4 hr	open	5	C – A	88.4	90.2
7	3.5-4 hr	closed	4	A – D	85.6	88.3
8	3.5-4 hr	open	4	D – A	87.1	88.5
9	1 hr	open	3	A – E	83.2	86.7
10	1 hr	closed	4	E – A	81.3	88.1
11	1 hr	open	1	A – E		84.2
12	1.5 hr	open	1	A – B		84.9
		Min (dBA)			**81.3**	**84.2**
		Max (dBA)			**88.4**	**92.1**
		Average (dBA)			**85.45**	**88.47**

Table 3. Correlation Test Results

Variable	Level	Hearing Status		P - Value	OR (95% CI)
		Normal	Disturbances		
Noise	Average noise	19	27	.000*	28.852 (6.307 – 131.988)
	High noise	2	82		
Age	≤ 37 years old	20	44	.000*	29.545 (3.825 – 228.245)
	> 37 years old	1	65		
Job position	Skipper	1	19	.195	
	Speedboat crews	20	90		
BMI	Normal	18	56	.008*	5.679 (1.581 – 20.396)
	Abnormal	3	53		
Smoking	No	17	2	.000*	227.375 (38.620 – 1,338.683)
	Yes	4	107		
Alcohol	No	19	24	.000*	33.646 (7.316 – 154.736)
	Yes	2	85		
Working experience	≤ 7 years	20	47	.000*	26.383 (3.417 – 203.679)
	> 7 years	1	62		
Work duration	1 – 5 hr	20	62	.002*	15.161 (1.964 – 117.047)
	> 5 hr	1	47		
Physical Activities	Yes	14	7	.000*	29.143 (8.890-95.534)
	No	7	102		
Hobbies	Not related high sound	20	34	.000*	44.118 (5.686 – 342.303)
	Related high sound	1	75		

*= $p < 0.05$

4. Discussion

NIHL is defined as a prevalent occupational disease. It is an avoidable or preventable disease. The WHO [20] identifies a number of additional noise-related causes of hearing loss, including engine and detonation noise at work and excessive noise. According to the examination and analysis findings, there is a correlation between noise level and hearing loss. The noise level in the speedboat ranges from 81.3 to 92.1 dBA, with an average of 85.45 dBA (skipper's position) and 88.47 dBA at the crew's place during the trip. Based on Table 2, although the aggregate measurement results at the captain's position did not exceed the TLV, they were distinct from those at the crew's position. The crew from six speedboats, are subject to noise levels above the TLV. Another study also found that the result of noise assessment among several kinds of ships was also greater than TLV [5], [21]–[24].

The present study found the sailors who were exposed to noise levels above the average have a 28 times greater likelihood of developing hearing loss. In the same similar results from prior research, Jumali et al. [25] found that 34.85% of ferry boat's employees experienced hearing difficulties. Even though hearing impairment is typically only experienced by employees with more than ten years working, in this study, 83.8% of speedboat members were hearing-impaired despite an average length of service of only seven years. This is due to the fact that they are perpetually exposed to it every day, as well as several other factors. Zaw et al. [26] mentioned that hearing loss can be caused by either a single exposure to exceedingly loud or prolonged exposure to loud noise. Noise-related pastimes also influence the incidence of hearing loss [4]. The statistical findings of this study are consistent with Jannah et al. [27]. Their study found that hobbies such as recreational exposure to loud noises from personal audio devices at high volume intensity and long periods also affect regular attendance at concerts, nightclubs, bars, and moderately noisy sporting events. Aging is an additional cause, primarily due to the degeneration of sensory cells.

Age-related hearing loss was one of the most prevalent causes of high-frequency hearing loss, with its effects beginning around age forty [28], [29]. This may be due to the phenomenon of presbycusis, which is the progressive loss of hearing that occurs with advancing age [25], [26]. In this study, average crew's age is 37 years. The seafarers who have aged > 37 years and older were 29.545 times more likely to have hearing disturbances than those

who were younger than 37. Similar results were also found in Zaw's study et al. [26] Workers aged > 35 were seven times more likely to suffer from hearing loss than those under 35 years.

Several modifiable lifestyle factors, including smoking, alcohol consumption [30], a high body mass index (BMI), and physical inactivity [31], have also been linked to hearing health. Statistical results also present the same as lifestyle factors correlated with hearing impairment (p value < 0.05). Over fifty percent of speedboat members have a normal BMI, but the majority of have hearing loss (43%), as shown in Table 1. While other members with an abnormal BMI also experience hearing loss (40%). This study classifies abnormal BMI categories ($\geqslant$ 25 kg/m^2) as pre-obesity, class I obesity, and class II obesity. A recent study revealed that patients with a body mass index (BMI) greater than 27.5 kg/m^2 were 1.59 times more likely to experience sudden sensorineural hearing loss than those with a BMI less than 23.5 kg/m^2. A potential mechanism has been proposed to explain the association between adiposity and hearing loss. By stiffening or constricting the internal auditory artery, obesity-related atherosclerosis may reduce blood flow to the cochlea. Blood supply impairment to the cochlea may contribute to diminished auditory sensitivity [32].

Accelerometer-based comprehensive physical activity measurement will measure weekly moderate-intensity physical activity (MPA) per participant by converting daily minutes to weekly minutes and each minute of vigorous-intensity activity to two minutes of moderate-intensity exercise [33]. However, in this study, physical activity was categorized based on whether or not respondents engaged in physical activities (such as walking, gym use, and other physical activities) in their free time. The study's results demonstrated physical activity correlates with hearing loss, as 102 respondents (79%) who did not engage in physical activity had hearing problems. Due to an increased likelihood of social isolation, individuals with moderate or severe hearing loss may engage in less physical activity than those with normal hearing. A person's inability to effectively monitor the acoustic environment could limit their capacity to engage in physical activities. Joint neural degeneration impacting the cochlear and vestibular sense organs (essential for balance) may also account for the association between hearing loss and physical activity [33].

Cigarette smoking has a substantial negative impact on the auditory system. Tobacco is known to impair hearing through direct and indirect mechanisms in the inner ear, resulting in hearing loss at various frequencies [33]. The influence of smoking on the blood circulation system in the cochlear organ is the cause of progressive high-frequency hearing loss, which occurs most frequently in old age [18]. However, the exact mechanism linking smoking and NIHL remains unknown. Nicotine and other tobacco constituents may be ototoxic, causing harm to cochlear hair cells by increasing carbon monoxide hemoglobin or decreasing cochlear blood flow volume [34], [35]. Several studies discovered that the combined impact of smoking and occupational noise was comparable to the sum of the effects of each factor individually [36].

In this investigation, alcohol consumption was divided into two categories: drinkers and non-drinkers. It was not specified how much alcohol was consumed daily by these alcoholics. The statistic results confirmed that alcohol consumption has a relationship with hearing loss. The speedboat crews have 33.646 times the possibility of experiencing hearing loss when drinking alcohol. Similar research conducted by Xu et al. [37] showed that the prevalence of hearing impairment was significantly higher than those who never consumed alcohol. In contrast with Curhan et al. [38] study, there was no association between alcohol consumed and the risk of hearing loss. Noise and alcohol consumption may have caused injury to the blood vessels, cochlear vestibular organs, and auditory nerves of the inner ear [39]. The biological mechanisms underlying the synergistic effects of noise exposure and alcohol consumption on hearing loss are not fully understood, and further research is needed [37], [39].

Noise measurements were conducted only once with a specific route and speedboat model, despite speedboats operating daily. Therefore, the results of noise measurements cannot represent the entire sample. To obtain a more reliable understanding of noise exposure levels, future studies must use a complete methodology that includes repeated measurements over several routes, speedboat models, other maritime settings or broader populations of seafarers, and operational situations.

The purpose of the present study was to establish a correlation between the independent and dependent variables and not to identify the underlying cause. The study used a cross-sectional design, which restricted its capacity to establish causal connections between factors and evaluate alterations in hearing problems over a period of time. Conducting longitudinal studies that follow the same individuals for a long time would provide useful insights into the development of hearing loss and the effectiveness of preventive measures.

A Sound Level Meter was employed for measuring noise. Nonetheless, using a shoulder-mounted personal noise dosimeter that assesses an individual's exposure to noise over a single working day will be more effective. The present questionnaire variables lack comprehensive explanations, which limits the appropriate interpretation of their meaning. In order to improve the transparency and repeatability of the study, future research should include more precise explanations or operational definitions of the variables in question.

Finally, efforts should be made to control noise on board ships. This includes exploring the effectiveness of strategies to reduce noise, studying the long-term impact of cumulative noise exposure on hearing health,

evaluating interventions to promote hearing protection among watercraft personnel, and creating policies to ensure safety and health in the maritime sector.

5. Conclusions

Finally, the results of noise measurement indicated that the captain position does not exceed the TLV. In contrast, six speedboats in the crew's place exceeded the threshold value based on the duration of exposure. A total of 109 participants (83.8%) had hearing loss, with the majority having mild (40.8%), moderate (39.2%), and severe (3.8%) levels. Noise has an effect on hearing impairment, as shown by statistical results indicating that all variables in this study are related to hearing impairment, except for job position. Noise is not the only cause of hearing loss because all variables are interconnected. For instance, members of speedboats are susceptible to hearing loss due to prolonged exposure to noise, high decibel levels, and other factors. They will also experience hearing loss due to their age, BMI, and other lifestyle-related factors, such as smoking, alcohol consumption, recreational activities, and daily exercise routines.

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