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Exploring Noise-Induced Hearing Loss: A Comprehensive Systematic Review

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ABSTRACT

Noise-induced hearing loss (NIHL) refers to hearing impairment caused by either a sudden traumatic noise event or long-term exposure to elevated sound levels. Such exposure can lead to irreversible damage to the inner ear, resulting in permanent changes to hearing thresholds. Several factors contribute to the risk of developing NIHL, including individual characteristics such as genetic predisposition, age, gender, and lifestyle, as well as environmental factors such as the duration, intensity, and frequency of the noise. This review examines recent global research on the causes, risk factors, diagnosis, and management of NIHL. Databases including PubMed, EBSCO, Science Direct, Web of Science, and the Cochrane Library were used to collect studies. Using Rayyan QCRI, research papers were initially screened by title and abstract before undergoing a full-text review. 11 studies, involving participants of various ages and genders, were included for analysis. The findings highlight the high prevalence of NIHL among workers in noisy environments, with primary risk factors being the type, volume, and duration of noise exposure. In addition, behaviors such as smoking and alcohol use were found to significantly affect hearing function.

Keywords: Hearing impairment, Noise exposure, Occupational hearing loss, Noise duration, Deafness, NIHL.

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Introduction

Noise is commonly referred to as “unwanted sound” that negatively impacts health. Noise-induced hearing loss (NIHL) occurs when the cochlear hair cells in the inner ear sustain permanent damage due to excessive sound exposure [1]. Prolonged use of headphones, particularly at high volumes, can transmit intense sound waves to the inner ear, damaging the cochlear hair cells in the vestibule, which ultimately leads to sensorineural hearing loss [2].

NIHL can affect one or both ears, with its severity largely dependent on the duration and intensity of the noise exposure [3]. Continuous exposure to loud sounds over time can cause irreversible hearing damage [1]. Research indicates that listening to audio at 60% volume for over an hour can contribute to NIHL, and prolonged exposure to 85 dB sound levels for eight hours a day may result in permanent hearing loss [4].

In many cases, hearing loss goes unnoticed until it reaches a level where communication becomes significantly impaired [5]. Despite being largely preventable, NIHL remains a major social and public health concern [6]. The widespread use of headphones, without proper hearing protection, significantly increases the risk of hearing damage when these devices are misused [7].

A study of university students found that most participants learned about the risks of noise exposure and NIHL through parents, peers, education, and the internet. However, a considerable number were unaware of the link between NIHL and noise exposure [8]. This lack of awareness, particularly in noisy environments or when using

headphones, is a concerning issue among college students [7]. It highlights the need for better education on hearing health and protection, as well as the promotion of preventive measures from an early age, particularly in schools [8].

The World Health Organization (WHO) recommends that college students limit the excessive use of personal listening devices (PLDs) by controlling both the duration and volume of usage [9]. Additionally, those who frequently use headphones should be educated on recognizing early signs of hearing loss and taking preventative measures to avoid further damage [10]. The first step in prevention is understanding which sound levels can harm the auditory system [11]. Early indicators of NIHL, such as tinnitus, often appear soon after exposure to loud noises, as highlighted in a study of college students in the United States [8].

Study objective

This study aims to review the latest evidence on the causes, risk factors, diagnosis, and management strategies for noise-induced hearing loss, as explored through global research.

Materials and Methods

This systematic review was conducted following the principles outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Study design

The study combines both a meta-analysis and a systematic review approach.

Study period

The review was carried out between February and July 2022.

Scope of the study

The focus of this review was to examine existing literature on noise-induced hearing loss (NIHL), specifically exploring its prevalence, associated risk factors, and the interaction between lifestyle choices and the development of hearing loss.

Literature search strategy

A thorough search was conducted in five major databases: PubMed, Web of Science, Science Direct, EBSCO, and the Cochrane Library. The search was limited to studies published in English, and the search terms were customized for each database. Keywords and MeSH terms like “noise,” “noise exposure duration,” “occupational noise,” “hearing loss,” “deafness,” and “noise-induced hearing damage” were employed. These terms were combined using Boolean operators (“OR” and “AND”) to refine the search results. Only full-text, freely available publications in English that focused on human subjects were considered relevant for inclusion.

Selection criteria

The inclusion of studies was based on the following parameters: cohort studies and retrospective cohort studies that provided either qualitative or quantitative data regarding the occurrence and risk factors associated with NIHL. Studies that were not available in English or those without free access were excluded from the review.

Data extraction

To ensure that duplicate results were excluded, Rayyan (QCRI) [12] was used to manage the search results. Titles and abstracts were initially reviewed to determine whether the studies met the predefined criteria for inclusion or exclusion. Studies that met these criteria were then subjected to a full-text review. Any disagreements among the researchers about inclusion were resolved through discussion. A data extraction form was developed to gather essential information such as study titles, authors, publication year, study design, sample characteristics, sample size, NIHL prevalence, and key findings related to occupation and hearing loss.

Risk of bias assessment

To evaluate the quality of the included studies, the ROBINS-I tool for non-randomized studies was used. Any inconsistencies identified in the evaluation of study quality were addressed by the review team.

Data synthesis

Summary tables were created to present an overview of the essential study details and findings from the included research. After completing the data extraction, the researchers decided on the best method to incorporate the available data from each study. Studies that fulfilled the inclusion criteria but lacked relevant data regarding the prevalence, risk factors, or effects of noise exposure on hearing loss were excluded from the final review.

Results and Discussion

Search results

The initial systematic search identified a total of 540 studies. After removing 57 duplicates, 483 titles and abstracts were screened. Out of these, 390 studies were excluded. Although 93 reports were considered, 10 could not be retrieved. Ultimately, 83 papers were selected for full-text evaluation. After further review, 52 were excluded due to flawed research results, 5 were removed because of insufficient data, and 13 were discarded due to incorrect population types. In the end, 11 studies met the inclusion criteria for this systematic review **(Figure 1)**.

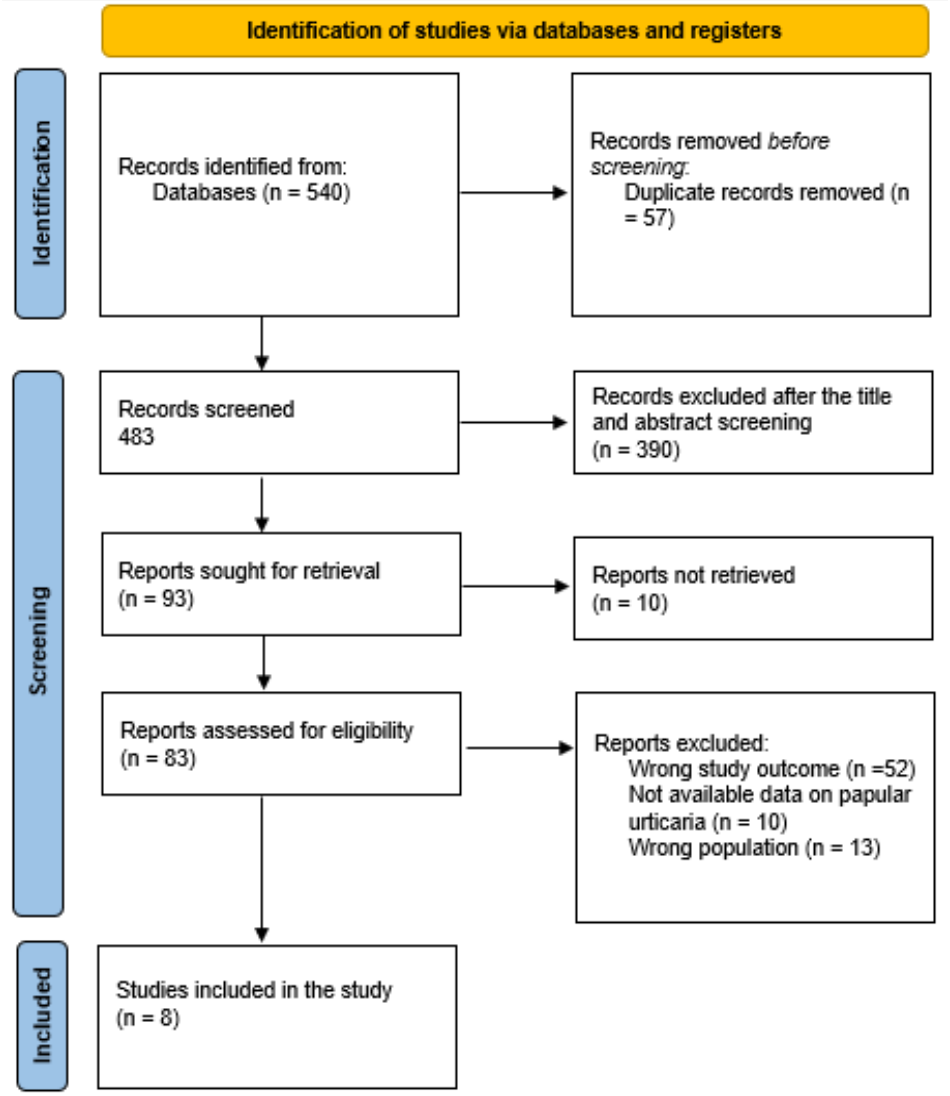

Figure 1. The PRISMA flowchart summarises the study selection process

Characteristics of the included studies

This review encompasses 11 studies in total. The majority of these studies focused on the prevalence of noise-induced hearing loss (NIHL), its associated risk factors, or the impact of noise exposure on hearing ability across various groups. The studies involved a wide range of participants with diverse characteristics and lifestyles. All participants underwent testing to assess ear function, hearing ability, and thresholds, with diagnoses indicating

varying levels of NIHL or related symptoms. Additionally, the studies explored correlations between personal characteristics and lifestyle factors about NIHL.

Our analysis suggests that NIHL is a significant concern, especially for individuals working in noisy industrial environments where exposure levels are high. The primary risk factors identified for NIHL include age, gender, occupation, genetic factors, as well as the type, intensity, and duration of noise exposure. Furthermore, behaviors such as smoking and alcohol consumption were found to have a notable impact on hearing performance.

This review highlights the detrimental effects that both environmental and occupational noise can have on inner ear function, which may lead to permanent or temporary hearing loss.

Table 1 provides a summary of the studies included in this review, outlining their key objectives, findings, and publication years.

Table 1 summarizes the details of the studies reviewed, including study design, sample size, participant demographics, key objectives, prevalence of noise-induced hearing loss (NIHL), and major findings regarding its management.

Table 1. Overview of the characteristics of included studies

Study	Study design	Sample size	Study population	Age of participants (years)	Objectives	Prevalence of NIHL	Key findings and management
Pollarolo *et al.* [13]	Systematic review	3273	Police officers	23-55	To analyze data on hearing loss in police officers and its correlation with occupational risks and clinical features	641	Noise exposure during leisure activities and failure to use ear protection were common. NIHL is linked to age, noise exposure quantity, and duration, particularly from shooting sessions and road noise exposure.
Basu *et al.* [14]	Systematic review and meta-analysis	2229	Industry workers	20-60	To assess the prevalence and risk factors of occupational NIHL among workers exposed to hazardous noise levels in India	--	NIHL remains a significant and unaddressed public health issue in India, requiring legislation and awareness campaigns for hearing protection.
Aboobackr *et al.* [15]	Cross-sectional study	31 cases, 30 controls	Stone-cutting workers	21-55	To assess the auditory pathway in stone-cutting workers	Mild: 7, Moderate: 24	Stone cutters face a risk of NIHL (mild to moderate), affecting the peripheral auditory system.
Gupta *et al.* [16]	Cross-sectional study	150	Traffic policemen	25-56	To assess NIHL prevalence and its correlation with noise exposure duration in traffic policemen	33	69.7% had mild to severe bilateral hearing loss. A strong correlation was found between NIHL and exposure duration.

Indora *et al.* [17]	Observational comparative study	35 cases, 35 controls	Traffic policemen	25-40	To investigate the hearing pathway in traffic police using BERA, MLR, and SVR	--	Chronic noise exposure led to delayed conduction in the auditory pathway but no cortical or association region impairment.
Jiang *et al.* [18]	Cross-sectional study	50539	Shipbuilding workers	25-55	To assess individual vulnerability to NIHL and identify genetic risk factors	2108	Discovered two genetic variations (CDH23 rs41281334 and WHRN rs12339210) linked to NIHL susceptibility.
Gopinath *et al.* [19]	Cross-sectional and longitudinal study	1932	Older workers	> 50	To explore the prevalence and development of hearing loss related to occupational noise exposure	227	Workplace noise exposure was linked to increased chances of incident hearing loss in older adults but not to progressive hearing loss.
Zhou *et al.* [20]	Systematic review and meta-analysis	71865	Adult workers	20-55	To examine the prevalence and characteristics of occupational NIHL in China	15307	Long-term and high-level noise exposure in various industries was linked to a high prevalence of NIHL, exacerbated by exposure to complex noise or other harmful substances.
Mostaghaci *et al.* [21]	Follow-up study	555	Workers from tile and ceramic factories	20-50	To track hearing threshold changes over two years among tile and ceramic workers	--	High incidence of NIHL in tile and ceramic workers highlights the importance of hearing protection.
You *et al.* [22]	Systematic review and meta-analysis	--	Young adults using PLDs	18-30	To evaluate short- and long-term hearing effects of heavy PLD use	--	Temporary hearing changes were observed at 4 kHz, with lasting high-frequency hearing changes in heavy PLD users. Awareness should be raised.
Kraaijenga *et al.* [23]	Prospective study	51	Music festival attendees	20-35	To analyze factors associated with transient threshold shift (TTS) after music exposure	--	TTS was observed at 3.0 and 4.0 kHz frequencies, linked to participant behavior and tinnitus. Multivariable regression was used to identify contributing factors.

Noise-induced hearing loss (NIHL) is a form of sensorineural hearing impairment that results from either sudden or prolonged exposure to high-intensity noise. Several factors contribute to the development of NIHL, including

personal traits such as genetics, as the susceptibility of the inner ear to noise varies widely between individuals after exposure to similar noise levels [24, 25]. Noise-related factors, such as the intensity, duration, frequency, and rate at which sound pressure levels increase, are also crucial in determining the likelihood of developing NIHL [26, 27]. Furthermore, individual lifestyle choices can influence the degree of risk, with several factors affecting a person's vulnerability to noise-induced damage.

Age is a primary factor contributing to NIHL, as the risk increases with age due to the cumulative exposure to noise over time [28-31]. Alcohol consumption has been identified as another factor that may exacerbate hearing loss. A 1978 study revealed that alcohol could diminish the protective reflexes in individuals with normal hearing [32]. Additionally, a study by Upile *et al*. found a connection between breath alcohol content and the worsening of hearing thresholds in those exposed to recreational noise [33].

The most common source of NIHL is occupational noise exposure, which typically occurs in environments with consistent or high noise levels, such as industrial workplaces or construction sites. Many studies indicate that men are more susceptible to NIHL than women. Research by Kovalova *et al*. showed that males experienced more severe NIHL than females despite being exposed to the same noise levels in their workplaces [34]. According to earlier studies, almost half of older individuals exposed to industrial noise show signs of hearing loss at the outset, making workplace noise a significant risk factor for sensorineural hearing loss in certain age groups. However, some studies have not found a strong link between workplace noise and the development of hearing loss in older workers.

A systematic review and meta-analysis by Basu *et al.* [14] explored the prevalence of occupational NIHL across various industries in India, including sectors such as stone cutting, mining, and plywood manufacturing. The research showed that almost half of the workers had signs of NIHL when evaluated using audiometric testing [14]. Prolonged noise exposure was the most frequently identified risk factor. Another study by Tikriwal *et al.* among carpet workers reported a high rate of hearing loss, with the severity of the loss increasing with the length of noise exposure [35]. Similarly, multiple studies have demonstrated a connection between the duration of noise exposure at work and the severity of hearing loss in employees [16, 36-38].

Indora *et al.* [17] examined traffic police officers and found that prolonged noise exposure led to delayed conduction along the auditory pathway, specifically affecting the auditory nerve up to the superior olivary nucleus, without any impairment in the subcortical, cortical, or association regions. Gupta *et al.* [16] also observed traffic policemen and confirmed the strong relationship between the length of exposure to noise and NIHL. A study by Marco Pollarolo *et al.* [13] further supported these findings, highlighting the significant correlation between police officers' exposure to occupational noise and NIHL, noting the additional risks posed by road noise and shooting practice sessions for motorcycle officers.

Gopinath *et al.* [19] reported that 44.9% of their study participants who had been exposed to noise in their workplaces exhibited hearing loss, slightly higher than Ferrite *et al*.'s [39] figure of 38% [39]. This variation may be attributed to the age difference in the study samples, with Gopinath *et al*.'s participants being younger, aged between 41 and 55 years. Soltanzadeh *et al*. found that workplace noise levels in Iran averaged 90.29 dB (A), corresponding to a hearing threshold of 26.44 dB [40]. In South Korea, Kim discovered that more than 90% of workplaces exceeded the recommended occupational noise limits, with 92.9% of hearing-related disorders attributed to NIHL [41]. Rubak *et al.* [42] identified a dose-response relationship between noise levels and NIHL prevalence, with higher noise levels correlating with an increased rate of hearing loss among Danish workers.

In China, Zhou *et al*. [20] reported that 21.3% of workers suffered from occupational NIHL, with 30.2% of cases being high-frequency NIHL (HFNIHL), 9.0% speech-frequency NIHL, and 5.8% noise-induced deafness. The average age of workers affected was 33.58 years, with the likelihood of developing HFNIHL increasing as workers aged.

Sex is an important factor in high-frequency noise-induced hearing loss (HFNIHL), with males showing a notably higher frequency of hearing loss compared to females. Smoking, when combined with noise exposure, is also considered a significant contributor to hearing impairment and NIHL [39, 43]. Although some researchers have suggested a potential link between cannabis use and NIHL, no conclusive studies have confirmed this relationship. Additionally, exposure to substances like MDMA and cocaine has been noted to increase the risk of NIHL [44-47].

Using ear protection is an effective way to reduce the likelihood of NIHL. Kraaijenga *et al.* [23] observed that failing to wear earplugs, along with the use of alcohol and narcotics, as well as being male, were all associated with temporary threshold shifts (TTS) during a music festival. The lack of ear protection was tied to subjective

hearing loss and tinnitus, and the amount of time spent near loudspeakers increased as alcohol consumption rose. The decision to use earplugs was influenced by the volume of the music, the listener's enjoyment, and their perception of speech while wearing earplugs. A systematic review highlighted a study in which earplugs were found to significantly reduce post-concert threshold shifts [48].

You *et al*. explored the impact of music exposure as a risk factor for NIHL, focusing on the duration and intensity of the exposure. Their study showed that using personal listening devices (PLDs) caused temporary changes in hearing at 4 kHz, but these changes were reversible [22]. However, those who frequently used PLDs or were exposed to loud music for extended periods experienced lasting changes in high-frequency hearing sensitivity. Four experiments with noise levels between 85 dB(C) and 100.3 dB(A) for durations ranging from 30 minutes to 4 hours revealed significant hearing threshold shifts. However, variability in measurement units between studies limits the ability to draw broad conclusions. Studies that did not find significant effects exposed participants to lower music levels (50.8 to 98.7 dBA) for shorter durations (30 minutes to 1 hour), which may not have been enough to cause substantial threshold shifts in healthy young listeners [49-53]. Prior research has shown that PLD users have worse hearing thresholds than non-users, especially at frequencies ranging from 0.25 to 8 kHz [54, 55].

Conclusion

In summary, noise-induced hearing loss (NIHL) is a prevalent condition that affects various populations, leading to hearing impairment or noise-induced deafness (IND). Several factors contribute to the development of NIHL, including the individual's age, sex, occupational environment, genetic predispositions, and the level and duration of noise exposure. Smoking and alcohol consumption also play significant roles in worsening hearing performance. This review underscores the critical impact of both environmental and occupational noise on the inner ear, potentially causing both temporary and permanent hearing loss. Our findings highlight the importance of addressing NIHL, particularly among industrial workers who face heightened noise exposure risks.

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