



The Relationship Between Occupational Environmental Noise Exposure and the Incidence of Tinnitus Symptoms Among Workers at X Coconut Flour Factory

Jasmine Raisa Rizky Putri¹, Ratih Anindita¹, Muhammad Edy Syahputra Nasution¹, Taya Elsa Savista¹

¹Fakultas Kedokteran, Universitas Muhammadiyah Sumatera Utara, Indonesia

*Corresponding Author: Jasmine Raisa Rizky Putri

E-mail: jasmine.raisa2708@gmail.com



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Abstract

Occupational noise exposure is one of the major risk factors for hearing disorders, including tinnitus, which is characterized by the perception of ringing, buzzing, or other sounds in the absence of an external auditory stimulus. This condition is commonly observed among industrial workers who are continuously exposed to high-intensity noise, including those employed in coconut flour processing industries. This study aimed to analyze the association between workplace environmental noise exposure and the incidence of tinnitus symptoms among workers at X Coconut Flour Factory in Kisaran City. A cross-sectional study design was employed involving 67 respondents selected through purposive sampling. Noise intensity was measured using a Sound Level Meter (SLM), while tinnitus symptoms were assessed using the Tinnitus Handicap Inventory (THI). Data were analyzed using univariate and bivariate analyses, with the Spearman rank correlation test at a 95% confidence level ($\alpha = 0.05$). The results showed that 62.7% of respondents worked in environments with noise levels exceeding 85 dBA, while 56.7% experienced tinnitus symptoms. Spearman correlation analysis revealed a statistically significant association between occupational noise exposure and tinnitus symptoms ($r = 0.419$; $p < 0.001$). The correlation coefficient indicated a moderate positive relationship, suggesting that higher levels of workplace noise exposure were associated with an increased likelihood of experiencing tinnitus symptoms. It can be concluded that occupational noise exposure is significantly associated with the occurrence of tinnitus symptoms among workers at X Coconut Flour Factory in Kisaran City.

Introduction

Occupational noise exposure remains one of the most significant physical hazards affecting workers' health across various industrial sector (Chis et al., 2025; Nasrolahi et al., 2025; Said et al., 2022). Noise is defined as unwanted sound that interferes with communication, reduces comfort, and may cause physiological and psychological disturbances when exposure occurs continuously (World Health Organization [WHO], 2018). Manufacturing industries, including agricultural product processing such as coconut flour factories, are among the sectors characterized by relatively high noise levels due to the continuous operation of production machinery. Exposure to noise exceeding the permissible exposure limit may lead to a variety of adverse health outcomes, including hearing impairment and non-auditory disorders that

negatively affect workers' productivity and quality of life (Themann & Masterson, 2019; Turan Dizdar et al., 2022; Tijani et al., 2026).

Globally, occupational noise-induced hearing loss (ONIHL) remains a major occupational health concern. The World Health Organization estimates that more than 1.5 billion people worldwide experience some degree of hearing loss, with approximately 430 million requiring hearing rehabilitation. Occupational noise exposure is recognized as one of the leading contributors to hearing impairment, particularly in developing countries where hearing conservation programs have not been fully implemented (WHO, 2021). Similarly, the International Labour Organization (ILO) reported that millions of workers worldwide continue to be exposed to hazardous noise levels each year, increasing the risk of occupational diseases, including permanent hearing loss and tinnitus (ILO, 2023; Elango & Kamalakannan, 2026; Farheen & Mandal, 2026).

In Indonesia, workplace noise control is regulated under the Minister of Manpower and Transmigration Regulation No. PER.13/MEN/X/2011 concerning Threshold Limit Values for Physical and Chemical Factors in the Workplace, which establishes a permissible noise exposure limit of 85 dBA for an 8-hour workday. Higher noise intensities require proportionally shorter exposure durations to minimize cumulative damage to the auditory system (Ministry of Manpower of the Republic of Indonesia, 2011). Nevertheless, numerous studies have shown that compliance with hearing protection device use and the implementation of Hearing Conservation Programs (HCPs) remain inadequate in many industries, thereby maintaining a high risk of occupational hearing disorders (Themann & Masterson, 2019; Efundipo et al., 2026; Cudjoe et al., 2025).

One of the most common health consequences of prolonged occupational noise exposure is tinnitus, defined as the perception of sounds such as ringing, buzzing, hissing, or humming in the absence of an external sound source. Tinnitus is not a disease itself but rather a symptom associated with dysfunction of the auditory system. It may be temporary or permanent and can significantly impair concentration, sleep quality, work performance, and psychological well-being (Baguley et al., 2013; Langguth et al., 2023). Among industrial workers, tinnitus is often considered an early indicator of noise-induced auditory damage before permanent hearing loss becomes clinically evident.

From a physiological perspective, prolonged exposure to high-intensity noise damages the outer hair cells of the organ of Corti within the cochlea. This damage disrupts neural signal transmission to the auditory cortex, leading the central nervous system to compensate through increased spontaneous neural activity. This neuronal hyperexcitability is considered one of the principal mechanisms underlying chronic tinnitus (Sundar et al., 2021). In addition, oxidative stress induced by continuous exposure to loud noise accelerates cochlear sensory cell degeneration, thereby increasing the risk of hearing impairment and tinnitus (Chen et al., 2023; Teraoka et al., 2024; Natarajan et al., 2023; Samara et al., 2024).

Several studies have demonstrated a significant association between occupational noise exposure and tinnitus. Haji et al. (2022) reported that 22.7% of young adults experienced tinnitus following exposure to loud noise, with many cases becoming persistent. Similarly, a study conducted among coffee factory workers in Bener Meriah Regency found that a substantial proportion of workers reported tinnitus symptoms of varying severity, particularly those with longer employment duration and extended working hours (Lestari et al., 2023). These findings suggest that both noise intensity and exposure duration are important determinants of tinnitus among industrial workers (Sunarto & Yudhastuti, 2022; Yang et al., 2025; Yang et al., 2025; Ristiani et al., 2026).

However, the relationship between occupational noise exposure and tinnitus remains a subject of ongoing debate. A systematic review by Biswas et al. (2023) concluded that although

occupational noise is an important risk factor, current evidence does not fully establish a direct causal relationship because tinnitus is influenced by multiple factors, including age, metabolic disorders, genetic predisposition, smoking, alcohol consumption, psychological stress, and the use of ototoxic medications. Similarly, Langguth et al. (2023) emphasized that tinnitus is a multifactorial condition requiring comprehensive assessment of its contributing risk factors.

Workers in the coconut flour processing industry represent a population at considerable risk of excessive occupational noise exposure due to the continuous operation of peeling, crushing, drying, grinding, and packaging machinery throughout the production process. Such conditions expose workers to high-intensity noise for prolonged periods, thereby increasing the likelihood of developing hearing disorders, including tinnitus. Despite this occupational risk, studies investigating the association between workplace noise exposure and tinnitus symptoms among coconut flour factory workers, particularly in Kisaran City, remain limited. Differences in production processes, exposure duration, hearing protection practices, and worker characteristics may distinguish this industry from other manufacturing sectors.

The limited availability of empirical evidence in this setting highlights the need for further investigation. Therefore, this study aimed to examine the association between workplace environmental noise exposure and the occurrence of tinnitus symptoms among workers at X Coconut Flour Factory in Kisaran City. The findings are expected to provide scientific evidence to support the development of hearing conservation programs, improve compliance with hearing protection device use, and strengthen workplace noise control strategies to prevent occupational hearing disorders and promote workers' health and safety.

Methods

This study employed a quantitative analytical survey with a cross-sectional design. This design was selected because both workplace noise exposure and tinnitus symptoms were measured simultaneously, allowing the association between these variables to be examined among workers at X Coconut Flour Factory in Kisaran City.

The study was conducted at X Coconut Flour Factory, Kisaran City, from July to December 2026. The study population consisted of all 93 production workers employed at the factory. The minimum sample size was calculated using Slovin's formula with a 10% margin of error, resulting in a required sample of 48 respondents. Participants were selected using purposive sampling based on predefined inclusion and exclusion criteria. The inclusion criteria were workers aged 20–50 years, having at least one year of work experience, and providing written informed consent to participate. The exclusion criteria included workers with a history of ear disease, diabetes mellitus, hypertension, ear surgery, ear trauma, congenital hearing impairment, or current use of ototoxic medications.

The independent variable was workplace environmental noise exposure, measured using a Sound Level Meter (SLM) and categorized according to the occupational noise exposure limits established by the Indonesian Minister of Manpower and Transmigration Regulation No. PER.13/MEN/X/2011 as ≤ 85 dBA and > 85 dBA. The dependent variable was tinnitus symptoms, assessed using the Tinnitus Handicap Inventory (THI). THI scores were classified into five categories: no tinnitus (0–16), mild (18–36), moderate (38–56), severe (58–76), and catastrophic (78–100). Covariates included age, sex, and the use of hearing protection devices (HPDs).

Data collection began with an explanation of the study objectives, followed by obtaining written informed consent from all participants. Otoscopic examinations were then performed to exclude participants with ear abnormalities that met the exclusion criteria. Workplace noise intensity was measured using a Sound Level Meter at each participant's work area in accordance with standard occupational noise measurement procedures. Subsequently,

participants completed a questionnaire on demographic characteristics and the Tinnitus Handicap Inventory (THI) independently, with assistance from the researchers when necessary.

The collected data underwent editing, coding, data entry, cleaning, and verification before being analyzed using IBM SPSS Statistics version 26. Univariate analysis was conducted to describe participants' characteristics and the distribution of study variables using frequencies, percentages, means, and standard deviations. Prior to inferential analysis, data normality was assessed using the Shapiro–Wilk test. Because the data were not normally distributed and the variables were measured on an ordinal scale, the association between workplace environmental noise exposure and tinnitus symptoms was analyzed using the Spearman's rank correlation test. Statistical significance was established at $\alpha = 0.05$, with $p < 0.05$ considered statistically significant.

Result and Discussion

Respondent Characteristics

The characteristics of the respondents included age, sex, length of employment, ear, nose, and throat (ENT) examination results, working hours, and the use of hearing protection devices (HPDs). The distribution of respondent characteristics is presented in Table 1.

Table 1. Characteristics of the Study Respondents

Characteristics	Category	n	%
Age	16–25 years	7	10.4
	26–35 years	28	41.8
	36–46 years	32	47.8
Sex	Male	60	89.6
	Female	7	10.4
Length of Employment	1–5 years	15	22.4
	6–10 years	30	44.8
	11–15 years	16	23.9
	>15 years	6	9.0
ENT Examination	Normal	67	100.0
	Abnormal	0	0.0
Working Hours	≤8 hours/day	67	100.0
	>8 hours/day	0	0.0
Use of Hearing Protection Devices (HPDs)	Yes	0	0.0
	No	67	100.0

As shown in Table 1, the majority of respondents were aged 36–46 years (32 respondents, 47.8%), followed by those aged 26–35 years (28 respondents, 41.8%), while respondents aged 16–25 years accounted for only 10.4% (7 respondents). Regarding sex, most participants were male (60 respondents, 89.6%), whereas female respondents represented 10.4% (7 respondents).

In terms of employment duration, the largest proportion of respondents had worked for 6–10 years (30 respondents, 44.8%), followed by 11–15 years (16 respondents, 23.9%), 1–5 years (15 respondents, 22.4%), and more than 15 years (6 respondents, 9.0%). The ENT examination revealed that all respondents (100%) had normal ear conditions, indicating that none met the exclusion criteria related to pre-existing ear disorders. All respondents worked 8 hours or less per day, in accordance with the standard working schedule. Notably, none of the respondents reported using hearing protection devices (HPDs) during work, indicating a complete absence of hearing protection practices among the study participants. This finding may increase workers' susceptibility to the adverse effects of prolonged occupational noise exposure.

Univariate Analysis

Distribution of Occupational Noise Exposure According to Tinnitus Symptoms

Univariate analysis was conducted to describe the distribution of respondents according to workplace noise exposure levels and the occurrence of tinnitus symptoms. The distribution is presented in Table 2.

Table 2. Distribution of Workplace Noise Exposure According to Tinnitus Symptoms Among Workers at X Coconut Flour Factory, Kisaran City (n = 67)

Noise Exposure	No Tinnitus n (%)	Mild Tinnitus n (%)	Moderate Tinnitus n (%)	Total n (%)
≤85 dBA	17 (25.4)	7 (10.4)	1 (1.5)	25 (37.3)
>85 dBA	12 (17.9)	17 (25.4)	13 (19.4)	42 (62.7)
Total	29 (43.3)	24 (35.8)	14 (20.9)	67 (100.0)

As shown in Table 2, 25 respondents (37.3%) worked in environments with noise levels of ≤85 dBA, whereas 42 respondents (62.7%) were exposed to workplace noise levels exceeding 85 dBA. Among workers exposed to ≤85 dBA, the majority did not experience tinnitus (17 respondents, 25.4%), while 7 respondents (10.4%) reported mild tinnitus and 1 respondent (1.5%) reported moderate tinnitus. In contrast, among respondents exposed to >85 dBA, 12 respondents (17.9%) reported no tinnitus, 17 respondents (25.4%) experienced mild tinnitus, and 13 respondents (19.4%) experienced moderate tinnitus. Overall, of the 67 respondents, 29 (43.3%) had no tinnitus symptoms, 24 (35.8%) experienced mild tinnitus, and 14 (20.9%) experienced moderate tinnitus. These findings indicate that tinnitus symptoms were more frequently observed among workers exposed to workplace noise levels exceeding the recommended occupational exposure limit.

Bivariate Analysis

Bivariate analysis was performed to examine the association between workplace environmental noise exposure and tinnitus symptoms among workers at X Coconut Flour Factory, Kisaran City. The association was assessed using Spearman's rank correlation test with a significance level of $\alpha = 0.05$. The results are presented in Table 3.

Table 3. Spearman's Rank Correlation Between Workplace Noise Exposure and Tinnitus Symptoms (n = 67)

Variables	Correlation Coefficient (r)	p-value	n
Workplace noise exposure and tinnitus symptoms	0.419	<0.001	67

The results of the Spearman's rank correlation analysis demonstrated a correlation coefficient (r) of 0.419 with a p-value < 0.001, indicating a statistically significant association between workplace environmental noise exposure and tinnitus symptoms among workers at X Coconut Flour Factory, Kisaran City. The positive correlation coefficient suggests that higher levels of occupational noise exposure were associated with an increased likelihood and severity of tinnitus symptoms. Based on the magnitude of the correlation coefficient, the relationship can be interpreted as moderate, indicating that workplace noise exposure is an important factor associated with the occurrence of tinnitus, although other contributing factors may also influence its development.

The present study found that most respondents were aged 36–46 years (47.8%), followed by those aged 26–35 years (41.8%), while only 10.4% were aged 16–25 years. This age distribution indicates that the workforce at X Coconut Flour Factory is predominantly composed of experienced workers within the productive age group. Increasing age is associated

with greater susceptibility to hearing disorders due to degenerative changes in the auditory system. Moreover, cumulative occupational noise exposure over years of employment may further increase the risk of tinnitus. These findings are consistent with those of Rini et al. (2023), who reported that industrial sectors are generally dominated by adult workers because of their greater work experience and physical capacity. Similarly, Themann and Masterson (2019) emphasized that both advancing age and prolonged occupational noise exposure contribute to the development of noise-induced hearing loss (NIHL) and tinnitus.

The majority of respondents were male (89.6%), while females accounted for only 10.4% of the study population. This predominance reflects the characteristics of the coconut flour processing industry, where production activities typically involve physically demanding tasks and continuous operation of heavy machinery. Comparable findings were reported by Nurudin et al. (2023), who observed that manufacturing industries are largely staffed by male workers due to the physical demands of industrial occupations. Nevertheless, sex itself is not considered a primary determinant of tinnitus. Instead, tinnitus is more strongly influenced by factors such as occupational noise intensity, cumulative exposure duration, and adherence to hearing protection practices (Langguth et al., 2023).

Most respondents had worked for 6–10 years (44.8%), followed by 11–15 years (23.9%), indicating prolonged occupational exposure to workplace noise. Long-term exposure to excessive noise may progressively damage cochlear hair cells, thereby increasing the likelihood of hearing impairment. This observation is supported by Themann and Masterson (2019), who reported that the risks of both NIHL and tinnitus increase with the cumulative duration of occupational noise exposure. All respondents demonstrated normal ear, nose, and throat (ENT) examination findings, indicating the absence of abnormalities in the external or middle ear that could explain hearing complaints. Therefore, tinnitus symptoms reported by participants are more likely attributable to pathological changes within the inner ear, particularly the cochlea. This finding is consistent with Halim (2023), who noted that occupational noise-induced hearing disorders generally originate from cochlear sensory damage despite normal findings on routine otoscopic examination.

This study also demonstrated that 62.7% of respondents were exposed to workplace noise levels exceeding the recommended occupational exposure limit of 85 dBA. According to the Indonesian Minister of Manpower and Transmigration Regulation No. PER.13/MEN/X/2011, continuous exposure to noise above this threshold for an eight-hour workday poses a substantial occupational health risk. High-intensity noise damages the outer hair cells of the organ of Corti, impairing their ability to transmit auditory signals to the brain. Such damage is irreversible when exposure persists without adequate preventive measures (Sundar et al., 2021). Similarly, Lintong (2013) explained that chronic occupational noise exposure leads to progressive degeneration of cochlear hair cells, ultimately resulting in permanent hearing loss and tinnitus.

More than half of the respondents (56.7%) experienced tinnitus symptoms, whereas 43.3% reported no tinnitus. This relatively high prevalence indicates that tinnitus is a common occupational health problem among workers exposed to excessive industrial noise. These findings are consistent with those reported by Lestari et al. (2023), who found that workers exposed to high levels of occupational noise had a substantially greater risk of developing tinnitus, particularly after prolonged exposure. Because all respondents worked no more than eight hours per day, the observed tinnitus prevalence appears to be associated primarily with noise intensity rather than daily working duration.

The distribution analysis further revealed that mild and moderate tinnitus occurred more frequently among workers exposed to noise levels above 85 dBA, whereas workers without tinnitus were more commonly found in environments with noise levels at or below 85 dBA. This pattern suggests a dose-response relationship, whereby increasing workplace noise

intensity is accompanied by a higher proportion of workers experiencing tinnitus symptoms. These findings strengthen the evidence that occupational noise exposure is an important factor associated with tinnitus among industrial workers.

Another notable finding was that none of the respondents reported using hearing protection devices (HPDs) during work. The complete absence of HPD use substantially increases the effective dose of occupational noise exposure, thereby elevating the risk of hearing disorders. According to Nair et al. (2019), inadequate compliance with hearing protection remains one of the principal reasons for the persistently high prevalence of occupational hearing disorders in industrial settings. Likewise, Petrescu et al. (2018) demonstrated that consistent use of earplugs or earmuffs significantly reduces the risk of tinnitus among workers exposed to noise levels exceeding 85 dBA. These findings underscore the importance of providing appropriate hearing protection devices and promoting their consistent use as integral components of workplace hearing conservation programs.

The Spearman's rank correlation analysis demonstrated a statistically significant positive association between occupational noise exposure and tinnitus symptoms ($r = 0.419$, $p < 0.001$). The correlation coefficient indicates a moderate positive relationship, suggesting that increasing workplace noise exposure is associated with a greater likelihood of experiencing tinnitus. These findings are consistent with those of Pratiwi and Nauval (2023), who reported a higher prevalence of tinnitus among workers exposed to noise levels exceeding 85 dBA compared with those exposed below the occupational threshold. Similarly, Kantu et al. (2022) concluded that prolonged occupational noise exposure contributes to cochlear hair cell damage, a key pathological mechanism underlying tinnitus.

From a physiological perspective, tinnitus develops when damage to cochlear hair cells reduces auditory input to the auditory cortex. This reduced sensory input triggers a compensatory increase in neuronal activity within the central auditory pathways, commonly referred to as the central gain mechanism, causing the perception of sound despite the absence of external acoustic stimuli (Sundar et al., 2021). Furthermore, chronic noise exposure induces oxidative stress and inflammatory processes within the inner ear, accelerating degeneration of cochlear sensory cells and further increasing the risk of tinnitus (Chen et al., 2023). These biological mechanisms provide a plausible explanation for the higher prevalence of tinnitus among workers exposed to excessive occupational noise.

The findings of this study have important implications for occupational health practice. Workplace noise should be controlled through engineering interventions, regular machine maintenance, routine environmental noise monitoring, provision and mandatory use of appropriate hearing protection devices, and implementation of a comprehensive Hearing Conservation Program (HCP). These preventive strategies are expected to reduce the incidence of occupational hearing disorders while improving workers' health, safety, and productivity.

This study has several limitations. First, the cross-sectional design identifies associations but does not establish causal relationships between occupational noise exposure and tinnitus. Second, the use of purposive sampling and a relatively small sample size limits the generalizability of the findings. Finally, several potential confounding factors including non-occupational noise exposure, smoking habits, ototoxic medication use, and metabolic diseases were not evaluated. Future studies should employ prospective cohort or longitudinal designs with larger sample sizes and comprehensive adjustment for potential confounding variables to provide stronger evidence regarding the relationship between occupational noise exposure and tinnitus among industrial workers.

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Conclusion

Based on the findings of this study involving 67 workers at X Coconut Flour Factory in Kisaran City, it can be concluded that there is a statistically significant association between workplace environmental noise exposure and the occurrence of tinnitus symptoms. The Spearman's rank correlation analysis demonstrated a moderate positive correlation ($r = 0.419$, $p < 0.001$), indicating that higher levels of occupational noise exposure are associated with an increased likelihood of experiencing tinnitus symptoms. The majority of workers (62.7%) were exposed to workplace noise levels exceeding the recommended occupational exposure limit (>85 dBA). Furthermore, more than half of the respondents (56.7%) experienced tinnitus symptoms, consisting of mild and moderate tinnitus. These findings suggest that excessive workplace noise exposure is an important occupational risk factor for hearing disorders among industrial workers. The respondent characteristics further revealed that most workers were 36–46 years of age, had 6–10 years of employment, and none reported using hearing protection devices (HPDs) during work. These conditions may contribute to cumulative occupational noise exposure and increase the risk of developing noise-related hearing disorders. Overall, the findings highlight the importance of implementing effective workplace noise control strategies, including regular environmental noise monitoring, provision and enforcement of hearing protection device use, and comprehensive hearing conservation programs to prevent occupational hearing loss and tinnitus.

Based on the study findings, the company is encouraged to strengthen workplace noise control measures through regular monitoring of environmental noise levels, provision and enforcement of appropriate hearing protection devices (HPDs), and implementation of a comprehensive Hearing Conservation Program (HCP) to reduce the risk of tinnitus and other occupational hearing disorders. Workers should also be encouraged to consistently wear HPDs as an essential protective measure against excessive noise exposure. Future researchers are recommended to conduct longitudinal studies with larger sample sizes to better establish causal relationships between occupational noise exposure and tinnitus. In addition, future studies should perform objective noise measurements across different workstations and control for potential confounding factors, including medical history, smoking habits, use of ototoxic medications, and cumulative noise exposure duration, to provide a more comprehensive understanding of occupational noise-related tinnitus.

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