Effective Strategies In The Prevention Of Noise Induced Hearing Loss

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A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland

Abstract

Effective strategies for the prevention of noise induced hearing loss have occupied researchers, OHS practitioners and enforcement agencies for many years. This paper reports on the second part of a major study on the epidemiology and prevention of NIHL in New Zealand. The objective of the project was to evaluate existing work-related interventions to reduce NIHL, to identify critical factors in the development and implementation of such strategies, and to propose strategies/interventions where current interventions are considered ineffective. In addition, the research examined those aspects of workplace culture that affect decision-making around NIHL. A systematic review of the research literature was completed specifically focussing on the effectiveness of interventions in the prevention of NIHL and five key strategies were identified. Data collection methodologies were developed for specific industry sectors which were segregated into high, medium and low sectors of risk of NIHL. In addition to area noise measurements and personal dosimetry, assessments of the organisation's conformance to current noise management standards and safety climate data were undertaken. As anticipated, area and personal noise exposures were found to vary considerably within the "high risk" (agriculture, manufacturing and construction; range: LAeq 8hr 80 - 90 dB), "moderate risk" (cafes and restaurants; range LAeq 8hr 60 – 75 dB) and "low risk" sectors (pre-schools; range LAeq 8hr 70 - 80 dB). Data on enterprise conformance with the Approved Code of Practice for the Management of Noise in the Workplace indicated that most enterprises surveyed did not conform to the specific requirements of the Code in relation to noise management. As a consequence of the research, a comprehensive multi level intervention strategy is proposed.

Introduction

Effective strategies for the prevention of noise induced hearing loss (NIHL) have concerned OHS practitioners and researchers for decades. This concern however, has turned to consternation in recent times, by the fact that although the causative mechanisms for NIHL is relatively well understood, exposure response relationships are well characterised, exposure and primary health effect is easily measurable and regulations based on these attributes have been in effect for decades (Daniell et al, 2006), the prevalence and incidence of NIHL remains a significant occupational health problem for society.

For New Zealand, noise induced hearing loss is a major cost and burden and projections based on current trends suggest that predicted future costs are likely to escalate. The prevention of work-related NIHL has become a top priority for prevention and enforcement agencies. In order to address these issues, the Occupational Safety and Health Joint Research Portfolio (OH&S JRP) of the Health Research Council in New Zealand, funded a future-focused research programme comprising two separate but interrelated projects: Research Project One: Epidemiology of NIHL in New Zealand and Research Project Two: Prevention of NIHL in New Zealand.

The overall objective across the two research projects was to provide the OH&S JRP partners with a knowledge base for understanding NIHL in New Zealand, currently and in the future, in both work-related and nonwork-related environments, and to provide them with the robust evidence upon which they could develop effective interventions for control of noise-at-source and hearing conservation.

The objective of the second project and topic of this paper was to evaluate existing work-related interventions to reduce NIHL in New Zealand, to identify critical factors in the development and implementation of such strategies, and to propose strategies/interventions where current interventions are considered ineffective. In particular, this research project was to identify barriers to implementation of known approaches for addressing noise exposure. This included the perspectives of social marketing and behavioural psychology with respect to barriers to noise control and effective marketing of noise control messages to employers and workplaces. In addition, the research was to examine those aspects of workplace culture that affect decision making around NIHL.

This paper provides an overview of the evidence from recent systematic evidence based reviews of interventions in the prevention of noise induced hearing loss and identifies the barriers and enhancers of effective interventions, presents data from a recently completed survey of workplaces in New Zealand

and outlines a framework for a proposed comprehensive multi- level intervention strategy.

Evidence From Systematic Reviews Of The Literature

A long awaited evidence based review of interventions to prevent occupational noise induced hearing loss has recently been reported (Verbeek et al, 2009). Twenty one studies were included in the review. Of those, one study evaluated a strategy to reduce noise exposure, fourteen studies with 75,672 participants evaluated hearing loss prevention programmes (HLPPs), and six studies with 169 participants evaluated hearing protection. The overall quality of studies was reported as low.

One ITS study evaluated the effect of new legislation in reducing noise exposure. It found that the median noise level decreased by 27.7 dB(A) (95% confidence interval (CI) 36.1 to 19.3 dB) with a change in trend in time of 2.1 dB per year (95% CI 4.9 to 0.7). A hearing protection study in army recruits compared those exposed to impulse noise with non-exposed recruits. The odds ratio (OR) for hearing loss was 3.0 (95% CI 1.1 to 8.0) despite hearing protection. In four studies, workers in a HLPP had a 0.5 dB HL greater hearing loss at 4 kHz than non-noise exposed workers (95% CI 0.5 to 1.7). In one study, the hazard ratio of hearing loss was 3.8 (95% CI 2.7 to 5.3) for workers exposed to noise compared to non-exposed workers. In three studies, a high quality HLPP had a lower risk of hearing loss than lower quality programmes. Noise attenuation ratings of hearing protection under field conditions were consistently lower than the ratings provided by the manufacturers.

The authors concluded that there is low quality evidence that legislation can reduce noise levels in workplaces. The effectiveness of hearing protection devices depends on their proper use. There is contradictory evidence that HLPPs are effective in the long-term. Even though case studies show that substantial reductions can be achieved, there is no evidence that this is realised in practice. Better implementation and reinforcement is needed. Better evaluations of technical interventions and long-term effects are needed. Audiometric and noise measurement data are potentially valuable for such studies (Verbeek et al, 2009).

A systematic evidence based review of literature (1999– 2008) evaluating occupational NIHL prevention strategies was also undertaken as a part of the Prevention of NIHL project undertaken in New Zealand (Johnston, 2009). In particular, the review examined specific features of effective NIHL interventions, and extended the evidence based on which workplace NIHL interventions could be developed and evaluated. The literature review addressed the following questions:

1. How effective are strategies implemented in workplaces to prevent NIHL or noise exposure? What are the barriers to implementation of these strategies?
2. What factors are associated with effective workplace interventions to prevent NIHL or noise exposure, particularly which relate to behavioural psychology or social marketing approaches?

It has been recognized that occupational intervention studies are under reported in the peer reviewed literature (Beahler, Sundheim &Trapp, 2000). To address this, the grey literature was also searched by accessing relevant websites to seek quality evidence for NIHL prevention programs from industry or regulatory bodies. Opinion or editorial pieces were excluded. Only English language publications were accepted. Extracted information was evaluated to determine the strength of the body of evidence supporting emergent aspects of NIHL prevention (NHMRC, 2008). The review included three key components of the body of evidence matrix: study quality (evidence base assessed using the NHMRC criteria (1999) for levels of evidence, study consistency, and impact (size of the effect of the intervention).

The initial search of the scientific and grey literature according to the processes above captured 403 titles of potential relevance to the review questions. Following screening of titles, 323 abstracts were identified for further investigation (270 peer reviewed, 53 non-peer reviewed). Examination of these abstracts (and full article text when required) identified 71 articles (61 peer reviewed, 10 from “grey” literature sources) that evaluated NIHL prevention interventions (31 studies) or addressed barriers/enablers to NIHL prevention (40 studies). The 31 articles (27 peer reviewed, four non-peer reviewed reports) that evaluated NIHL prevention interventions were included in this review.

Most of these studies were undertaken in the United States (71%), with five studies (16%) from Australia, two from the United Kingdom, and one each from Canada and India. The identified studies showed a range of industries where NIHL prevention was being addressed, with manufacturing and mining each representing 19% of all included studies. Programs in agriculture (16%), construction (13%) and music industries (10%) were represented, along with programs in mixed (10%) or other workplaces (13% including military, hospital, school and local government). Two studies that did not meet the participant inclusion criteria were also reviewed to examine any factors that may be transferable to the study population and aims of this review. These included a recent controlled trial of a NIHL intervention in school students, and a study in a hospital where noise was troublesome but <80dB.

Identification of five key NIHL prevention strategies

The range of programs and interventions identified to prevent NIHL was heterogeneous in study design, outcome measures, geographical locations and industry types thus precluding any statistical meta-analysis. Interventions that reported positive effects on NIHL ranged from large scale legislative change, to one-off workplace training sessions. Thematic synthesis of the intervention studies identified the following five key strategies for NIHL prevention: introduction of legislation, leadership, multifactorial interventions, implementation of engineering and design controls, and one-off training interventions.

While the hierarchy of noise control is an important over-arching occupational health framework used for control and management, NIHL intervention effectiveness did not correspond in a simple direct way with this framework

alone. For example, an intervention to promote the use of hearing protection (HP) using a comprehensive, multifactorial strategy led by management (Hughson, Mulholland & Cowie, 2002) was more effective than an intervention that consisted of a single training session (Lusk et al., 2003).

The evidence identified from this systematic review has been presented in the NHMRC body of evidence framework for each key strategy in Table 1. Grading of study generalisability and applicability (other components of the body of evidence matrix) have not been included, as these require understanding of local target populations and industrial contexts to be meaningful (Johnston, 2009).

The key findings of the review are summarised below, including key barriers and enablers of the strategy:

Strategy One: Legislative change

Key finding 1: Introduction of legislative rule and consequent introduction of Hearing Loss Prevention Programs (HLPP) have reduced noise exposure, incidence of NIHL and increased the use of control measures, including the use of hearing protectors.

Key barriers to this strategy

- Low use of data collected to provide feedback to employees, inform practice, effect and evaluate change
- Incomplete implementation of key features of hearing loss prevention programs
- No or limited use of noise controls (engineering/ administrative)
- Incomplete collection of audiology or noise exposure data in mobile and high risk workforce, resulting in inadequate NIHL prevention

Key enablers to this strategy

- Completeness of noise exposure and audiology data, facilitated by regulation and centralized database
- Statistical expertise in appropriately interpreting long-term data with multiple confounding factors
- More complete hearing loss prevention program associated with greater use of preventive behaviours

Strategy Two: Championed by leaders

Key finding 2: Strategies championed by leaders and managers promote effective NIHL prevention.

Key barriers to this strategy

- Inconsistencies between management and employee responses to questions about noise at work regulations, impact of NIHL, sort of training provided, limitations of HP
- Management and supervisors not wearing HP
- Supervisors not enforcing HP usage due to perceived inability to listen to the functioning of the machines, difficulty in visually monitoring usage and proper fit of HP, reluctance to jeopardize management/union relations, lack of incentive to enforce company policy.
- Reduced supervisor/employee ratio associated with deterioration in enforcement
- Use of hearing protection advised but not enforced
- Direct relationship between independent responses of management and employees to questions about workplace focus on NIHL prevention
- Mobile workforce and management

Key enablers to this strategy

- Demonstrate cost benefit to managers
- External driver for the process
- Leadership formulated intervention in response to needs assessment data

Table 1. Strategies to prevent NIHL in body of evidence framework

	Grade, Body of evidence	Comments
Key strategy 1: Legislative change		
Evidence base	C-Satisfactory Level III studies with low risk of bias, or Level I or II studies with moderate risk of bias	Three level III studies, two with low risk of bias, others level IV
Consistency	B-Good Most studies consistent and inconsistency may be explained	4 Comparative studies with or without concur-rent controls provide consistent evidence supporting legislative change. Review and cross-sectional study concur.
Workplace impact	B-Good Substantial work-place impact	Clinically significant outcomes in risk of STS(1 study), self reported use of HP (2 studies) and noise exposure (1study)
Key strategy 2: Championed by leaders		
Evidence base	D-poor Level IV studies, or Level I-III studies with high risk of bias	Three level IV studies and one RCT (indirect influence on NIHL)
Consistency	A-excellent All studies consistent	All studies linked leadership & management support to positive outcomes
Workplace impact	C-satisfactory Moderate work-place impact	More noise controls implemented/ improved staff perceptions but not reflected in noise exposure (2 studies). Good improvements in all outcomes (1). Improved management commitment and employee participation (1)
Key strategy 3: Multifactorial approach		
Evidence base	D-poor Level IV studies, or Level I-III studies with high risk of bias	One level II study (in students) One level III study with high bias Three level IV studies
Consistency	C-satisfactory Some inconsistency reflecting genuine uncertainty around clinical question	Some common elements to interventions (assessment, individualized results, strategies for change, follow-up) but many inconsistencies and insufficient information to determine best approach
Workplace impact	B-Good Substantial work-place impact	Moderate-large in-creases in HP use in 4studies
Key strategy 4: Implement engineering		
Evidence base	D-poor Level IV studies, or Level I-III studies with high risk of bias	All level IV studies
Consistency	A-Excellent Most studies consistent & inconsistency may be explained	Consistent reductions in noise exposure, but acceptance (to workers and managers) and sustainability unknown
Workplace impact	C-satisfactory Moderate work-place impact	Only immediate effects on noise exposure reported
Key strategy 5: One-off training		
Evidence base	D-poor Level IV studies, or Level I-III studies with high risk of bias	Three level II studies Two level II studies with high bias (dropouts 34-47%) and five level IV studies
Consistency	B-Good Most studies consistent; inconsistency may be explained	Most studies reported immediate effects but these were unreported or not sustained in short-longer term
Workplace impact	D-Poor Slight or restricted work-place impact	Size of effects on reported or intended HP use insufficient to prevent NIHL

Strategy Three: Multifactorial approach

Key finding 3: Interventions which combine multiple strategies are effective in NIHL prevention.

Key barriers to this strategy

- Requires a great deal of effort to encourage employers and employees to fulfil their statutory requirements
- Long term persistence of changes uncertain

Key enablers to this strategy

- Leaders who actively and enthusiastically encourage intervention practices
- Long intervention associated with improvement, but still unknown if this was sustained

Strategy Four: Implement engineering

Key finding 4: Engineering controls reduce noise exposure but little is known about the logistics and economics of their implementation.

Key barriers to this strategy

- Controls are situation and site specific
- Requires multidisciplinary collaboration: acoustic engineering, construction and industrial expertise
- A lengthy and costly process in tough industries where solutions are not simple
- No or limited use of noise controls (engineering/ administrative)
- Perceived gap between knowledge of the experts, and actual action taken in workplaces

Key enablers to this strategy

- Links between regulators, researchers, industry and suppliers, where policies, collaborations and initiatives work together to facilitate NIHL prevention
- Financial incentive for suppliers, supported by effective regulators enforcing lower noise practices
- Regulators worked with companies who had expressed interest in changing practices or had already started to implement some noise control measures
- Low cost interventions ready to go, but long term sustainability and effectiveness of these approaches unknown
- Different approaches for new workplaces compared with established workplaces
- Cost of administrative control may be an advantage compared to engineering controls, but no data was provided to support this opinion

Strategy Five: One off training

Key finding 5: One-off training has modest immediate effects, but is insufficient to prevent NIHL in the long term.

Key barriers to this strategy

- Underlying difficulties when key goal of intervention is to promote hearing protection use (requirement for 100% of time use, low wearer acceptability, variability in attenuation)
- Changes in attitudes, perceived benefits/barriers/ susceptibility not associated with more preventive behaviour, so evidence base for what to include in training is low

Key enablers to this strategy

- Face-to-face informal training sessions appear more effective
- Practical participation involving selection and use of devices important
- Messages focussing on the positive aspects of NIHL prevention more effective than those emphasizing the negative results of no prevention

Barriers identified with each of the key intervention strategies have already been highlighted. In addition to the intervention studies described, many nonintervention, qualitative studies have sought to determine barriers to NIHL prevention. Most of these have involved surveys, interviews or focus groups with workers and have concentrated on barriers to the use of personal hearing protection.

The influence of workplace safety climate, an important concept in occupational health and safety literature, has been addressed in some of the NIHL prevention literature. Safety climate may be described as reflecting the priority given to safety in an organisation (or safety culture). Although there appears to be no general consensus on what constitutes safety climate, employee perceptions of management commitment to safety are fundamental (Griffiths 1985; Hofmann, Jacobs et al. 1995).

Evidence from Survey of Workplaces

A primary objective of the Prevention of NIHL project was to undertake workplace studies to (1) determine the nature and effectiveness of interventions currently used in industry to reduce noise exposure and the incidence of NIHL and identify the barriers to the implementation of noise management strategies and programmes, (2) determine whether identified "high risk" sectors and occupations are conforming with current industry recommendations (e.g.. Codes of Practice) and standards to prevent NIHL and (3) determine what aspects of workplace culture and environment affect decisions around NIHL, including cultural barriers to preventive actions and what motivates individuals to prevent hearing loss.

The survey of workplaces was designed as a multiple case study approach where the unit of analysis was the workplace. As the association between noise exposure and health outcome (NIHL) is well known and recorded, the focus of the study was primarily on what are the current noise exposures, what is currently being done to control exposures and what potentially could be done to reduce exposures. Unlike aetiological studies where typically large samples, randomization, blinding etc are required, intervention effectiveness studies utilise case studies of different settings in which to test the programme theory for prevention effectiveness (Rogers et al, 2000; Kristensen, 2005).

A case study design was utilised to identify, describe and evaluate intervention/control strategies used by those "high risk", "moderate risk" and "low risk" industries in relation to noise exposure and the incidence and/ or severity of NIHL. The case studies included site visits, where existing noise control strategies/ interventions, barriers to implementation or adoption of existing controls/ interventions, and critical factors that need to be considered when designing and implementing effective noise control interventions were recorded.

A list of high, moderate and low risk industry sectors was developed by reference to the findings of Research Project One as this information became available. Other selection criteria included identifying industry sectors where noise exposure has been traditionally regarded as low e.g. Education, hospitality, health services. This was undertaken with reference to;

1. The data provided by Thorne et al. (2008) that identified specific industry sectors based on their ACC claims experience for noise induced hearing loss.
2. ACC and Department of Labour target industry sectors for excessive noise exposure
3. Recommendations from the Noise Induced Hearing Loss Stakeholder Group (initiated by Project 1 – Epidemiology of NIHL project)

The industry sectors identified included those shown in Table 2. An industry database for these sector groups was developed (a) with advice from the NIHL Stakeholder Group, (b) from the ACC dataset for enterprises within the selected regions, and then (c) reconciled and validated by reference to the regional telephone business directory.

A combination of both quantitative and qualitative techniques were used in the collection of primary and secondary data. The techniques included; workplace observations, noise exposure assessments, semi-structured interviews, self administered questionnaires, and reference to archival data. Data collection for the workplace surveys were divided into 3 component parts:

Part 1 described the nature and effectiveness of interventions currently used in industry to reduce noise exposure and identify barriers to the implementation of noise management strategies.

Table 2. Industry sectors selected for survey of workplaces with relative risk of NIHL

Risk of NIHL	Industry sector	ANZSIC
High risk	Agriculture,	A – 0149 Grain, Crop,0161 Dairy
	Manufacturing	C – 1211 Beverages,1340, Knitted products,2221 Steel fabrication
	Construction	E – 3019 Residentialbuilding, 3101 Roadconstruction, 3212Demolition
Moderate risk	Hospitality	H – 4511 Cafes, restau-rants and bars
Low risk	Education	P – 8010 Preschool,8021 Primary

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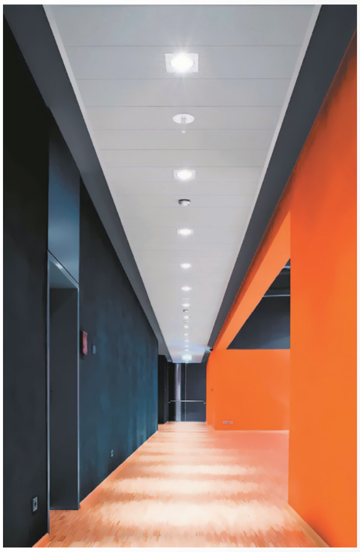

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Part 2 determined whether identified "high risk" sectors and occupations were complying with current recommendations (e.g. Codes of Practice) and legislation to prevent NIHL?

Part 3 determined what aspects of workplace culture affect decisions around noise exposure and NIHL.

The three parts of the workplace survey strategy, with their specific data collection instruments and methodologies, were incorporated into one integrated survey tool. This aimed at reducing the impact of research team members engaging the organisations selected on more than one occasion, for differing survey objectives; eliminate duplication of data collected and provided a single point of contact and communication for the industry sector and individual organisation's management and employees. Data collection instruments were modelled after those developed by Purdy and Williams (2002) and Williamson et al. (1997).

Noise at Work Survey (Evaluation of existing noise sources and controls)

This section of the survey provided demographic details of the selected organisations, including the physical characteristics and details of work areas assessed; identification of existing noise sources; identification of existing noise control strategies; assessment of the options/ strategies for reducing noise exposure further. Noise exposure data including area noise levels and personal noise dosimetry.

Noise sources, paths and controls

Generally noise sources could be readily identified in the workplaces. For the high risk industry sectors, the sources were primarily due impact noise; rotational noise due to machinery, gears, conveyers and electric motors; engine noise; high frequency pneumatic noise due to hydraulic equipment and operations; pipe noise due to turbulent flow within pressurized steam lines; compressor noise; alarm noise due to operational alarm activation. For the medium and low risk sectors, noise sources tended to be related to the task, activity and equipment being used and the interaction of other, usually external sources of noise not directly related to the workplace. i.e. traffic noise.

Identification of noise paths in relation to the noise sources was complex as it included indoor and outdoor environments. However, airborne paths were primary route for noise, with some cases of structure borne and duct borne noise/vibration transmission.

The predominant noise control strategy in the majority of organisations surveyed was that of minimization, specifically the use of hearing protection. Although many operations were complex, noise control strategies aimed at the noise source and noise paths but could have been investigated further, including more specific and direct enclosure of machinery and equipment, use of vibration isolation, regular maintenance of machinery and equipment, elimination or replacement of old machinery and implementation of a "buy quiet" purchasing policy. Administrative controls were not used in any of the organisations surveyed.

Noise exposure and dose measurements

Median $L_{Aeq.8hr}$ and L_{Cpeak} levels, dose estimates and percentage of work areas equal to (=) or greater (>) than 85 dB were recorded. Of the "high" risk industry sectors wood process and sawmills and engineering manufacturing sites and construction operations experienced the highest noise exposures with median $L_{Aeq.8hr}$ values of 95 dB, 92 dB and 90 dB respectively. Median L_{Cpeak} levels were similarly high at 130 dB, 125 dB and 120 dB. The remaining high risk industry sectors surveyed (agriculture, bottling and textile industry) had median $L_{Aeq.8hr}$ values of 85 dB, 83.5 dB and 80 dB, and median L_{Cpeak} level of 115 dB, 105 dB and 100 dB respectively.

Noise dose estimates for employees working in these businesses indicated a very wide range of personal exposures (10 – 600%), with wood processing and sawmills, engineering and construction operations experiencing the highest dose estimates and widest dose range. The medium risk industry sector (cafes) surveyed had a median $L_{Aeq.8hr}$ values of 74 dB, and median L_{Cpeak} level of 105 dB. Noise dose estimates for cafe employees ranged between 8 – 26%. The low risk industry sector (preschools) had median $L_{Aeq.8hr}$ values of 70 dB, and median L_{Cpeak} level of 110.5 dB. However, the noise dose estimate ranges for employees working in preschools (4 – 98%) was very large in comparison to café measurements. Two employees in preschool facilities had one daily dose estimates of 194% and 316%.

Noise at Work Survey (Noise control conformance assessment)

This section of the survey essentially audited the employers and employees responsibilities under the Health and Safety in Employment Act 1992 with respect to noise, utilising the Approved Code of Practice for the Management of Noise in the Workplace. Data was collected through semi structured interviews, observational data and investigation of archival data and information.

With few exceptions, there was insufficient evidence that the key requirements of the Approved Code were met. In summary;

1. Noise tended to be identified as an issue, and some informal assessments were undertaken (e.g. Difficulty having a conversation). No evidence existed that noise was identified as a significant hazard. i.e. Preliminary noise assessments.
2. Some evidence existed that elimination and isolation strategies were explored to reduce noise exposure, but were not generally utilised. Administrative controls were not used in any of the organisations surveyed.
3. Evidence that minimization (use of hearing protection) tended to be employed as the key control strategy.
4. No evidence that information or training was provided for noise control/ management in the workplace.
5. No evidence that noise monitoring or audiometry was routinely undertaken.

The third survey (Noise at Work – Workplace Safety Culture/ Climate) is currently being analysed.

Development of an intervention strategy in prevention of NIHL

The overall outcome of the Epidemiology and Prevention of NIHL project was to provide recommendations for the development of an effective intervention strategy. A key approach would be to incorporate the conceptual

model for intervention research proposed by Goldenhar et al, in 2001. The model attempts to provide an integrating framework for diverse activities; articulate relationships among various types of intervention research; facilitate assessment of the current state of the field in order to guide strategic planning (for example, specific requests for intervention research proposals) and develop a common language to facilitate communication.

The model suggests that the intervention research process is cyclical and progressive and involves three broad research phases of intervention development, implementation and evaluation. It includes a set of five tasks that are important in any intervention research study:

1. Gathering background information and conducting needs assessment on the problem and the range of possible intervention strategies.
2. Developing partnerships with relevant stakeholder groups.
3. Choosing appropriate research methods and study designs.
4. Conducting the research.
5. Reporting on and disseminating findings.

Intervention research can be conducted at levels ranging from simple worksite programmes to national or international policy. LaMontagne and Shaw (2004) expanded this approach to describe a conceptual model that relates directly to occupational health interventions. As well as illustrating the intervention research process, it incorporates the differing levels and focus for evaluation; that is, from the national or international policy level, to the national campaign level, to the local/ organisational programme level.

The first phase of this strategy has been developed by the integration and assimilation of a variety of sources of data and information. The extensive evidence based review of literature on the effectiveness of intervention strategies in the prevention of NIHL, provided useful insights into a complex issue without simple solutions.

The survey of workplaces provided data on the nature and effectiveness of interventions currently used in industry to reduce noise exposure and the incidence of NIHL, to identify the barriers to the implementation of noise management strategies and whether identified "high risk" sectors and occupations were conforming to current industry recommendations. Additional components of the first phase include the safety climate/ culture data in relation to attitudes, values and beliefs around NIHL in the workplace, the social marketing and behavioural psychology perspectives on intervention development and the effectiveness of OHS regulatory instruments.

The second phase of the strategy involves developing partnerships and wider consultation. This would lead to the development of an intervention strategy at National, Industry and Organisational level. Phase three involves development of the strategy, Phase four, implementation of the strategy and Phase 5, evaluation of the strategy with Phase 6, reporting and dissemination.

The development of a national strategy should use a multilayered approach, based on consultation with industry associations, union organisations, government, community agencies and professionals. There needs to be a long-term commitment to the development and resourcing of a strategy for noise injury prevention for New Zealand industry, which can be effectively initiated or incorporated into existing/ ongoing programs. A communications system needs to be established that allows information to flow between all stakeholders and establishment of relevant partnerships for action. Related national strategies include the Workplace Health and Safety Strategy for New Zealand to 2015 and the National Foundation for the Deaf (NFD) National Noise Induced Hearing Loss Strategy.

Another key component of a national strategy involves the hierarchy of legislation, regulations and an approved code of practice encompassing the minimum requirements and best practice principles for the management of workplace noise. In general, minimum requirements are at the legislative top of this hierarchy, with increasing detail on how to meet these requirements presented by advisory codes of practice at the base.

Barriers to meeting regulatory requirements and recommendations (e.g. Lack of access to services, lack of information about machinery noise levels / exposure limits, infrastructure costs, confusion about requirements vs. Recommendations, lack of national consistency) also need to be identified where they exist, so that ways of overcoming these may be addressed in both the government and private sectors (Gunningham and Associates, 2008).

A model industry level intervention strategy for the prevention of NIHL (applicable in New Zealand industry) has been recently developed by Farmsafe Australia (2009).

"The Noise Injury Prevention Strategy for the Australian Farming Community 20092012" provides a structure within which to focus efforts to reduce the incidence, severity and impact of noise injury across all members of the farming community.

The Strategy encompasses noise injury prevention / promotion; service delivery; and quality of life issues, for all members of the farming community who may be already affected by noise injury or are at risk of hearing loss from noise. Suggested actions are congruent with a new model for farm safety adoption, drawing on the experience of farm safety programs and research conducted in Australia over the past 20 years.

The Strategy recognises the existence of other types and causes of hearing loss amongst farmers (e.g. Noisy off farm recreational activities, chemical exposure). However, action to reduce the risks associated with exposure to excessive noise during agricultural production is a matter of priority, to reduce the incidence and impact of noise injury and hearing loss in the farming community" (Farmsafe, 2009).

At the organisational level, the practice of occupational hygiene entails the anticipation, recognition, evaluation, and control of exposures to health hazards in the workplace (Mulhausen & Damiano, 1998). The further "upstream" from exposure one aims, the more likely one is to achieve the preferred goal of exposure prevention versus control. The principle in fundamental to OHS practice, but

even so relevant and challenging for implementation in small enterprises/businesses which constitute the largest proportion of NZ businesses, where the burden of exposures to noise and NIHL lie.

Hasle and Limborg (2006) developed a useful model of intervention research in small businesses. They suggest that researchers focusing on the development of interventions for small business need to study the complete system. Developing that model further in relation to small business interactions with government agencies, highlights the important role of intermediaries in the "embedment" or "ownership" of the intervention in the small business.

Conclusions

The evidence identified and collated in this review suggests that NIHL prevention is a complex issue without simple solutions. Effective interventions will require a combination approach, taking the best strategies from different types of intervention. In the intervention studies identified, the best of these approaches combined "high level" interventions (e.g. active management targeted with greater use of noise elimination, design and engineering noise controls). The least effective contained a lower level component (e.g. person centred behavioural approaches with little management support to promote the wearing of personal hearing protection).

The results of the workplace surveys confirmed that within the industry sectors selected, noise sources were extremely varied, but readily identifiable. Noise controls strategies primarily adopted a minimization approach (use of personal hearing protection devices), with little evidence of consideration of control options at the source of the noise or in the air path (engineering controls). Administrative controls were not utilised in any of the cases examined. In assessing the systems, procedures and activities of the organisations surveyed in relation to the requirements of the Approved Code of Practice for the Management of Noise in the Workplace, not one of the businesses surveyed (n=33) conformed to all the requirements. Noise exposure and noise dose estimates for employees working in these businesses were very wide and personal exposures ranged from 4% to in excess 600% daily dose.

A comprehensive multilevel intervention strategy has been proposed that may provide a useful framework for national, industry sector and organisational intervention design and implementation. The challenge for designing effective NIHL intervention strategies will be to integrate and build on evidence from previous international quantitative and qualitative studies, in combination with attention to optimal occupational intervention study design, and a clear understanding of the local context gained through primary research (Johnston, 2009).

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