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Preventing Occupational Noise-Induced Hearing Loss: A Systematic Review of Effective Interventions and Best Practices

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Abstract

Introduction: Noise is a common workplace hazard that can seriously affect worker health, including causing occupational noise-induced hearing loss (ONIHL). Under the Health and Safety at Work Act 2015, workplaces in New Zealand must take all reasonably practicable steps to manage this risk. This systematic review aims to identify evidence-based interventions to prevent occupational-induced hearing loss, with a focus on guiding workplaces in adopting the most effective measures.

Methods: A systematic review was conducted to synthesise evidence from studies published between 2000 and 2024. Relevant literature was identified through a PubMed/MEDLINE database search using a combination of keywords and terms related to occupational noise, hearing loss, interventions, and best practices.

Results: The review identified several effective strategies to minimise the risk of occupational noise-induced hearing loss, including purchasing quieter machinery, insulating noisy equipment, and improving workplace practices such as regular hearing tests, employee training, and awareness programmes. Additionally, the use of hearing protection devices was recommended to address residual noise exposure.

Keywords: Occupational noise; Hearing loss; Best practices; Intervention; Systematic review

1.0 Introduction

Noise is any unwanted sound or combination of sounds that can cause both physiological harm and psychological harm (Seidman and Standring, 2010, Rabinowitz, 2000). Prolonged exposure to high noise levels primarily affects the auditory system, where sound waves are transformed into vibrations and subsequently into electrical signals by the stereocilia within the cochlea. Excessive noise exposure repeatedly over activates the stereocilia, causing irreversible damage and resulting in noise-induced hearing loss (Hu, 2012).

In occupational settings, prolonged or intense exposure to noise contributes to a specific form of hearing damage known as occupational noise-induced hearing loss (ONIHL). ONIHL arises from moderate to high levels of noise exposure, which can be either continuous or intermittent, depending on the nature of the work environment (Chen et al., 2020, Santaolalla Sanchez et al., 2024). In addition to auditory damage, noise exposure activates the sympathetic nervous system and triggers stress responses. Acute noise exposure results in annoyance, impaired concentration, and reduced cognitive performance, whereas chronic exposure is linked to long-term health risks, including cardiovascular disease (Arnold et al., 2023). The consequences of ONIHL extend beyond individual health and significantly impact workplace productivity and safety. ONIHL is associated with increased workplace accidents and diminished operational efficiency (Arnold et al., 2023). Given these multifaceted effects, ONIHL represents a critical occupational hazard that requires targeted preventive and control measures.

According to the World Health Organisation (WHO), occupational noise is responsible for approximately 16% of adult hearing loss worldwide (Zhou et al., 2020, Etemadinezhad et al., 2023). In New Zealand, the burden of hearing loss mirrors global trends, with the 2023 New Zealand Hearing Industry Association (NZIER) report noting an increase in prevalence from 7.5% in 2018 to 20.8% in 2022. Among the working-age population, self-reported hearing loss increased from 7.4% in 2018 to 8.4% in 2022 and is expected to rise further in the coming decades. Together, these factors contribute to economic losses for the country due to early retirement, aged care, poor quality of life, impeding children's learning ability, reducing labour productivity, employment and government revenue. This growing burden significantly leads to reduces employment opportunities, absenteeism, and presenteeism. The cost of addressing the unmet need for hearing aids would be $30 million and 104 million annually (Bealing, 2023).

The Health and Safety at Work Act 2015 (HSWA) requires workplaces to take all reasonably practicable steps to protect workers from health and safety risks. This responsibility falls primarily on the person conducting a business or undertaking (PCBU), but the participation of workers is also legally required *(Health and Safety at Work Act 2015, s.36(1))*. Regarding occupational noise exposure, the Health and Safety at Work (General Risk and Workplace Management) Regulations 2016, stipulate that workers must not be exposed to continuous noise levels above 85 decibels (dB) over an 8-hour workday. Additionally, noise should not exceed a peak level of 140 dB at any point ("Health and Safety in Employment Regulations 1995," 1995).

To comply with these requirements, PCBUs are required to implement measures to manage noise risks, following the hierarchy of controls. This framework encourages eliminating or substituting hazards first, followed by implementing engineering controls, administrative measures, and, as a last resort, using personal protective equipment (PPE) (HSWA 2015, s.30(1)). Despite these regulatory frameworks, their implementation in workplaces often fails to achieve meaningful results. Many organisations in New Zealand continue to rely on PPE as the primary method of noise control, rather than integrating it into a comprehensive risk management approach (John et al., 2014). This not only undermines the overall effectiveness of noise control programmes but also fails to meet best practices for achieving sustainable, long-term risk reduction. The following systematic review aims to synthesise evidence on interventions and best practices for preventing occupational noise-induced hearing loss (ONIHL). The findings aim to guide New Zealand workplaces in adopting efficient, effective, and compliant measures to protect workers and improve workplace health and safety outcomes.

2.0 Methods and Materials

2.1 Review typology

This study adopted a systematic review methodology to identify and synthesise evidence on interventions and best practices for preventing ONIHL. Systematic reviews follow a structured and transparent process designed to identify, evaluate, and summarise relevant studies. This approach ensures a comprehensive and unbiased assessment of the available evidence (Clarke and Chalmers, 2018).

2.2 Search strategy

A comprehensive search of PubMed/MEDLINE databases was conducted to identify articles published between 2000 and 2024. Both keywords and Medical Subject Headings (MeSH) terms were included to capture a wide range of relevant studies. Boolean operators, such as "AND" and "OR," were applied to refine and combine search terms effectively.

> **Keyword Search:** Title and abstract searches were performed using the following terms:
>
> “Occupation*” AND “Noise*” AND (“Hearing” OR “Hearing loss”) AND (“Prevent*” OR “Control*”) AND (“Intervention*” OR “Best practice”).
>
> **MeSH Search:** The search was extended using the following MeSH terms to capture relevant indexed articles:
>
> (Noise, Occupational/Prevention and Control [MeSH Terms]) OR
>
> (Hearing Loss, Noise-Induced/Prevention and Control [MeSH Terms]).

This dual approach ensured that both free-text and indexed terms were covered, maximising the capture of relevant literature.

2.3 Eligibility criteria

2.3.1 Inclusion criteria

The following inclusion criteria were developed to select relevant and high-quality evidence for the review (Table 1).

Table 1 Inclusion criteria

Inclusion Criteria	Interventions for prevention/control of ONIHL	Best Practice for prevention/control of ONIHL
Study design	Systematic review	Clinical commentaries expert opinions or narrative reviews
Study objectives	Investigates the impact of an implemented prevention measure on occupational noise levels or ONIHL outcomes.	Discusses the relationship between a prevention measure and occupational noise levels or ONIHL
Year of publication	2000 - present	2000 – present

2.3.2 Exclusion criteria

Studies were excluded if they did not focus on interventions or best practices for preventing ONIHL or controlling occupational noise hazards, or if they were published in a language other than English.

2.4 Screening and data extraction

The screening and selection of articles were conducted systematically using EndNote citation management software (Endnote, 2013). Initially, two reviewers independently performed the database search and screened the retrieved articles based on their titles and abstracts. Articles deemed irrelevant to the review objectives were excluded at this stage. For the remaining articles, full-text versions were retrieved and independently assessed by the reviewers using the pre-defined eligibility criteria. Discrepancies in inclusion or exclusion decisions were resolved through discussion until a consensus was reached. Relevant data were extracted from the included articles using a standardised template based on the Joanna Briggs Institute (JBI) guidelines for data extraction (Vardell and Malloy, 2013). Key information such as the first author’s last name, year of publication, study typology, and the number of studies included in systematic reviews or commentaries was recorded.

2.5 Data analysis

The data were reviewed to identify common themes and patterns. A Microsoft Word template was used to organise the findings from each study. The key findings were then summarised to provide a clear and consistent overview of the evidence.

2.6 Quality appraisal

The quality of the systematic review articles included in this study was assessed using the PRISMA 2020 guidelines (Page et al., 2021) and the AMSTAR 2 critical appraisal tool (Shea et al., 2017). The PRISMA guidelines were used to evaluate the transparency and completeness of the systematic reviews, ensuring that key elements, such as the search strategy, study selection, and data synthesis, were adequately reported. The AMSTAR 2 tool was used to assess the methodological rigour of the reviews, focusing on factors such as the quality of the included studies, management of potential biases, and the appropriateness of the synthesis methods.

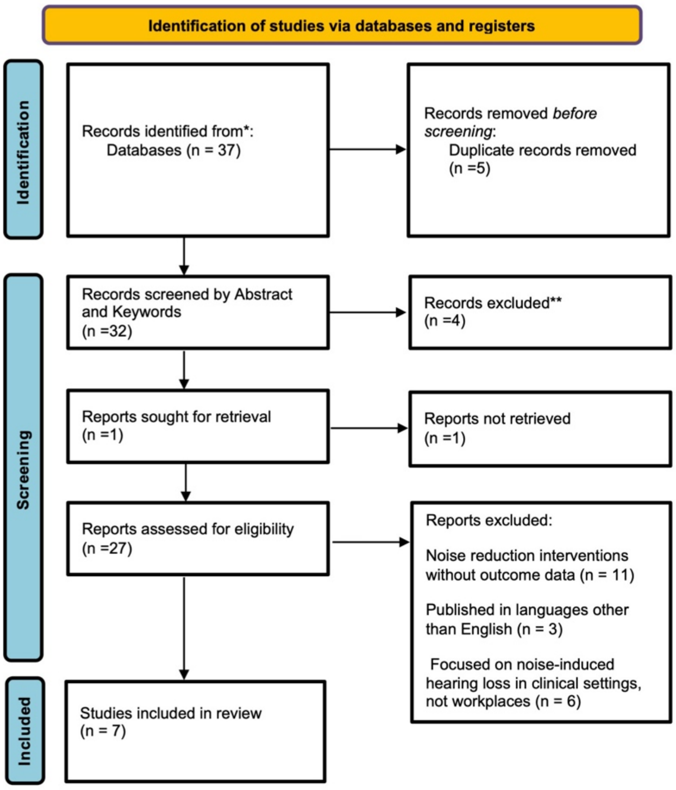
For narrative commentaries and expert opinions, the Joanna Briggs Institute (JBI) criteria for the critical appraisal of textual evidence were applied (Vardell and Malloy, 2013). These criteria evaluate the clarity, relevance, and credibility of the arguments presented in textual evidence. Two authors independently conducted the quality appraisal for all included studies. Any disagreements during the evaluation process were resolved through discussion until a consensus was reached.

3.0 Result

3.1 Search outcomes

The initial database search identified 37 resources as potentially relevant based on the keyword and MeSH term searches. These were then screened against the predefined eligibility criteria. Following this process, two systematic reviews and five narrative reviews/ expert commentaries met the criteria and were included for synthesis (Figure 1).

Figure 1 PRISMA flowchart for the selection of eligible articles on interventions to prevent Occupational Noise Induced Hearing Loss, 2010 to 2024.



3.2 Characteristics of included studies

The two systematic review articles included in this study synthesised evidence from a combined total of 46 interventional studies. These reviews included Randomised Controlled Trials (RCTs), Controlled Before-After studies (CBAs), and Interrupted Time-Series studies (ITS). Of the included studies, RCTs accounted for the majority (approximately 60%), followed by CBAs (25%) and ITS studies (15%). The risk of bias assessment was conducted using the AMSTAR-2 (A MeaSurement Tool to Assess systematic Reviews) checklist, which is specifically designed to evaluate the methodological quality of systematic reviews. The tool assesses critical domains such as the clarity of research questions, adequacy of literature search, risk of bias assessment within included studies. Accordingly, both systematic reviews adhered to established methodological standards and were rated as having moderate risk of bias based on AMSTAR 2 and PRISMA assessments, reflecting their methodological rigor and reliability (Table 2).

Table 2 Characteristics of included articles on intervention for prevention of Occupational Noise Induced Hearing Loss

Author and Publication year	Review typology	The type of studies included	Number of studies	PRISMA assessment	AMSTAR 2 checklist	Risk of bias
Tikka et al. (2020)	Systematic review	RCT, CBA and ITS	29	25/27	12/16	Moderate
Samelli et al. (2021)	Systematic review	RCT, CBA and ITS)	17	26/26	12/13	Moderate

Note: RCT= Randomised Controlled Trials; CBA= Controlled Before-After studies; ITS= Interrupted Time-Series studies; PRISMA= Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Five additional articles on best practices for ONIHL prevention were included in the review. These included two narrative reviews that discussed successful examples of noise prevention strategies used in different industries, one in-depth review on noise control practices in high-noise industrial sectors, and two expert commentaries with practical recommendations based on professional experience. Together, these resources covered a range of perspectives, from general summaries to specific industry insights. All five articles were appraised using the JBI checklist (Table 3).

Table 3 Description of included articles on best practices for prevention of Occupational Noise Induced Hearing Loss

Author name and Publication year	Study Design/review typology	Number of studies included	JBI checklist	Risk of bias
Azizi (2010)	Narrative review	Na	6/6	Low
McBride (2004)	In-depth review	11	6/6	Low
Royster (2017)	Commentary	Na	6/6	Low
Hong et al. (2013)	Narrative review	Na	6/6	Low
William (2014)	Commentary	Na	6/6	Low

3.3 Evidence-based strategies for the prevention and control of ONIHL

The identified documents provided evidence from 61 sources, including 46 primary interventional studies, 11 observational studies, and five expert commentaries. Together, these resources addressed a range of strategies, including hearing protection devices (HPDs), engineering controls, education and training programs, audiometric monitoring, and comprehensive hearing conservation initiatives. These approaches were systematically mapped across the hierarchy of controls as follows:

Elimination and Substitution

Eliminating noise at its source was identified as the most effective control strategy across the reviewed documents. However, it was often acknowledged as impractical in many workplace settings due to operational constraints. Accordingly, substitution, such as replacing high-noise machinery with quieter alternatives, was recommended as a practical and achievable approach (McBride, 2004). According to William (2014), this approach has the potential to achieve up to an 80% reduction in noise exposure.

Engineering controls

Engineering controls, aimed at reducing noise at its source or along its transmission path, were widely recognized for their effectiveness. Several studies reported noise reductions of 4–5 dB in workplaces that implemented measures such as soundproof barriers, machinery insulation, and acoustic damping (Azizi, 2010; Hong et al., 2013; Royster, 2017).

Administrative controls

Administrative controls were similarly emphasised across the documents as critical for managing noise exposure, particularly when combined with engineering solutions:

- **Audiometric Monitoring**: Regular hearing tests were highlighted as an essential measure for early detection of hearing loss and adjustment of noise control measures (Royster, 2017). While not a direct method of noise reduction, audiometric monitoring allows workplaces to track the effectiveness of interventions (Azizi, 2010).
- **Training and Awareness Campaigns**: Education and awareness campaigns have led to measurable improvements in compliance with hearing protection measures, resulting in noise attenuation improvements of up to 8.6 dB when ear protection is used and fitted correctly (Tikka et al., 2020).
- **Workplace Policies**: McBride (2004) highlighted the importance of implementing policies such as job rotations to minimise prolonged exposure to high-noise environments. Regular noise surveys and quantitative fit testing for hearing protection devices (HPDs) were also identified as important measures to reduce individual noise exposure and ensure the long-term effectiveness of protective equipment (William, 2014).

Hearing protection devices (HPDs)

HPDs, such as earplugs and earmuffs, were widely reported as key interventions for reducing noise exposure. Evidence summarised in Tikka et al. (2020) reported that training workers to fit earplugs correctly improved noise attenuation by up to 8.6 dB. Samelli et al. (2021) similarly reported short-term improvements in noise attenuation when HPDs were paired with training. However, neither study found strong evidence for the long-term effectiveness of HPDs as standalone interventions, with their success reliant on integration into broader prevention strategies.

Comprehensive hearing conservation programs

Programs combining a range of interventions demonstrated sustained reductions in noise exposure and improved compliance. Royster (2017) and Hong et al. (2013) noted that successful HCPs include a combination of substitution and engineering controls, administrative measures, HPDs, and continuous worker engagement. Azizi (2010) further emphasised that tailoring these programmes to specific workplace conditions is critical for maximising their effectiveness.

Table 4: Summary of evidence-based strategies for preventing ONIHL

Control Level	Intervention	Key Findings	Sources
Elimination/ Substitution	Replace noisy machinery with quieter alternatives	Up to 80% reduction in noise exposure.	McBride (2004) Royster (2017) William (2014)
Engineering Controls	Install soundproof barriers, dampen machinery surfaces	4–5 dB reductions in noise	Tikka et al. (2020) Samelli et al. (2021) Royster (2017)
Administrative Controls	Audiometric monitoring, Job rotation, Training, Regular noise surveys, Quantitative fit testing for HDPs	Audiometric monitoring enables the early detection of hearing loss in 15–20% of workers.	Samelli et al. (2021); Royster (2017) Hong et al. (2013)
Hearing Protection Devices (HPDs)	Use of earplugs and earmuffs, supplemented with training for proper fitting	Improve noise attenuation by up to 8.6 dB when paired with training	Tikka et al. (2020); Samelli et al. (2021) Azizi (2010)
Comprehensive Programs	Integration of engineering and administrative controls with HPDs	Comprehensive programs demonstrated the highest effectiveness, reducing noise exposure and improving compliance	Royster (2017); Hong et al. (2013)

4.0 Discussion

Occupational noise-induced hearing loss (ONIHL) is a pressing global issue that continues to affect workers across industries with persistent noise exposure. This systematic review highlights evidence-based strategies for preventing ONIHL, offering valuable lessons that can apply to New Zealand workplaces. A key takeaway from this review is the importance of reducing noise at its source through substitution and engineering controls. These strategies, address the root cause of noise exposure. This approach aligns with the hierarchy of controls outlined in New Zealand's HSWA, which prioritises hazard elimination and substitution over-reliance on other measures *(HSWA 2015, s.30(1))*.

International examples further illustrate the potential of these interventions. In the United States, policies incentivising quieter technologies through grants and tax benefits have successfully encouraged workplaces to invest in noise-reducing solutions (William, 2014). Drawing on such examples, New Zealand could explore similar initiatives to address the perceived cost barriers often associated with such controls.

Likewise, administrative controls play an essential supporting role in noise management, particularly when other more effective solutions alone cannot fully eliminate risks. Measures such as audiometric monitoring, worker training, and job rotation help manage residual exposure and provide early detection of hearing loss. Effective implementation of these interventions is important, as they bridge the gap between hazard control measures and worker behaviour. As shown in this review, education and training are particularly impactful in improving compliance with protective measures such as HPDs. However, these measures are most effective when implemented within a workplace culture that prioritises safety.

Evidence from Australia and the United States shows that participatory approaches—where workers are actively involved in designing and implementing noise management strategies—result in better compliance and more sustainable outcomes (Safe Work Australia, 2020, Cavallari et al., 2021). Empowering workers to contribute to noise control initiatives fosters a sense of shared responsibility, encouraging long-term adherence to safety measures. For New Zealand, this could involve establishing feedback loops in workplaces where employees can identify noise risks, propose solutions, and assess the effectiveness of implemented measures

Finally, comprehensive hearing conservation programs (HCPs) consistently emerged as the most effective strategy for managing occupational noise exposure (Azizi, 2010, McBride, 2004, Royster, 2017). These programs integrate measures across the hierarchy of controls, combining engineering and administrative strategies with the use of hearing protection devices (HPDs) to create a multi-faceted approach to noise management. To maximise their effectiveness in the New Zealand context, HCPs should be tailored to address the unique challenges of specific industries and actively engage workers at every stage. Collaborative efforts, such as involving employees in identifying risks, developing solutions, and evaluating the success of implemented measures, can foster a culture of shared responsibility and long-term commitment to hearing conservation. By embedding these principles into workplace practices, New Zealand can strengthen its approach to ONIHL prevention and create safer, healthier work environments.

Conclusions

This review outlines a clear and actionable pathway for New Zealand to improve current ONIHL prevention efforts. By prioritising noise reduction at its source, optimising administrative measures, and fostering a worker-centric safety culture, workplaces can create safer and healthier workplaces. These findings provide a strong case for aligning New Zealand's noise management policies with global best practices.

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Conflicts of interest

None

Author contributions

Conceptualisation AC Investigation AC, MZ, AK; Methodology AC, AK, Supervision MZ; Validation MZ; Visualisation AC, AK; Writing – original draft AC; Writing – review & editing AC, MZ, AK

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