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FULL PAPER

The prevalence of occupational noise-induced hearing loss among workers in metal industries in the Sulaimani governorate

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Occupational Noise-Induced Hearing Loss (ONIHL) is a prevalent occupational health concern, particularly in industries with high noise levels. The aim of this study was to determine the association between total noise exposure time and severity of Noise-Induced Hearing Loss (NIHL). This cross-sectional study was conducted between 2021 and 2023 in the Sulaimani Governorate. A total of 503 people were included in the study. The demographic characteristics, subjective hearing status, and noise exposure outside of work were assessed. The NIHL severity was classified into five categories, and the affected frequency range among workers with NIHL was determined. Statistical analyses were conducted to determine the most sensitive frequency for noise damage and the relationship between exposure time and NIHL severity in this population. The majority of workers (434) were in the early adult age group (19-45 years), and 500 were male. 394 workers reported normal hearing, while 109 reported impaired hearing. There was a significant association between the total noise exposure time and the NIHL severity, with 4 kHz being the frequency most frequently impacted ($p<0.05$). Higher categories of hearing loss severity were correlated with longer noise exposure times. The study revealed a significant prevalence of ONIHL among workers in the metal industry, with most workers experiencing mild to moderate degrees of hearing loss. The findings underscore the urgent need for comprehensive occupational health and safety policies and interventions to prevent and manage ONIHL in this population.

KEYWORDS

Cross-sectional studies; hearing loss; occupational exposure; workers.

Introduction

Undesirable or unwanted sound, referred to as noise, is a pervasive form of pollution encountered in work settings. Prolonged and excessive exposure to high-intensity noise levels has been identified as a leading cause of irreversible hearing impairment [1]. The Noise-Induced Hearing Loss (NIHL) has been a recognized problem for centuries and continues to be widespread globally [2].

Sensorineural hearing loss (SNHL) is a condition in which hair cell stereocilia lose their ability to transmit sound information to the brain. NIHL is the second most prevalent cause of SNHL and occurs due to damage to stereocilia caused by exposure to hazardous levels of noise [3]. Occupational noise-induced hearing loss (ONIHL) is the term used to describe sensorineural NIHL that results from exposure to dangerously high levels of workplace noise [4].

The World Health Organization (WHO) reports that one of the top three causes of hearing impairment internationally and among the top 10 work-related factors worldwide is ONIHL [5]. According to the National Institute for Occupational Safety and Health (NIOSH), approximately one-third of workers worldwide are exposed to harmful levels of noise that could potentially lead to ONIHL, specifically if the noise levels are greater than 85 decibels (dB) [6].

After noise exposure has ceased, NIHL symptoms may persist for a few minutes, hours, or even days. As NIHL advances, individuals may experience an abnormal increase in loudness, known as recruitment, which can result in a reduction in dynamic range to a discomfort level. Over 50% of individuals with NIHL experience either intermittent or ongoing bilateral tonal tinnitus [7].

Since noise exposure causes cumulative, permanent hearing loss, early diagnosis through screening is essential to preventing ONIHL and other avoidable hearing loss [8]. ONIHL represents a financial burden for both employers and employees. It is imperative to recognize and treat ONIHL as soon as possible due to its significant medical, social, and financial consequences [9]. Furthermore, ONIHL may result in a loss of employment because of safety requirements or communication issues [10].

A combination of the patient's medical history, physical examination, and hearing tests, such as audiometry, tympanometry, otoacoustic emissions, and speech audiometry, are frequently used to diagnose NIHL. The results of these assessments can help determine the kind and severity of a person's hearing loss and serve as a guide for developing a treatment plan [11].

Studies investigating NIHL in Sulaimani Governorate have been limited in number. One such study examined hearing loss in a heavy engineering industry, encompassing both machine shop and press divisions, where sound levels ranged between 83 and 116 dB. This study found that hearing impairment was gradually increasing across all of the study groups. A study of weavers in a textile mill revealed sound levels ranging from approximately 102-104 dB, with poor hearing acuity among the textile workers [12].

Although ONIHL is preventable, it is irreversible and persists even after exposure to noise has ceased, due to the permanent damage incurred. Since metal industry workers are most exposed to noise damage and since limited studies have been done in this field in Iraq. Therefore, it was necessary to conduct the present study with the aim of determining the ONIHL prevalence and its severity as well as its relationship with the total hours of exposure among metal industry workers in Soleimani province, focusing on SNHL.

Materials and methods

Study design and setting

This cross-sectional study was conducted between 2021 and 2023 in the Sulaimani Governorate. The study was conducted in 8 small, medium, and large-scale metal industries located in the Sulaimani Governorate. The industries were selected from Sulaimani Governorate through simple random sampling using a computer-generated list.

Study population

The target population was all workers engaged in various jobs such as welders, press operators, foundry workers, grinders, and assembly line workers in metal industries in Sulaimani Governorate. The accessible population was workers from the selected industries who met the inclusion criteria.

Inclusion and exclusion criteria

The inclusion criteria were being over 18 years old, giving informed consent, having a minimum of 2 years of experience in their current role, not having any pre-existing ear diseases, having no history of using ototoxic drugs, and not having diabetes, high blood pressure, or any other conditions that could affect hearing. Exclusion criteria include unwillingness to continue cooperation, failure to provide consent and having a disease that prevents continued cooperation.

Sample size calculation

The sample size was calculated using the Cochran formula:

$$n=(Z/2+Z1)^2 * P\ (1-P)(d)^2$$

Where, P is the predicted prevalence, d is the accuracy, Z is the z statistic for a degree of confidence, and n is the sample size. Based on a 95% confidence level, 17% predicted prevalence, and 5% precision, 488 was determined to be the minimal sample size. Finally, 503 people were included in this study based on the entry and exit criteria. Within each selected industry, workers were recruited using a convenience sampling method.

Data collection

A questionnaire was used to gather information on demographics, occupational noise exposure history, and subjective hearing status. Noise exposure levels were estimated based on each participant's self-reported occupational history, including their specific job title, years worked, and daily noise exposure duration.

To measure subjective hearing, participants were asked to rate their hearing status on a scale, with options ranging from ''excellent'' to ''poor''. They were also inquired about any difficulties they might have experienced in hearing conversations in noisy environments or any instances of tinnitus. These subjective reports were crucial for understanding the personal impact of noise exposure on hearing and for correlating with the objective audiometric findings.

Audiometric testing was performed using a Madsen astera^2 audiometer (GN Otometrics, manufactured at Denmark) with TDH-39 air transducer headphone and B71 bone transducer in a soundproof booth meeting American National Standards Institute (ANSI) standards. Pure tone air conduction thresholds were measured at 0.5, 1, 2, 3, 4, 6, and 8 kHz. Hearing loss was categorized based on the WHO grading system as normal (<25 dB), mild (26-40 dB), moderate (41-60 dB), severe (61-80 dB), or profound (>80 dB) [13]. The affected frequencies were identified based on the audiogram results.

Information on non-occupational noise exposure was obtained through the questionnaire. This included exposure to hobbies, music, power tools, or attending venues with loud music. Noise exposure outside of work was categorized as:

Category 1 (low): No regular exposure to loud impulse noises (e.g., fireworks) or continuous noise exceeding 80 dBA (e.g., attending concerts).

Category 2 (high): Regular exposure (at least monthly) to impulse noises exceeding 140 dBC peak or continuous noise exceeding 80 dBA without hearing protection. Examples included hunting, attending loud concerts/parties frequently, use of power tools.

Workers who did not report any activities from the above Category 2 list were placed under Category 1, while those engaging in one or more Category 2 activities were placed in the Category 2 group for analysis. This helped evaluate the potential effect of non-occupational noise exposure on hearing function independently of occupational exposure.

The questionnaire was administered in person by trained research assistants to ensure clarity and help with any misunderstandings. Each participant was given a quiet space to complete the questionnaire, and confidentiality was maintained throughout the process. Participants were informed that their responses would be anonymized and used solely for research purposes.

Statistical analysis

Data analysis was performed using SPSS version 26.0. Median and interquartile ranges (IQR) were calculated for non-normally distributed continuous data. The Kruskal-Wallis test was used to compare noise exposure levels between hearing loss severity groups. The Mann-Whitney U test compared noise exposure period based on age group, sex, and subjective hearing status. A p-value <0.05 was considered statistically significant.

Ethical considerations

The study protocol was approved by the Research Ethics Committee of Sulaimani Medical University. Written informed consent was obtained from all participants prior to enrollment. Participation was voluntary and participants could withdraw at any time. All personal information was kept confidential.

Results

Table 1 presents the age distribution, sex, subjective hearing status, and noise exposure levels of the research participants. A total of 503 workers were included in the study. The majority, 434 workers, were in the early adult age group of 19-45 years while 69 workers were in the mature adult age group of 46-65 years. 500 were male while only 3 were female. Regarding subjective hearing status, 394 reported normal hearing while 109 reported impaired hearing. When grouped by noise exposure outside of work, 478 reported exposure level 1 while 25 reported exposure level 2.

TABLE 1 Demographic characteristics and noise exposure

Variable	N (%)	Total hours of exposure Median (Q1 – Q3)	Min - Max	*P*-value
		Age group		
19-45 early adult	434 (86)	11520.00 (6912.00-18432.00)	2304-79488	<0.001
46-65 mature adult	69 (14)	20736.00 (16128.00-26496.00)	4608-66816	
		Sex		
Male	500 (99.5)	13824.00 (6912.00-20736.00)	2304-79488	0.21
Female	3 (0.5)	18432.00 (13824.00-0.00)	13824-25344	
		Subjective hearing status		
Normal hearing	394 (78.8)	11520.00 (6912.00-19260.00)	2304-79488	<0.001
Impaired hearing	109 (21.2)	16128.00 (11520.00-23040.00)	2304-69120	
		Noise out of work		
1.0 (Low)	478 (95)	13824.00 (6912.00-20736.00)	2304-66816	0.01
2.0 (High)	25 (5)	20160.00 (6912.00-30528.00)	2304-79488	

Table 2 lists the NIHL severity grouped by total noise exposure time. The 503 workers were classified into five categories of severity: normal, mild, moderate, severe, and profound hearing loss. Those with normal hearing had the lowest median exposure time at 9216 hours while those with profound hearing loss had the highest median exposure time at 16704 hours. A notable significant difference was found between the groups with respect to total noise exposure hours ($p<0.001$). Longer periods of noise exposure were often linked to greater levels of hearing loss severity. Figure 1 displays the NIHL severity based on mean total hours of exposure.

TABLE 2 NIHL severity by exposure time

Severity of NIHL	Total hours of exposure			*P*-value
	N	Median (Q1 – Q3)	Mini – Maxi	
Normal	207	9216.00 (5760.00-16128.00)	2304-55296	<0.001
Mild HL	165	13824.00 (8928.00-20736.00)	2304-79488	
Moderate HL	90	16128.00 (11232.00-23040.00)	2304-66816	
Severe HL	31	16128.00 (11520.00-23040.00)	2304-57600	
Profound HL	10	16704.00 (6912.00-24192.00)	6912-57600	
Total		503		

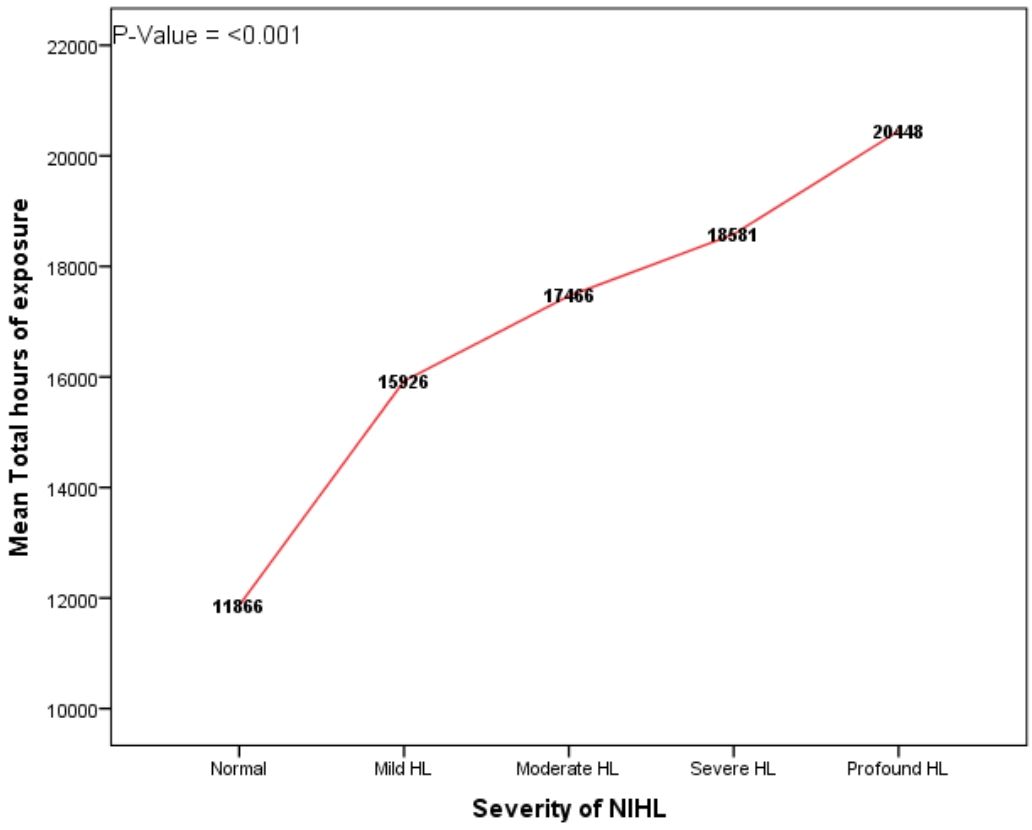

FIGURE 1 Relationship between prolonged exposure to loud noises and NIHL onset

Table 3 indicates the affected frequency range among the workers with NIHL. Of 503 total workers, 206 (41%) had normal hearing while the majority, 297 (59%), had some degree of hearing loss. The frequency most commonly affected was 4 kHz, accounting for 52.1% of cases. Only a small percentage, 0.4%, and 6.6% were affected at 2 kHz and 8 kHz, respectively. This suggests that 4 kHz was the most vulnerable frequency for noise damage in this population. Figure 2 shows more detail about the frequency range affected among workers with NIHL.

TABLE 3 Affected frequency range of NIHL

Affected frequency					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	206	41.0	41.0	41.0
	4 KHz	262	52.1	52.1	93.0
	2 KHz	2	0.4	0.4	93.4
	8 KHz	33	6.6	6.6	100.0
	Total	503	100.0	100.0	

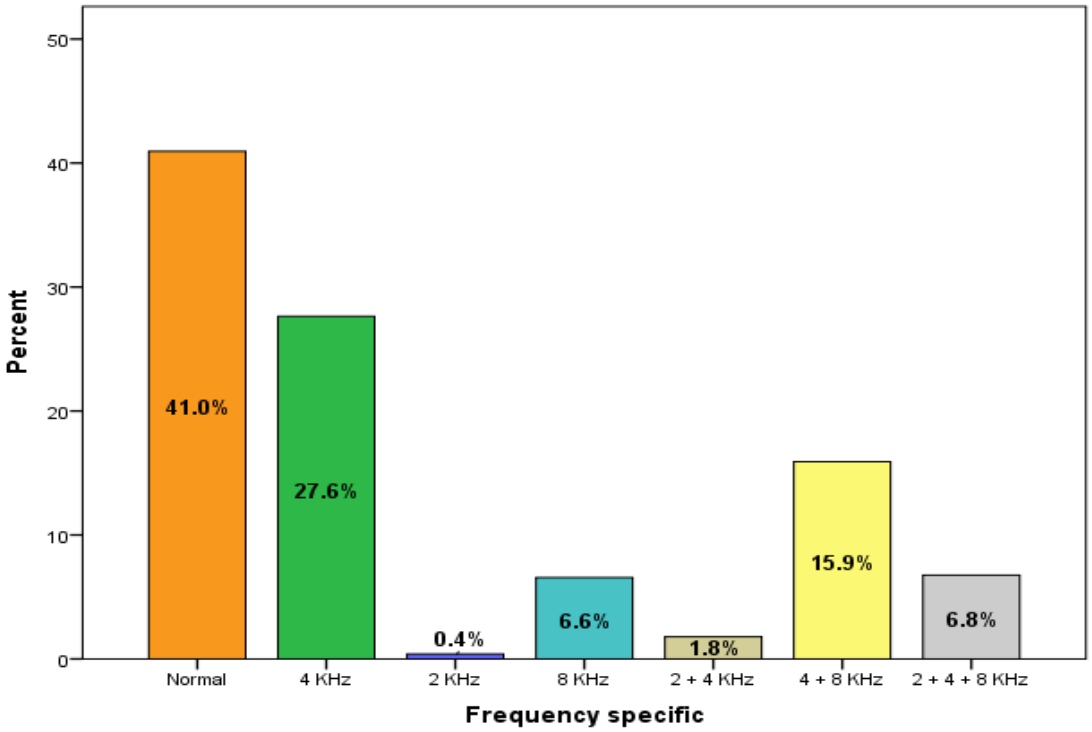

FIGURE 2 Frequency specific of NIHL

Table 4 indicates the distribution of NIHL severity among the workers. Normal hearing was seen in 207 workers (41.2%). Mild hearing loss was the most frequent at 165 cases (32.8%), followed by moderate at 90 cases (17.9%). The severe and profound hearing loss affected fewer workers at 31 (6.2%) and 10 (2.0%) cases respectively. Figure 3 provides an overview of the severity of occupational NIHL in this industrial population.

TABLE 4 Distribution of NIHL severity

Severity of NIHL	Frequency	Percent
Normal	207	41.2
Mild HL	165	32.8
Moderate HL	90	17.9
Severe HL	31	6.2
Profound HL	10	2.0
Total	503	100.0

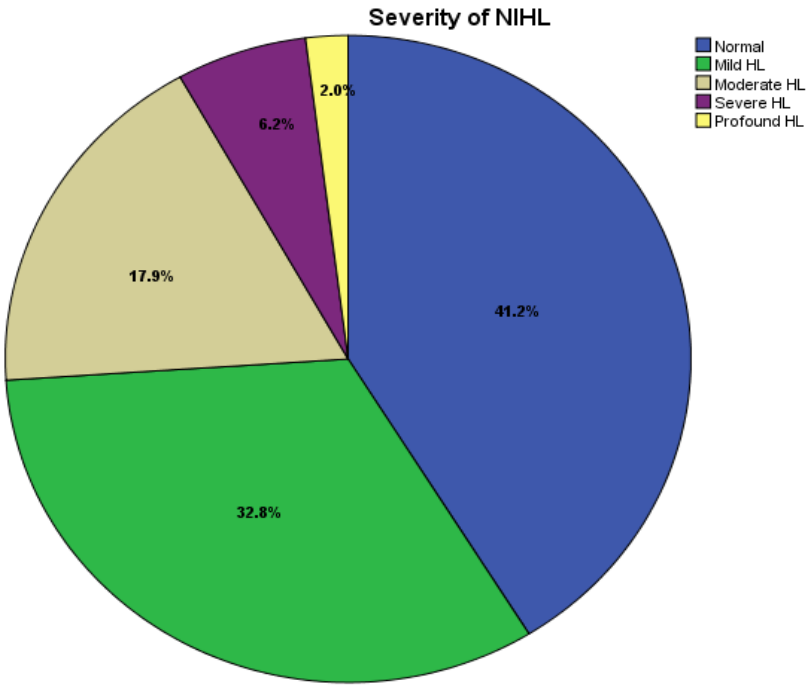

FIGURE 3 The severity of occupational NIHL

Discussion

The aim of the present study was to determine the prevalence and severity of ONIHL among workers in metal industries in the Sulaimani Governorate, with a focus on SNHL. The present study's findings indicated that ONIHL was common among Iraqi metal sector workers in the Sulaimani Governorate area. The majority of workers had some degree of hearing loss, with the highest percentages having mild or moderate loss. The study also found that the severity of NIHL was significantly associated with total noise exposure time. Given that 4 kHz was the frequency most frequently impacted, it is likely that this demographic was most susceptible to noise-related harm at this frequency.

The findings of this study shows a significant prevalence of ONIHL among workers in the metal industry, with most workers experiencing mild to moderate degrees of hearing loss. This aligns with previous research that has identified NIHL as a common occupational health risk in both developed and industrialized countries [14]. The metal industry, characterized by high noise levels ranging from 90.5-105 dB, which is above the recommended noise level of 75 to 85 dB, increases the risk of developing occupational hearing loss among workers [15]. A research carried out in Nepal provides more evidence in favor of this, revealing that

metal workers had a 30.4% prevalence of NIHL, which is much greater than the 4.1% incidence among hotel workers in the control group [16]. A study conducted by Rastogi *et al.*, found an overall prevalence of 41.5% hearing loss in the noise-exposed group, with 77.5% experiencing mild hearing loss and 22.5% experiencing moderate hearing loss [17]. However, it is important to note that the ONIHL prevalence can vary depending on factors such as the specific nature of the work, the duration of noise exposure, and the use of protective measures.

The length of time spent in environments with loud noises has a big impact on how NIHL develops. Research indicated that workers with more than 10 years of experience in the field were six times more likely to have hearing loss than workers with 10 years or less of experience. This implies that the longer a person spends time in a high-noise setting, the higher their chance of developing NIHL [18]. The findings of this study demonstrate a direct correlation between the NIHL intensity and the exposure duration to noise and sound. Several studies done in similar industrial settings throughout the world reported similar results in terms of the link between noise exposure levels and durations and an elevated risk of NIHL. The longer the exposure period, the more severe the NIHL [7,19]. A study by Bukuru *et al.* (2019), conducted on workers in the metal and wood manufacturing sector of Gakiriro, Kigali, found that working in excessively noisy workplaces could be a high risk for developing SNHL among young adults [20]. In addition, a systematic review on NIHL risk factors among manufacturing industry workers identified noise intensity, years of service, and exposure duration as significant risk factors. These factors are inherently related to the prevalence and frequency-specific impact of NIHL, as seen in the present study [21].

The predominant affecting of the 4 kHz frequency agrees with the literature, as this mid-frequency range in the spectrum is generally the most susceptible to damage from typical noisy industrial environments. In line with the present study, the study conducted by Harshitha *et al.* (2016) on spinning factory workers showed that the high prevalence of NIHL was observed in about 81% of people. Furthermore, many of them had the least SNHL because their exposure time was between 3 and 5 years. On the other hand, dip at 4 kHz frequency, NIHL characteristic, was observed in 54.71% of the workers [22]. The results of the study by Ranga *et al.* (2014) also confirm the findings of the present study and state that chronic exposure to noise is a common hazard in industrial workers that affect bilateral cochlea and causes high frequency SNHL with 4 kHz notch [23]. The reason why noise mostly affects frequencies about 4 kHz is probably because of the resonance frequency of the middle ear and outer ear canal, in addition to the mechanical properties of the middle ear [24].

However, the study had some limitations. The sample size was predominantly male, which may limit the generalizability of the findings to female workers. Furthermore, the study relied on self-reported hearing status, which may be subject to bias. Future research should consider using objective measures of hearing loss and expanding the sample to include a more diverse population of workers.

Conclusion

To sum up, the study reveals a significant prevalence of ONIHL among workers in the metal industry, with the majority experiencing mild to moderate degrees of hearing loss. The severity of Noise-Induced Hearing Loss (NIHL) was found to be significantly associated with the total duration of noise exposure, with longer exposure periods often linked to greater levels of hearing loss severity. The frequency most commonly affected was 4 kHz, suggesting that this demographic was most susceptible to noise-

related harm at this frequency. The findings underscore the importance of implementing effective noise control measures and regular hearing assessments in the workplace to prevent and manage ONIHL.

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Conflicts of interest

The authors declare that there are no relevant conflicts of interest in this study.

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Authors' Contributions

All authors contributed equally in this research.

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