e-ISSN : 2597-6052

MPPKI MEDIA PUBLIKASI PROMOSI KESEHATAN INDONESIA

Research Articles Open Access

Age and Working Hours as Predictors of Hearing Loss Among Workers in a High-Noise Glass Factory in Indonesia: A Cross-Sectional Study

Hotmaria Agustina Pakpahan[1], Evi Ulina Margareta Situmorang[2*], Hadiyanto Usman[3], Gunterus Evans[4], Lonah Lonah[5]

[1]Center for Health Research, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia

[2]Department of Physiology, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia

[3]Department of Public Health and Nutrition, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia

[4]Department of Otolaryngology, Head, and Neck Surgery, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia

[5]Department of Pharmacology, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia

***Corresponding Author**: E-mail: evi.situmorang@atmajaya.ac.id

ARTICLE INFO

Manuscript Received: 14 Nov, 2025
Revised: 02 Mar, 2026
Accepted: 24 May, 2026
Date of Publication: 12 Jun, 2026
Volume: 9
Issue: 6
DOI: 10.56338/mppki.v9i6.9190

KEYWORDS

Hearing Loss;
Occupational Risk Factors;
Noise Exposure;
Working Hours;
Industrial Workers

ABSTRACT

Introduction: This study aims to address the gap by investigating the factors associated with hearing loss among industrial workers at a high-quality glass factory located in the Cikarang Industrial Area, Bekasi.

Methods: A descriptive-analytic study with a cross-sectional design was conducted in 2023, involving 101 industrial workers aged 36.7 ± 10.1 years old with 54 men and 47 women at PT X, Cikarang, Bekasi. The total population consisted of 159 workers, based on the Slovin formula, a sample of 101 respondents was obtained. The sample was selected using a simple random sampling technique. Data were analyzed using SPSS version 22 for Windows with Chi-square and multiple logistic regression tests.

Results: Significant associations were found between hearing loss and the following factors: age, noise exposure intensity, working hours, length of employment ($p<0.05$). Multivariate logistic regression analysis showed that age ≥40 years (aOR=41.65; 95% CI: 11.19–154.97) and extended working hours (aOR=5.63; 95% CI: 1.50–21.07) were significant independent predictors of hearing loss. Although occupational noise exposure showed a significant association in bivariate analysis, its effect was attenuated after adjustment for other variables, suggesting potential interrelationships among occupational risk factors and hearing impairment.

Conclusion: Noise-induced hearing loss (NIHL) among industrial workers in PT X, Cikarang, Bekasi is significantly associated with age and working hours, after controlling for noise exposure intensity, nutritional status, length of employment and the use of hearing protection devices (HPDs). Therefore, the company is advised to develop a comprehensive hearing conservation program that includes regulated working hours, regular health check-ups, job rotation, training and supervision on the proper use of HPDs, and the implementation of engineering controls to reduce noise at its source.

Publisher: Fakultas Kesehatan Masyarakat Universitas Muhammadiyah Palu

INTRODUCTION

Industrial workers are often exposed to occupational hazards, one of which is noise generated by production machinery. Prolonged exposure to high levels of noise, particularly above 85 decibels (dB), is a well-known risk factor that can cause hearing loss. When the condition becomes permanent and irreversible, it can significantly impair communication, productivity, and quality of life (1,2).

Factors contribute to hearing loss among workers, including noise intensity above 85 dB, depending on the duration of exposure. The government has set 85 dB as the permissible exposure limit (PEL) for an 8-hour workday or 40 hours per week (1,3,4). Furthermore, long working hours can reduce productivity and increase the risk of health problems. Ideally, working hours should be limited to 6–8 hours per day or 35–40 hours per week (5). Prolonged employment in noisy environments (≥85 dB) has been indicated to increase the risk of hearing loss, especially after 5 years of continuous exposure (6). Work environments that involve exposure to heat, dust, chemicals, and noise may have cumulative effects on workers' health (7,8). Biological factors such as age can increase susceptibility to hearing loss due to cochlear degeneration over time (8,9). Health conditions such as Diabetes Mellitus or ENT disorders may also impair auditory function (10–12). Ototoxic drugs such as kanamycin, streptomycin, and quinine can damage cochlear hair cells and increase the risk of permanent hearing loss, particularly when combined with noise exposure (13,14). The use of Hearing Protection Devices (HPDs), such as earplugs and earmuffs, is highly effective in reducing noise exposure. Earplugs can reduce sound by up to 30 dB, while earmuffs can reduce it by 40–50 dB within the 100–8000 Hz range, although their effectiveness may decrease with prolonged use (15).

The results of this study align with numerous studies in other industrial sectors, which have shown that age and noise exposure are important factors that can cause occupational noise-induced hearing loss (NIHL). For example, studies conducted in Tanzania, Spain, and China reported that older workers and those exposed to noise for longer periods of time had a higher risk of developing NIHL. In general, these studies emphasize that the intensity and duration of noise exposure are key factors influencing hearing loss (1,16,17). In addition, occupational hearing loss can incur additional costs for medical care and workers' compensation, making it one of the most common occupational diseases, even in countries with advanced occupational safety and health regulations (18–20).

Previous research has suggested that noise intensity is the primary factor causing hearing loss, while age and job characteristics are often considered control variables or additional factors. In contrast, the results of this study show that after adjusting for noise exposure intensity, both age and long working hours remain significant independent factors influencing hearing loss. This finding suggests that in industrial environments with relatively high noise levels, susceptibility caused by aging and long working hours may contribute more to hearing loss than variations in exposure intensity alone.

Thus, this study also extends the conventional model that focuses on noise intensity by emphasizing the importance of the interaction between individual factors and working conditions as risk factors for hearing loss. These findings have important implications for workplace prevention strategies. Hearing conservation programs typically focus on controlling noise intensity through engineering controls and the use of personal protective equipment. While this is important, the results of this study suggest that an approach focused solely on noise control may not be sufficient. Age and long working hours indicate that the risk of hearing loss is also related to cumulative exposure and individual susceptibility.

Therefore, companies need to develop policies that integrate more flexible working hours, job rotation, routine health monitoring that takes age into account, and ongoing education regarding the use of hearing protection. Such a comprehensive approach has the potential to increase the effectiveness of hearing loss prevention efforts in industrial environments with high noise levels.

This research was conducted in a manufacturing industry located in the Cikarang Industrial Estate, Bekasi, Indonesia, that produces high-quality glass packaging for the pharmaceutical sector, such as vials, ampoules, and dropper containers. This industry is considered a high-noise sector due to the use of heavy machinery and continuous production processes. Despite the high risk of NIHL in this sector, research on this issue in Indonesia is still limited. Previous studies on occupational hearing loss have generally focused on other manufacturing sectors, such as metal or textile industries, while high-quality glass packaging for the pharmaceutical sector has received relatively little attention. Given the limited research on NIHL in high-noise glass manufacturing industries in Indonesia, this study provides context-specific evidence that may inform occupational health policies in similar industrial sectors.

Therefore, this study aims to investigate the factors associated with hearing loss among production workers in a high-quality glass factory located in the Cikarang Industrial Area, Bekasi and to identify the most dominant risk factors influencing hearing loss among workers. It is expected that the identification of these key risk factors will support the development of more effective and economical prevention strategies, as well as provide policy recommendations to enhance worker health protection in the industrial sector.

METHOD

Research Type

This research employed a cross-sectional design to identify the risk factors associated with hearing loss among industrial workers at PT X, Cikarang, Bekasi, West Java Province, Indonesia**.** Quantitative data were collected offline through a structured questionnaire distributed to both production and non-production employees. A total of 101 respondents were analysed using Chi-Square tests and multivariate logistic regression analysis**.** The study was conducted from August 2023 to September 2023.

Population and Sample/Informants

The population of this study consisted of employees at PT X, a glass manufacturing company located in Cikarang, Bekasi**.** A total of 159 workers were identified as the study population. From this population, 101 respondents were determined using the Slovin formula, with 6% margin error and 95% confidence level. The sample was selected using a simple random sampling technique and based on predetermined inclusion and exclusion criteria. The inclusion criteria for this study were active workers aged 20–59 years, who had worked for ≥1 year in a production area with a noise exposure level of ≥85 dB(A), were willing to be respondents and sign a consent form, were generally healthy, and were able to communicate well. Exclusion criteria included a history of hearing loss before working in the industry, use of ototoxic drugs (such as streptomycin, kanamycin, or quinine), suffering from a severe chronic illness that affects hearing, experiencing an ear infection or severe earwax blockage, and unwillingness to participate or withdrawing from the study. In sampling, it can be ensured that every qualified worker has an equal opportunity to be selected as a respondent. This is intended to minimize selection bias and increase the representativeness of the sample in describing the overall characteristics of the production workforce at PT X.

Research Location

This research was conducted at PT X in Cikarang, Bekasi, Indonesia. The Cikarang industrial area is a modern industrial center with complete infrastructure, a large number of employees, and busy manufacturing activities, making it an ideal location for our research.

Instrumentation or Tools

Primary data were collected through face-to-face interviews using questionnaires to identify respondent characteristics and obtain demographic information. Height and weight were also measured to determine nutritional status. Height was measured using a portable stadiometer (SECA 213, Germany) with an accuracy of ±0.1 cm. Participants were asked to stand upright barefoot, with heels together, arms at their sides, and eyes looking straight ahead. Weight was measured using a digital scale (Omron HN-289, Japan) with an accuracy of ±0.1 kg. Participants wore light clothing and were barefoot during the measurements. Direct measurements of workplace noise levels were conducted using a Sound Level Meter. Measurements were conducted during representative working hours when machinery was operating at normal capacity, at several key work positions where employees spent most of their time reflecting routine exposure conditions. Personal noise dosimetry and cumulative exposure indicators, such as equivalent continuous sound level (Leq) or 8-hour time-weighted average (TWA), were not collected. Therefore, exposure classification is based on occupational noise measurements and categorized according to an occupational exposure threshold of 85 dB(A). This approach may not fully reflect an individual's level of noise exposure, and this should be taken into account when interpreting the findings. Audiometric testing was performed using a calibrated audiometer. Calibration was performed according to standard audiometric guidelines. Environmental noise levels were monitored to ensure appropriate testing conditions. Testing was performed by trained and certified professionals. Participants were asked to avoid noise exposure for at least 14 hours prior to testing to minimize the

influence of transient threshold shifts. Each ear was tested separately, starting with the better ear, using standard air conduction and bone conduction techniques at predetermined frequencies. Hearing loss was defined as a threshold >25 dB HL, while a threshold ≤25 dB HL was classified as normal hearing.

Data Collection Procedures

Data was collected through direct interviews with respondents at the factory site. Prior to data collection, the research team obtained official permission from the company management, which appointed the occupational safety and health (OHS) unit to coordinate and schedule the interviews without disrupting production activities. A structured questionnaire covering demographic information, employment history, length of employment, noise exposure, and use of hearing protection equipment (PPE) was used as an interview tool. Each interview lasted approximately 15–20 minutes and was conducted in a quiet area within the factory to minimize noise and ensure participant comfort. Prior to the interview, respondents were given a brief explanation of the study's purpose, procedures, and confidentiality assurance, and then signed a consent form. The researchers also ensured that all data was collected anonymously to maintain participant confidentiality.

Data Analysis

The univariate analysis was used to describe the distribution of variables. Bivariate analysis using Chi-Square tests identified associations between variables. Multivariate analysis was conducted using multiple logistic regression to determine the most significant factors associated with hearing loss. Data were analysed using SPSS 22 for Windows, applying the Chi-square test and multiple logistic regression analysis.

Ethical Approval

This study was approved by the Ethical Committee of the School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia (Approval Number: 05/12/KEP-FKIKUAJ/2023). All participants provided informed consent prior to participating in the study. The confidentiality of all participants was strictly maintained throughout the research process.

RESULTS

The characteristics of respondents in this study can be seen in the following table.

Table 1. The Characteristics of Respondents (n=101)

Characteristics	Description	Frequency	%
Department	Production	91	90.1
	Non-Production	10	9.9
Age (Mean±SD = 36.7 ± 10.1)	<40 Years	64	63.4
	≥40 Years	37	36.6
Gender	Male	54	53.5
	Female	47	46.5
Education	Senior High School	87	86.1
	Bachelor's degree	14	13.9
Marital Status	Married	78	77.2
	Unmarried	23	22.8
Nutritional Status	Normal	62	61.4
	Overweight	39	38.6
Noise Exposure Intensity	>85dB	77	76.2
	≤85dB	24	23.8
Working Hours	≥8 hours/day	51	50.5
	<8 hours/day	50	49.5
Length of Employment	<10 Years	29	28.7
	≥10 Years	72	71.3

Characteristics	Description	Frequency	%
Hearing Protection Devices (HPDs)	Yes	74	73.3
	No	27	26.7
Hearing Loss	Yes (threshold >25 dB HL)	39	38.6
	No (threshold ≤25 dB HL)	62	61.4

Table 1 shows that this study involved 101 respondents with diverse demographic characteristics. The majority of respondents came from the production department (90.1%), indicating that most participants consisted of workers directly involved in operational activities who are potentially exposed to higher noise levels than non-production workers. The average age of respondents was 36.7 ± 10.1 years, with a larger proportion in the <40 years age group (63.4%). The gender distribution was balanced, with 53.5% male and 46.5% female. Most respondents had a high school education (86.1%), while only 13.9% had a bachelor's degree. Marital status was dominated by married respondents (77.2%). Regarding nutritional status, 61.4% of respondents had normal nutritional status, while 38.6% were classified as overweight.

The table also shows that the majority of respondents (76.2%) work in areas with noise levels above 85 dB, meaning they exceed the safe threshold based on occupational health and safety standards. Working hours appear to be almost the same, with 50.5% of respondents working ≥8 hours per day and 49.5% working <8 hours per day. Regarding work experience, it is dominated by employees with ≥10 years of experience (71.3%), indicating that most respondents have long-term exposure to noise risks. Regarding the use of Hearing Protection Equipment (PPE), 73.3% of workers were seen using PPE, while 26.7% did not. Despite the high level of use, some workers still do not receive adequate protection. This can be seen from the results of audiometric examinations, 38.6% of respondents were indicated to have hearing loss, while 61.4% did not experience hearing loss.

Table 2. Bivariate Factors Associated with Hearing Loss

Characteristics	Description	Hearing Loss n (%)		p-value	COR** (95% CI)
		Yes	No		
Age (Years)	< 40	7 (10.9)	57 (89.1)	0.000*	52.11 (15.28-177.69)
	≥ 40	32 (86.5)	5 (13.5)		
Nutritional Status	Normal	21 (33.9)	41 (66.1)	0.217	1.67 (0.74-3.80)
	Overweight	18 (46.2)	21 (53.8)		
Noise Exposure Intensity	>85dB	34 (44.2)	43 (55.8)	0.04*	3.01 (1.02-8.87)
	≤85dB	5 (20.8)	19 (79.2)		
Working Hours	≥8 hours/day	31 (60.8)	20 (39.2)	0.000*	8.14 (3.17-20.88)
	<8 hours/day	8 (16)	42 (84)		
Length of Employment (Years)	<10	5 (17.2)	24 (82.8)	0.005*	4.29 (1.48-12.51)
	≥10	34 (47.2)	38 (52.8)		
Hearing Protection Devices (HPDs)	Yes	33 (44.6)	41 (55.4)	0.07	2.82 (1.02-7.78)
	No	6 (22.2)	21 (77.8)		

*: significant (p< 0.05)
**: COR (*Crude Odds Ratio*)

Table 2 shows that several risk factors were significantly associated with hearing loss, including age (COR = 52.11, p = 0.000). Respondents aged ≥40 years had a higher prevalence of hearing loss (86.5%) compared to those aged <40 years (10.9%). The very high odds ratio for age may reflect a cumulative susceptibility effect, where there is a relationship between biological aging and long-term occupational noise exposure that can accelerate hearing loss. However, the wide confidence interval indicates limited precision and requires careful interpretation of the magnitude of the relationship. Noise intensity also showed a significant association with hearing loss (COR = 3.01, p = 0.04), with workers exposed to noise levels >85 dB having a 44.2% prevalence of hearing loss, compared to only 20.8% for

those working in areas with noise levels ≤85 dB. Working hours were also found to be a highly significant factor associated with hearing loss (COR = 8.14, p = 0.000). Respondents working ≥8 hours per day had a hearing loss prevalence of 60.8%, which was considerably higher than those working <8 hours per day (16%). Length of employment was also significantly associated with hearing loss (COR = 4.29, p = 0.005), as workers with ≥10 years of employment had a prevalence of 47.2%, compared to only 17.2% among those with <10 years of employment.

Risk factors that were not statistically significant included nutritional status (p = 0.217), although the prevalence of hearing loss was higher in the overweight group (46.2%) than in the group with normal nutritional status (33.9%). Another factor was the use of HPDs, which showed a tendency to be associated with hearing loss, although the p-value of 0.07 was slightly above the significance threshold of 0.05. Workers who used HPDs had a higher prevalence of hearing loss (44.6%) compared to those who did not use them (22.2%).

Table 3. Multiple Logistic Regresion Model for Hearing Loss Status

Characteristics	p-value	95% CI	AOR**
Age	0.000*	11.19-154.97	41.65
Working Hours	0.010*	1.50-21.07	5.63
Noise Exposure Intensity	0.416	0.39-9.35	1.93

*: significant (p< 0.05)
**: aOR (*Adjusted Odds Ratio*)

Based on the multiple logistic regression analysis in table 3, there are two main predictors of hearing loss in workers. Age ≥40 years is the strongest predictor, increasing the risk by 41.6 times, and working hours ≥8 hours per day is another significant predictor, increasing the risk by 5.6 times. Meanwhile, noise intensity >85 dB, which is theoretically a risk factor for NIHL, did not appear as an independent predictor in this model.

DISCUSSION

Interpretation of Key Findings and Comparison with Previous Studies

The research found that the prevalence of hearing loss among workers at PT X was 38.6%. This figure is quite high and aligns with several studies that state that industrial work environments with high noise exposure also carry a high risk of hearing loss. The study also showed that most respondents worked in production departments and were exposed to noise levels above 85 dB, which increases the cumulative risk of hearing damage.

This study showed that age ≥40 years was the strongest risk factor in both bivariate and multivariate analyses. The strength of the association was very high (COR = 52.11; 95% CI: 15.28–177.69; aOR = 41.65; 95% CI: 11.19–154.97), indicating a highly significant increase in risk in older workers. Epidemiologically, this finding is understood as age-related degenerative changes in the auditory system (presbycusis), when older age is associated with long-term occupational noise exposure, it can substantially increase susceptibility to hearing loss (21). In this study, the largest proportion of workers aged ≥40 years experienced hearing loss, suggesting a strong cumulative risk effect in high-noise industrial environments. However, the wide confidence intervals indicate limitations in the precision of the estimates, likely due to the relatively small number of non-hearing loss cases in the older age group and the influence of sparse data. It is important to emphasize that although age emerged as the strongest risk factor, this result should not be interpreted as the sole cause of hearing loss. All participants were exposed to high levels of occupational noise, and age likely acts as a susceptibility modifier, increasing the risk of noise-induced hearing loss. These findings reflect a cumulative susceptibility process, in which biological aging and long-term occupational exposure are interrelated, rather than competing etiologies. While the strength of this association underscores the important role of age in this context, its large effect still requires caution in its interpretation. These findings are consistent with several studies showing that older age can increase susceptibility to noise-induced hearing loss and reduce recovery capacity (22–25). The higher aOR in the ≥40 age group highlights the importance of cumulative risk in industrial settings. However, age ≥40 should not be considered solely due to age-related hearing loss. Instead, it may reflect a persistent interaction between biological aging and occupational noise exposure. Therefore, further research with larger sample sizes and other modeling approaches is needed to confirm the stability and precision of these estimates.

The results of the study showed that working ≥8 hours per day was identified as a risk factor significantly associated with hearing loss. Workers with a working duration of ≥8 hours per day had a 5.63 times higher risk of experiencing hearing loss. If exposure exceeds the safe time limit, hair cells in the cochlea can be gradually damaged. Therefore, it is very important to ensure that the duration of noise exposure does not exceed 8 hours per day. Some ways to ensure the duration of exposure does not exceed 8 hours per day include limiting work time in noisy areas to a maximum of 8 hours (or less if the intensity is very high), implementing job rotation so that workers are not continuously in noisy areas and providing rest time in quieter areas (quiet zones) (26).

Several studies have acknowledged that continuous exposure is an important factor in the development of NIHL (Noise-Induced Hearing Loss). These findings support occupational health recommendations such as job rotation, rest periods, and routine hearing monitoring for workers exposed to high levels of noise (13,22). Although noise exposure ≥85 dB was significant in the bivariate analysis, it was not a significant independent predictor in the multivariate model. This finding should be interpreted with caution. After adjustment, statistical insignificance does not eliminate the biological possibility that persistent exposure to high decibel levels is associated with cochlear hair cell damage. Several methodological factors may explain this weak effect. First, the lack of exposure stratification based on noise intensity may not fully reflect cumulative dose or temporal variation. Second, the limited diversity of exposure levels within industrial settings, where noise is common, may reduce the ability to detect independent effects. Third, the concurrent diversity of interacting occupational variables such as age, working hours, and tenure may weaken the contribution of independent effects to noise intensity in the final model. The results of this study are also in line with the regulatory threshold of 85 dB(A) for an 8-hour shift, as stipulated by the Ministry of Manpower of the Republic of Indonesia through Regulation No. 5/2018 (18,27), and of course, it remains consistent with international occupational safety standards.

Work tenure ≥10 years was significantly associated with hearing loss in the bivariate analysis. Long-term noise exposure over many years increases cumulative risk, which is consistent with studies conducted by Yap KK (2023) and Mutthumanickam G (2024) among industrial workers (10,28). However, in the multivariate model, this factor became no significant, indicating that age and daily exposure duration may have a more direct influence.

No significant association was found between nutritional status based on BMI and hearing loss ($p = 0.217$), consistent with several studies showing that the effects of noise are more strongly influenced by environmental factors and age rather than anthropometric factors. Nonetheless, some literature suggests a possible vascular link between obesity and hearing impairment (29). A study by Suwimol Ruencharoen (2024) reported that non-communicable diseases such as obesity, diabetes, and hypertension may have inconsistent associations with hearing loss, which is in line with the findings of this study (27). Nevertheless, overweight workers still require health interventions due to their increased risk of other comorbidities.

Interestingly, workers who reported using HPDs demonstrated a higher prevalence of hearing loss. This finding should not be interpreted as evidence of reduced protective effectiveness. Rather, this likely reflects an inverse relationship and confounding caused by exposure intensity and job classification, as workers in higher noise environments or those already experiencing hearing symptoms may be more compliant with HPD use. Given the cross-sectional design of this study, causality regarding the effectiveness of HPDs cannot be established. Although HPD use was not significantly associated ($p = 0.07$), the high crude odds ratio (COR) (2.82) likely reflects underlying differences in exposure levels. This insignificance is due to improper HPD use, failure to use personal protective equipment during noise exposure, inadequate quality or type of HPD, or inappropriate size. This explanation aligns with previous research findings (30–32). It is important to note that, if used correctly and consistently, HPDs can be an effective measure to reduce daily noise exposure and prevent occupational hearing loss. Therefore, further research with longitudinal designs, stratified analyses, and interaction modeling is needed to elucidate the complex relationships between HPD use, exposure intensity, and compliance patterns.

Limitations and Cautions

The limitations of this study are: (1) The study design was cross-sectional, thus limiting the ability to determine a causal relationship between occupational factors and noise-induced hearing loss; (2) Data were collected from only one company (PT X, Cikarang, Bekasi), thus limiting the scope of observations to other industries or regions with different work environments and noise exposure profiles; (3) Some risk factors, such as the use of

hearing protection devices (HPD) and working hours, were based on self-reports, potentially subject to respondent recall bias; (4) Limited control for other unmeasured confounding factors not included in the analysis (e.g., smoking habits and use of ototoxic medications) that could influence hearing loss even if a multivariate analysis was performed; (5) The study was conducted over a short period of time (two separate days), so it may not fully identify high and low levels of noise exposure or working conditions over time; (6) The assessment of noise exposure in this study was based on area measurements during representative working hours, not personal dosimetry. Cumulative exposure indicators such as continuous equivalent noise level (Leq) or time-weighted average were not calculated. Therefore, the binary classification of exposure (>85 dB(A) vs. ≤85 dB(A)) may not fully reflect the level of exposure or cumulative dose, which could lead to bias; (7) With 39 (38.6%) hearing loss events and six risk factors in the final model, the incidence-to-variable ratio (EPV) was approximately 6.5. Although slightly below the traditional threshold of 10 EPVs, recent literature suggests that lower EPV values can still provide acceptable estimates if interpreted cautiously. Therefore, further research with a larger sample size is needed to validate these findings.

Recommendations for Future Research

Suggestions for developing hearing conservation programs in the workplace include: (1) Regulating working hours, ensuring that employees do not exceed the 40-hour workweek limit in accordance with labor regulations (optimizing work shifts); (2) Regular health checks, particularly annual hearing tests, especially for employees aged 40 and over or those exposed to high noise levels; (3) Job rotation, especially for employees aged 40 and over or with more than 10 years of service, to minimize continuous exposure to high-noise environments; (4) Education and training programs to raise awareness about the importance of proper and correct use of hearing protection; (5) Improving monitoring and supervision of hearing protection use, including implementing a reward or sanction system to encourage compliance; (6) Recommending further research including personal noise monitoring and more detailed exposure modeling to better describe the pathophysiological mechanisms of noise-induced hearing loss.

CONCLUSION

This study showed four factors significantly associated with hearing loss in production workers at PT X: age, intensity of noise exposure, working hours, and length of employment. Age ≥40 years was the most dominant factor (OR = 41.65; $p < 0.001$), indicating a higher risk of noise-induced hearing loss (NIHL) in older workers. Noise exposure >85 dB (OR = 3.01; $p = 0.04$), working hours ≥8 hours/day (OR = 8.14; $p < 0.001$), and length of employment ≥10 years (OR = 4.29; $p = 0.005$) also showed significant associations. Nutritional status ($p = 0.217$) and use of hearing protection devices (HPD) ($p = 0.07$) were not significantly associated with hearing loss. After multivariate statistical analysis, only age and working hours were significant independent predictors. The observed relationship between the variables of noise exposure intensity and length of employment in the bivariate analysis was no longer significant after multivariate analysis, indicating that their independent contribution may be reduced when analyzed together with other correlated occupational factors.

AUTHOR CONTRIBUTION STATEMENT

HAP: conceptualization, investigation, methodology, supervision, data analysis, writing original draft, writing review and editing; EUMS: methodology, writing original draft; HU: methodology; formal analysis, writing original draft; GE: methodology, writing original draft; LL: methodology; formal analysis, writing–original draft

CONFLICT OF INTEREST

All authors have no conflict of interest regarding this article.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors disclose that AI-assisted technologies, specifically Grammarly, were used solely to support language refinement relating to grammar and tense consistency. This disclosure is in accordance with ethical publication standards to ensure transparency and academic integrity.

SOURCE OF FUNDING STATEMENTS

This research was funded by the Institute for Research and Community Development of Atma Jaya Catholic University of Indonesia, grant number: 1279/III/D.FKIK-KP.104.01/04/2023.

ACKNOWLEDGMENTS

We would like to thank the entire team, particularly from PT X, Cikarang Industrial Area, Bekasi, for participating in this research, and the Institute for Research and Community Development of Atma Jaya Catholic University of Indonesia for their generous support of this study, without whom this research would not have been possible.

BIBLIOGRAPHY

1. Abraham Z, Massawe E, Ntunaguzi D, Kahinga A, Mawala S. Prevalence of Noise-Induced Hearing Loss among Textile Industry Workers in Dar es Salaam, Tanzania. *Ann Glob Health*. 2019 Jun 17;85(1):1–6. https://doi.org/10.5334/aogh.2352
2. Khoshakhlagh AH, Yazdanirad S, Sarsangi V. The Relationship between Individual Risk Factors and Hearing Loss in Textile Workers. *Archives of Occupational Health* [Internet]. 2018 Apr [cited 2024 Nov 12];2(2):121–127. Available from: https://aoh.ssu.ac.ir/article-1-73-en.pdf
3. Panggeleng AMF, Ananda R, Maharja R. Faktor Yang Berhubungan dengan Gangguan Fungsi Pendengaran Pekerja. *Jurnal Keperawatan Profesional (KEPO)*. 2022 Nov 30;3(2):108–114. https://doi.org/10.36590/kepo.v3i2.436
4. Sriopas A, Chapman RS, Sutammasa S, Siriwong W. Occupational noise-induced hearing loss in auto part factory workers in welding units in Thailand. *J Occup Health*. 2017 Jan 24;59(1):55–62. https://doi.org/10.1539/joh.15-0291-OA
5. Aqsyari R, Sumardiyono S, Murti B. Meta-Analysis the Effect of Excessively Loud Sounds on Noise Induced Hearing Loss in Manufacturing Industry Workers. *Journal of Epidemiology and Public Health*. 2023 Apr 16;8(2):275–283. https://doi.org/10.26911/jepublichealth.2023.08.02.12
6. Chen Y, Zhang M, Qiu W, Sun X, Wang X, Dong Y, et al. Prevalence and determinants of noise-induced hearing loss among workers in the automotive industry in China: A pilot study. *J Occup Health*. 2019 Sep 3;61(5):387–397. https://doi.org/10.1002/1348-9585.12066
7. Kurniawidjaja LM, Ramdhan DH. *Buku Ajar Penyakit Akibat Kerja dan Surveilans*. Jakarta: UI Publishing; 2019.
8. Makaruse N, Maslin MRD, Campbell ZS. Occupational noise-induced hearing loss in high-income countries: A multi-country analysis of compensation records. *Heliyon*. 2025 May;11(10):e43164–e43174. https://doi.org/10.1016/j.heliyon.2025.e43164
9. Chuangkrud S, Chaiklieng S. Eye Fatigue of Workers in an Electronic Manufacturing Industry. *KKU Research Journal* [Internet]. 2024 [cited 2026 Feb 26];24(4):186–197. Available from: https://ph02.tci-thaijo.org/index.php/gskku/article/view/252441
10. Mutthumanickam G, Supramanian RK, Lim YC. Prevalence and Factors Associated with Occupational Noise-Induced Hearing Loss Among Palm Oil Mill Workers in Selangor, Malaysia. *Cureus*. 2024 Aug 3;16(8):e66077. https://doi.org/10.7759/cureus.66077
11. Natarajan N, Batts S, Stankovic KM. Noise-Induced Hearing Loss. *J Clin Med*. 2023 Mar 17;12(6):2347–2381. https://doi.org/10.3390/jcm12062347
12. Caballero-Borrego M, Andujar-Lara I. Type 2 Diabetes Mellitus and Hearing Loss: A Prisma Systematic Review and Meta-Analysis. *Otolaryngology–Head and Neck Surgery*. 2025 Nov 8;173(5):1041–1053. https://doi.org/10.1002/ohn.1346
13. Hurtado VAQ, Aulestia JVM, Solano SJN. Hearing Impairment Due to Occupational Noise Exposure in Workers in A Plastics Industry, 2024. *Lex Localis - Journal of Local Self-Government*. 2025 Oct 19;23(S6):2447–2455. https://doi.org/10.52152/9af3d406

14. Joo Y, Cruickshanks KJ, Klein BEK, Klein R, Hong O, Wallhagen MI. The Contribution of Ototoxic Medications to Hearing Loss Among Older Adults. *The Journals of Gerontology: Series A*. 2020 Feb 14;75(3):561–566. https://doi.org/10.1093/gerona/glz166
15. Kwak C, Han W. The Effectiveness of Hearing Protection Devices: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*. 2021 Nov 7;18(21):11693–11708. https://doi.org/10.3390/ijerph182111693
16. Pelegrin A, Canuet L, Rodríguez Á, Morales MA. Predictive factors of occupational noise-induced hearing loss in Spanish workers: A prospective study. *Noise Health*. 2015;17(78):343–349. https://doi.org/10.4103/1463-1741.165064
17. Wang Y, Mei P, Zhao Y, Lu J, Zhang H, Zhang Z, et al. Associations Between Occupational Noise Exposure, Aging, and Gender and Hearing Loss: A Cross-Sectional Study in China. *Audiol Res*. 2025 Jul 23;15(4):1–19. https://doi.org/10.3390/audiolres15040091
18. Peraturan Menteri Ketenagakerjaan Nomor 5 Tahun 2018 tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja [Internet]. 2018. Available from: https://jdih.kemnaker.go.id/katalog-1546-Peraturan%20Menteri.html
19. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. *The Lancet*. 2014 Apr;383(9925):1325–1332. https://doi.org/10.1016/S0140-6736(13)61613-X
20. Themann CL, Masterson EA. Occupational noise exposure: A review of its effects, epidemiology, and impact with recommendations for reducing its burden. *J Acoust Soc Am*. 2019 Nov 1;146(5):3879–3905. https://doi.org/10.1121/1.5134465
21. Handayani RE, Baluqia B. PRESBIKUSIS: Masalah Telinga pada Usia Tua. *Jurnal Anestesi: Jurnal Ilmu Kesehatan dan Kedokteran*. 2024 Apr 7;2(2):122–132. https://doi.org/10.59680/anestesi.v2i2.1059
22. Rasasoran DR, Atil A, Jeffree MS, Saupin S, Lukman KA. Hearing Loss and Associated Factors Among Noise-Exposed Workers in Palm Oil Mills. *Risk Manag Healthc Policy*. 2021 Sep;14:3653–3658. https://doi.org/10.2147/RMHP.S319858
23. Wang L, Chen M, Liang M, Liu Q, Yao H. A Demographic Analysis of Hearing Impairments among People of Uyghur and Han Ethnicity in Xinjiang, China. *Iran J Public Health*. 2022 Apr 18;51(4):770–778. https://doi.org/10.18502/ijph.v51i4.9237
24. Roscoe R, Purwito Adi N, Kekalih A. Analysis between Demographic Factors, Chronic Conditions and Its Association with Increased Hearing Threshold On Factory Workers Exposed to Noise: A Cross Sectional Study in 2022. *The Indonesian Journal of Community and Occupational Medicine*. 2024 Mar 27;3(3):150–154. https://doi.org/10.53773/ijcom.v3i3.121.150-4
25. Golmohammadi R, Darvishi E. The Combined Effects of Occupational Exposure to Noise and Other Risk Factors − A Systematic Review. *Noise Health* [Internet]. 2019 [cited 2026 Feb 26];21(101):125–141. Available from: https://pubmed.ncbi.nlm.nih.gov/32719300/
26. Samara P, Athanasopoulos M, Markatos N, Athanasopoulos I. From sound waves to molecular and cellular mechanisms: Understanding noise induced hearing loss and pioneering preventive approaches (Review). *Medicine International*. 2024 Jul 30;4(60):1–12. https://doi.org/10.3892/mi.2024.184
27. Ruencharoen S, Lertsukprasert K, Suvanich R, Seesangnom J, Chockboondee M, Aekplakorn W, et al. Hearing health survey of the population in Bangkok. *BMC Public Health*. 2024 Apr 12;24(1):1024. https://doi.org/10.1186/s12889-024-18424-x
28. Yap KK, Ismail NH, Supramanian RK, Lim YC. Noise-Related Hearing Disorder Among Vector Control Workers in Kuala Lumpur. *Cureus*. 2023 Oct 13;15(10):e46965. https://doi.org/10.7759/cureus.46965
29. Jung SY, Kim SH, Yeo SG. Association of Nutritional Factors with Hearing Loss. *Nutrients* [Internet]. 2019 Feb [cited 2024 Nov 11];11(2):307. Available from: https://www.mdpi.com/2072-6643/11/2/307
30. Choirunisa R. Hearing Loss and Health Complaints in Technicians Air Skadron 3 Iswahjudi Airport and Its Association with Aircraft Noise. *Jurnal Kesehatan Lingkungan*. 2019 Feb 1;11(1):61–68. https://doi.org/10.20473/jkl.v11i1.2019.61-68

31. Su Z, Fan S, Niu Y, Wu J, Wu Q, Zhou B, et al. The association between occupational noise exposure and hearing loss among petrochemical enterprise workers in Hainan, South China. *Sci Rep*. 2025 Mar 19;15(1):9447–9456. https://doi.org/10.1038/s41598-025-90023-1
32. Zhou J, Shi Z, Zhou L, Hu Y, Zhang M. Occupational noise-induced hearing loss in China: a systematic review and meta-analysis. *BMJ Open*. 2020 Sep 28;10(9):e039576. https://doi.org/10.1136/bmjopen-2020-039576