Noise induced hearing loss (NIHL): Possible long-term research projects

Monash University Centre for Occupational and Environmental Health

Authors

Dr Samia Radi, Senior Research Fellow, MonCOEH, Monash University
Dr Geza Benke, Senior Research Fellow, MonCOEH, Monash University
Dr Frederieke Schaafsma, Senior Research Fellow, MonCOEH, Monash University
Prof Malcolm Sim, Director, MonCOEH, Monash University

29 November 2010

Accompanying documents to this report

Title	*Report number*
Noise induced hearing loss (NIHL): Possible long-term research projects	Research Brief No. 1110-004-R8B

Research Report No. *1110-004-R8*

A joint initiative of

Noise induced hearing loss (NIHL) project:

Possible long-term research program

Analysis of NIHL claims data identified higher risk groups in relation to occupational and demographic characteristics in the working population lodging a compensation claim in the last decade in Victoria. The two industries with higher numbers and incidence rates of NIHL claims were manufacturing and construction. Claimants employed in these industries were also more likely to work in small workplaces. Furthermore, age was a strong determinant for lodging a successful claim. Over the period analysed, workers aged 56 to 65 years had the highest number of claims, followed by the 66+ workers and both age groups had also the highest rise in the number of claims across the period. However, the increase in the number of accepted claims may only reflect increased awareness among eligible workers.

A national and international literature review identified gaps in epidemiological research. The long-term research program is aimed at designing feasible epidemiological studies applicable to the Victorian situation in light of the results of claims analysis.

The following possible research projects could be developed in the Victorian jurisdiction in order to assist in implementing targeted prevention measures and decreasing the number of future NIHL claims.

1. Determination of the size of the potential NIHL claimant population in Victoria
2. Examination of the effectiveness of interventions to reduce exposure to NIHL in the workplace:
    a. Assessment of the effectiveness of regulations and barriers to compliance
    b. Identification of barriers and enablers to the proper use and implementation of hearing protection devices.

These projects are described in greater detail in the following sections.

1. Determination of the size of the potential noise induced hearing loss (NIHL) claimant population in Victoria

Background

Noise induced hearing loss (NIHL) is a disease of gradual onset but it is entirely preventable as hearing damage does not progress once exposure to noise is discontinued. However despite regulations on occupational noise, NIHL remains an important cause of workers' compensation claims in Victoria. The dramatic increase in the number of NIHL claims experienced in the last five years in this jurisdiction has raised concern about their costs in the future. The upward trend may progress and challenge the workers' compensation scheme liability.

Hearing loss in the community places a substantial social and economic burden on the Australian population. Prevalence of hearing loss has been reported in population-based health surveys such as the 2007-08 National Health Survey conducted by the ABS (ABS 2009). Estimates based on self-report are available for Victoria. Overall, 10.1% of the Victorian population reported partial or complete deafness. Prevalence of hearing loss was higher in males (12.5%) than in females (7.8%) and increased with increasing age from 4.5% in people aged 25 to 44 years to 31.9% in people aged 65 years and over. The limitation of this survey is due to the collection of self-reported conditions that can lead to misclassifications. Prevalence of hearing loss in the community has also been derived from audiometric testings in a representative South Australian adult population. The data showed that 16.6% of the population had hearing impairment in the better ear at or above 25 dB and 22.2% in the worse ear at the same level (Wilson et al 1999). More recently, it was estimated that 21.6% of the Australian adult population had hearing loss (Access Economics 2006).

Uncorrected hearing loss is closely related to quality of life and affects not only the person with the hearing loss but also those they communicate with. It has been linked to poor quality of life and social isolation. Hearing loss was found to impact on physical, psychological and emotional well-being, people with hearing disability being reported to have lower physical and mental health status than those with no hearing disability (Hogan et al 2009a, Arlinger 2003). Reduced communication abilities have

also an impact on a person's chances to gain competitive skills and employment. This explains why the larger component of the financial cost of hearing loss in 2005 was productivity loss, accounting alone for more than half of all the financial costs while direct health costs only accounted for 6% of the financial costs. The productivity cost arises due to lower employment rates for people over 45 years suffering of hearing loss and subsequent losses in earnings (Access Economics 2006). Analysis of the 2003 Australian Survey of Disability, Aging and Carers (SDAC) showed that hearing loss was associated with an increased rate of non-participation in employment. Reduced participation in the labour force was greater in females with hearing loss than in males with hearing loss and in those having low education and communication difficulties. People with hearing loss were also less likely to be found in highly skilled jobs and were over-represented among low income earners (Hogan et al 2009b).

Despite an increase in the number of successful NIHL claims, compensation data are likely to underestimate the incidence of this condition. While a worker may already have reached the hearing threshold that entitles them to compensation, incidence rates may be affected by both the extent to which NIHL is reported and the timing of reporting in the course of the disease which is of gradual onset. A Victorian study comparing notifications of compulsory abnormal audiometry tests and subsequent claim lodgement suggests that only one in four eligible workers claimed for NIHL (Benke et al 1988). Another example is the Washington State in the USA which experienced a sharp increase in workers' compensation claims for hearing loss in earlier years (between 1984 and 1998) with a higher increase in claimants above 65 years. The authors concluded that the striking rise over this period may be partly explained by changes in the reporting of NIHL, particularly in older claimants who prefer to lodge a claim after retirement when noise exposure has ceased. Interestingly, the claims increase was less for self-insurers than for State fund claims (which usually comprises smaller workplaces), suggesting a more stable workforce, more resources, and greater access to the workplace for claim investigation for self-insurers compared to smaller non self-insured employers. Another suggested contributing factor for the increase in NIHL claims in Washington State was the involvement of a small percentage of health care providers identified as the principal

provider for a major proportion of accepted claims, preferentially in older workers (Daniell et al 2002).

Research question and objectives

Modelling of future incidence rates

Victoria experienced a significant reduction in the number of NIHL claims from late 1997 to the mid 2000's but this was subsequent to an increase in the hearing loss threshold in 1997. Nonetheless, compensation data show no steady or downward trends in the recent years. To the contrary, there has been again an upward trend with the number of claims doubling in the past five years. The aim of the modelling is to forecast the likely number of NIHL claims in the future in order to plan better resources to cover liability and develop targeted prevention.

Prevalence of occupational exposure to noise

Prediction of future NIHL incidence involves assumptions about past and current noise exposure and its relation to the disease. An attempt has been made to estimate the number of workers potentially exposed to hazardous noise at work in the absence of hearing protection using two different models. The first model involved extrapolation of audiometry testing data in Western Australia from the early 1990's. The second model examined at risk groups, as identified from high rates of national compensation claims. From the models examined an estimated 900,000 to 1,000,000 workers (i.e. around 12 % of the workforce) were estimated to be potentially exposed to hazardous levels of noise at work (Safe Work Australia 2006). More recently, 32% of the workers who participated in the National Hazard Exposure Worker Surveillance (NHEWS) survey reported that they were exposed to loud noise during work. After data weighting, it was estimated that 28% of the Australian workforce was exposed to loud noise at work (Safe Work Australia 2010). These figures may be overestimated as no measurement of noise levels was performed and some workers exposed to levels below 85 dB may have considered themselves exposed to loud noise.

Statistical models

Regression techniques can be used to project in the future using data available for the period from 1998 to 2008. Using past number of incident cases by age, gender and industry, and industry-specific incidence rates, the number of future cases will be derived by applying the rates to projection population estimates.

A previous work (AIHW 2007) modelled hearing loss as a progressive condition with mild, moderate and severe stages. Prevalence data from the South Australian survey were used as a basis (Wilson et al 1999). From examination of the prevalence data by level of severity and age, and assuming that all cases progress from the mildest to most severe category, it was assumed that on average progression to the next severity level occurs at 5 year intervals between mild (25 to 34 dB) and mild (35 to 44 dB), and at 10 year intervals from mild (35 to 44 dB) to moderate and moderate to severe. A 25-year lag was applied for severe hearing loss, 15 years for moderate and 5 years for the mild (35 to 44 dB) categories.

Although population data on measured hearing loss thresholds will be used to estimate disability for this condition, there will be some uncertainty associated with the modelling of the average durations associated with progressing from mild through moderate to severe hearing loss.

References

1. ABS 2009. 2007-2008 National Health Survey: summary of results. ABS Cat. No.4364.0. Canberra: ABS.
2. Access Economics. The economic impact and cost of hearing loss in Australia, 2006.
3. Hogan A, Loughlin K, Miller P, Kendig H. The health impact of a hearing disability on older people in Australia. J Aging Health 2009a;21:1098-11.
4. Arlinger S. Negative consequences of uncorrected hearing loss – a review. Int J Audiol 2003;42:2S17-S20.
5. Hogan A, O'Loughlin K, Davis A, Kendig H. Hearing loss and paid employment: Australian population survey findings. Int J Audiol 2009b;48:117-22.
6. Benke G, Groenewald R. Compulsory screening audiometry: protection from whom? Seventh Annual Conference of the Australian Institute of Occupational Hygienists. Leura, NSW, 1988.
7. Daniell WE, Fulton-Kehoe D, Cohen M, Swan S, Franklin GM. Increased reporting of occupational hearing loss: workers' compensation in Washington Stata, 1984-1998. Am J Ind Med 2002;42:502-10.
8. Work-related noise induced hearing loss in Australia. Safe Work Australia, April 2006.
9. National Hazard Exposure Worker Surveillance: noise exposure and the provision of noise control measures in Australian workplaces. Safe Work Australia, January 2010.
10. AIHW 2007. Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez AD. The burden of disease and injury in Australia 2003. Australian Institute of Health and Welfare 2007. PHE 82. Canberra: AIHW.
11. Wilson DH, Walsh PG, Sanchez L, Davis AC, Taylor AW, Tucker G, Meagher I. The epidemiology of hearing impairment in an Australian adult population. Int J Epidemiol 1999;28:247-52.

2.a. Prevention of noise induced hearing loss (NIHL) in the workplace: effectiveness of regulations and barriers to compliance

Background

Despite existing regulations and more stringent eligibility criteria, occupational NIHL still occurs and moreover the number of noise induced hearing loss (NIHL) claims has increased in the recent years. It is likely that the rise in the number of claims be due to increased awareness about individual hearing status. The little variation of the percentage of rejected claims versus the total number of claims over the past ten years may reflect an increase in awareness of entitlements among workers eligible for compensation.

Analysis of the Victorian NIHL compensation claims data showed that manufacturing and construction were the two industries with the highest numbers and incidence rates of claims. These two industries experienced a more than twofold increase over a nine-year period from 1999-00 to 2007-08 but a sharper rise was observed from 2003-04. In manufacturing, the recent upward trend was however twice as high in small workplaces compared to large workplaces. Over the same period, workers aged 56 to 65 years had the highest number of claims, followed by the 66+ workers. Both age groups had also the highest rise in the number of claims across the period, the number of claims in these age groups increasing by fourfold and tenfold respectively. Tradespersons, intermediate production and transport workers, and labourers were the three occupations with the highest number of claims. They accounted for 90% of all claims.

NIHL presents a safety hazard in the workplace by altering speech communication or recognition of audible warning signals. It may have a negative impact on an individual's life and amongst others lead to social isolation as a result of withdrawal from various social activities. Effective primary and secondary prevention should be implemented in the workplace in order to avoid occupational hearing loss in workers not yet affected by the disease and further damage in those already suffering a hearing loss.

Estimation of the number of workers exposed to excessive noise

Previous data on extensive audiometry testings performed on workers from Western Australia in the early 1990's found that 7% of people examined were found to have noise related percentage of hearing loss above 5% (Monley et al 1996 cited in Safe Work Australia 2006). These audiometry data also served as a basis to estimate the overall number of workers exposed to noise in combination with data of employment numbers in each industry across Australia taken from the Australian Bureau of Statistics (ABS) 2001 Census. The number of exposed employees was predicted by multiplying the industrial exposure rate by the number of employees in the industry and adding together the total for each industry. This gave an estimated total exposure of around 900,000 Australian employees (Safe Work Australia 2006).

In the recent National Hazard Exposure Worker Surveillance (NHEWS) survey (NHEWS, Safe Work Australia 2010), workers were asked to estimate their duration of occupational exposure to loud noise. Loud noise was defined as 'noise loud enough that a person would raise their voice to be heard when speaking to people who are at one arm's length away from them'. No measures of the level of noise were performed in conjunction with the self-reported exposures but the assumption was that reported loud noise exposure corresponded to a level of noise of at least 85 dB(A) as suggested by a previous study (Neitzel et al 2009). Overall, one third of the participants in the NHEWS survey (32%) reported that they were exposed to loud noise but more than half of male workers (52%) compared to one in five females (20%) employed in the five national priority industries (manufacturing; construction; agriculture, forestry and fishing; transport and storage; health and community services) reported that they were exposed to loud noise. In contrast with Victorian claims data that show that older workers more often than young workers lodge a successful NIHL claim, the likelihood of a person reporting loud exposure to noise in the NHEWS survey decreased with increasing age. This can be partly explained by the fact that older workers may be accustomed to loud noise or already suffering from hearing loss and therefore less likely than younger workers to report it.

Another nationwide questionnaire survey of workers was conducted to describe behaviour towards the use of hearing protectors (Safe Work Australia 2010b). Over one-third of responding workers (35%) self-reported hearing difficulty. Half of the respondents (49%) stated that they were exposed to loud noise at work in the last two weeks. In the five at risk industries, 34% of workers had been exposed to

excessive noise for one to 10 years and 27% for over 10 years. A total of 28% of exposed workers reported being constantly exposed during a day of work.

Noise control measures in the workplace

The best strategy to avoid hearing damage is prevention. Nevertheless, a recent systematic literature review showed that there is little evidence that hearing protection programs are effective (Verbeek et al 2009). This review analysed the immediate temporary effect of noise exposure called ‘temporary threshold shift’ while long-term effects of noise reduction interventions such as the provision and use of hearing protectors or changes in equipment or machinery were measured as permanent noise induced hearing loss. Most of the reviewed studies either yielded to non significant results or were of low quality. In one good quality study however, instructions for inserting earplugs into the ear canal had a significant effect on the noise attenuation of the hearing protectors (Park et al 1991). Only a few studies evaluated the long-term effect of noise induced hearing loss prevention programs. A meta-analysis of four of these studies versus non-exposed workers after 5 years indicated that the protected workers had the same amount of hearing loss as the non-exposed workers. Only one study showed that the introduction of a legislation to reduce noise levels in a particular industry decreased the median noise level as an immediate effect but that the long-term effect on noise reduction was not significant (Joy et al 2007). The overall quality of evidence for this study was however low.

The use of personal hearing protectors is the least reliable control measure in the hierarchy of control. It is however often relied on due to economic and other limitations. In the NHEWS survey, the provision of hearing protectors was the most common form of noise control measure provided to the workers with 72% of workers being provided with hearing protectors. Less than half the workers (41%) who reported that they were exposed to loud noise also reported they had received training on hearing loss prevention. The odds of not being provided with training or control measures increased with decreasing workplace size. Workplaces with less than 20 employees were four times more likely to provide no control measures for their workers and three times more likely to provide hearing protectors only as a

control measure compared to large workplaces (with 200 employees or more) (NHEWS, Safe Work Australia 2010).

Barriers to the implementation of effective noise control measures

Technical measures should be the first choice in noise management and theoretically, efficient noise control measures in the workplace should decrease exposure of workers to excessive noise levels and therefore decrease incidence of hearing loss. However, there are barriers to implementing an effective prevention of NIHL. A recent report from Safe Work Australia explored these barriers to effective noise control and hearing loss prevention using a series of research studies with a qualitative approach (Safe Work Australia 2010). The aim of this report was to provide an understanding of the occurrence of NIHL while appropriate regulations exist in each jurisdiction and to assist in the design, implementation and evaluation of strategies and interventions for facilitating more effective occupational noise control.

A focus group survey of employers and managers in five high risk industries and various business sizes was conducted nationwide to among other aims determine the type of noise control measures in the workplace and to understand attitudes towards hearing loss and workplace noise. It showed that occupational NIHL was not considered a high priority work health and safety issue because most participants in the survey believed that hearing loss was not an immediate life threatening condition and did not have visible consequences. Several barriers to the adoption of preventive behaviours were identified. Managers who were reluctant to learn more about hearing loss and NIHL reported that they were concerned about the additional costs. Workers expressed a range of barriers to the wearing of hearing protectors including discomfort and in some cases an increased risk level due for example to failure to hear machinery or vehicles. Half of the workers believed that the level of noise to which they were exposed was not problematic and the majority of workers and many managers of smaller companies underestimated the harmful effects of exposure to intermittent loud noise.

A nationwide questionnaire survey of workers and employers or managers was conducted to understand attitudes towards occupational hearing loss. The most commonly cited noise control measures were administrative (73%) and engineering control (69%). There were significant differences between industries. For example, businesses in construction were less likely than other to isolate loud machines (59% versus 69% in average), to place physical barriers around noise sources (50% versus 62% in average) and to place sound absorbing material on ceilings or walls (33% versus 42% in average) but they were more likely to schedule noisy work when there are fewer workers (60% versus 50% in average). Consistently across industries, a comparison between workers' and managers' responses showed that managers were more likely to say that noise controls were used in the workplace. When asked about recent investments in noise control, transport and storage managers (30%) and small businesses were less likely to have made an intentional investment compared with 53% of large businesses. When asked about the type of investment made, 49% of those who invested in noise control invested in hearing protection devices. This type of investment was more likely to be made by small businesses. Cost of new equipment was the most important cost consideration for managers when making noise control investment (this consideration was very / somewhat important for 72% of managers). It was followed by engineering control and equipment maintenance costs (both were very / somewhat important for 68% of managers). The main motivations for noise control investment were a boost in worker morale (63%), reduction in the number of accidents (60%), increased productivity (54%) and fewer compensation claims (43%). The majority of managers were aware that hearing loss can affect a person's quality of life (95%) and that hearing protection is important even when hearing loss has begun (92%).

Semi-structured interviews showed that exposure to loud noise was found to be of most concern with participants from manufacturing but it was less of a work health and safety issue than slips and falls and operation of power tolls in construction.

Enablers to the implementation of effective noise control measures

The range of qualitative studies undertaken by Work Safe Australia to gain insight into the barriers and enablers of noise control measures from the point of view of

both the management and workers revealed barriers but also suggested possible interventions. Possible interventions are aimed at changing the awareness and behaviour of individuals. Application of behavioural change models to the workplace is thought to be able to increase the likelihood of adopting effective noise control measures. Behaviour change models have been used extensively in public health. To a lesser extent, they have also been used in the workplace to change individual behaviour in regard to personal protective equipment. While not focused on changing decision-makers behaviour, this strategy could be targeted at the person in a business that makes the decision whether or not to adopt a noise control measure and influence employers to make informed noise control investment decisions. Several theoretical models exist (Galloway 2003). They are based on the assumption that an individual's belief about a particular behaviour will determine this individual's attitude and intentions regarding the behaviour. They have in common element of self-efficacy (belief in one's ability to implement the new behaviour), perceived risk and advantages of adopting the desired behaviour and readiness to change behaviour.

However, knowledge and awareness about noise health effects are the most important factors for an intervention to be effective. Lack of knowledge of the effects of noise on hearing has been identified as an important barrier to effective noise control and NIHL prevention. Authors of the report suggested that this could be overcome by providing concise and simple information to managers and workers about the consequences of noise exposure and poor noise control. This information could be conveyed by leaflets or information sessions. Potential effective ways of communication may include small group meetings in the workplace with visits from union representatives or hearing specialists. The message could be reinforced in a systematic fashion through industry-led education campaigns and mass media campaigns.

Research question and objectives

To be effective, a prevention program on NIHL in the workplace needs to address the barriers identified in previous work and to take account of possible enablers.

In light of the results of recent Australian and international studies, a holistic approach could be developed in order to help improve prevention of occupational noise exposure.

The following areas could be addressed:

- Improve knowledge about and recognition of NIHL amongst employers and workers by mean of education and information on health effects of excessive noise exposure:
    - Involve safety representatives, unions and hearing professionals
    - Reinforce the message through industry-led bodies
    - Organise specific mass media campaigns in coordination with public health bodies
- Influence behaviour change in decision- makers in regard to the benefits of adopting effective noise control measures by promoting noise control:
    - Identify opinion leaders with positive influence
    - Use exemplary businesses as a model
- Address concerns of employers about the cost of noise control measures:
    - Highlight the hidden costs associated with noise exposure
    - Facilitate a buy-quiet policy in collaboration with machinery designers and suppliers
    - Create a database of noise control solutions
    - Develop business case studies
- Increase involvement of the regulatory body:
    - Inform employers about their duties
    - Assess compliance to regulations
    - Reward compliance through incentives.

Objective

Using our previous work on NIHL claims data which identified the higher risk groups (i.e. manufacturing and construction industries, small workplaces), an intervention study could target these groups in order to reduce the number and incidence rate of NIHL claims in the future.

Study design

Based on the above possible approach, an intervention study could test the effectiveness of a tailored approach in improving implementation of noise control measures using the higher hierarchy of control level, i.e. engineering measures.

We propose that a randomised control trial be conducted amongst an intervention and a control group of businesses from manufacturing and/or construction of different sizes.

The intervention would consist of tailored education and implementation of behaviour change process amongst employers and comparison with a control group receiving either standard information about noise control measures or another type of intervention. Workplaces would be randomly allocated to either the intervention or the control group.

Outcome measures, such as the percentage of companies that implemented or contemplated to implement engineering noise control measures, will be developed to compare the two groups following the intervention after a 12 month period.

We will determine whether the intervention has significantly increased high level hierarchy noise control measures implementation and the cost of this program.

References

1. Work-related noise induced hearing loss in Australia. Safe Work Australia, April 2006.
2. National Hazard Exposure Worker Surveillance: noise exposure and the provision of noise control measures in Australian workplaces. Safe Work Australia, January 2010.
3. Neitzel R, Daniell W, Sheppard L, Davies H, Seixas N. Comparison of perceived and quantitative measures of occupational noise exposure. Ann Occup Hyg 2009;53:41-54.
4. Verbeek JH, Kateman E, Morata TC, Dreschler W, Sorgdrager B. Interventions to prevent occupational noise induced hearing loss. Cochrane Database of Systematic Reviews 2009, Issue 3. Art. No.: CD006396. DOI:10.1002/14651858. CD006396.pub2.
5. Park MY, Casali JG. A controlled investigation of in-field attenuation performance of selected insert, earmuff, ear canal cap hearing protectors. Hum Factors 1991; 33:693-714.
6. Joy G, Middendorf PJ. Noise exposure and hearing conservation in US coal mines, a surveillance report. J Occup Environ Hyg 2007; 4:26-35.
7. Occupational noise-induced hearing loss in Australia: overcoming barriers to effective noise control and hearing loss prevention. Safe Work Australia, August 2010.
8. Galloway D. Health promotion: causes, beliefs and measurements. Clin Med Res 2003;1:249-58.

2.b. Hearing protection devices use in noisy environments: identification of barriers and enablers to their proper use and implementation of an intervention study to identify the most effective way to promote their proper use

Background

Noise induced hearing loss (NIHL) is a growing problem in Victoria where a sharp rise in the number of claims has been observed in the last five years. Similar trends have been reported in New Zealand (Thorne et al 2008) and elsewhere (Daniell et al 2002).

Occupational Health and Safety regulations exist in Victoria, which require employers to control workplace noise by implementing hierarchical measures. Elimination of noise at its source has been shown to be the most effective (Verbeek et al 2009) but the most difficult measure to implement. If noise elimination is not reasonably practicable, workers noise exposure should be reduced using engineering and/or administrative control measures. However, economic and other limitations can lead companies to rely on the least reliable control measure in the hierarchy of controls, i.e. the use of personal protection equipment.

Workplace size may be an important determinant of the type of control measures provided. The recent Australian NHEWS (National Hazard Exposure Worker Surveillance) survey reported that the likelihood of reporting the use of hearing protection devices (HPD) only as a control measure increased with decreasing workplace size. For example, workers employed by workplaces with less than 20 workers were 2.5 times more likely to report that they were provided with HPDs only compared to those working in workplaces with 200 workers or more (Safe Work Australia 2010).

While HPDs are often relied on, they may not provide efficient protection against noise if they are not correctly fitted and maintained. The risk of hearing loss increases exponentially with the amount of time protections are not worn (Else 1973). It is therefore paramount to identify factors that influence the use of HPD to

identify the most effective interventions for those workers who do not use them at all or who do not wear them or maintain them properly.

Barriers and enablers to the proper use of HPD

Occupational as well as behavioural factors have been reported to influence the use of HPD. They include, among others, perceived risk, comfort of the device, requirement to wear hearing protection, enforcement of this requirement and appropriate education and training.

Occupational factors influencing HPD use

HPD provision as part of a hearing conservation program

Independent of noise levels, a study showed that the use of HPDs was higher in companies where protector use policies were actively promoted or enforced (Daniell et al 2006). In particular, management commitment and compliance of supervisors in wearing HPD has been shown to increase workers' use (Prince et al 2004).

Previous studies have shown that sufficient noise attenuation, measured by real ear attenuation performance can be achieved by small groups training on the proper fitting of earplugs (Toivonen et al 2002, Joseph et al 2007). Education on NIHL and individual training as part of a hearing conservation program can also increase both the usage rate and the proper use of HPD (Tsukada et Sakakibara 2008).

Noise characteristics

The use of HPD has been reported to be related to the level and type of noise. A Danish study reported an increase in the use of HPD with increasing noise exposure, ranging from 63% at levels between 80 and 90 dB(A) to 90% in workers exposed to more than 90 dB(A). Likewise, the duration of use of HPD was higher in this latter group. However, only one-fourth of the highly exposed workers reported wearing HPD for 6 to 8 hours daily (Kock et al 2004). Another study looking at hearing loss prevention programs in industries with higher rates of NIHL claims in Washington

State showed that the frequency of hearing protectors use was higher in companies where noise exposures were higher and more common (Daniell et al 2006).

Type of HPD and work requirements

HPD type should be chosen according to the type of work, job requirement, and noise exposure pattern.

There are two main types of hearing protections; they are ear muffs and ear plugs. The most commonly used ear plugs are expandable foam ear plugs, pre-molded plugs and semi-aural devices. Recent improvement in technology has made custom-molded silicone ear plugs available. The proper HPD can be selected among a variety of devices, taking into account both the worker and the work environment.

The spectrum of attenuation across frequencies can vary between HPD. These must provide appropriate attenuation for noise exposure levels. For example when good verbal communication, detection of machinery or of warning signals is required in the job, HPDs that are not appropriately chosen can prevent the worker from performing their job properly and thus from wearing them.

Other features include comfort and acceptability. Disposable ear plugs may not be the appropriate choice if they have to be inserted during work with dirty hands. On the other hand, when HPDs are to be used for a long period of time during work, ear muffs are generally less often preferred than ear plugs as they are reported to be cumbersome, hot and uncomfortable.

An adequate choice can improve the rate of HPD use (Prince et al 2004). A study on hearing protectors comfort reported a positive correlation between comfort and time of HPD use. As a result, a higher time of use in turn increased effective attenuation (Arezes et Miguel 2002). The worker should therefore be involved in the choice of hearing protectors.

Behavioural factors influencing HPD use

Qualitative studies have examined the reasons why workers do not use hearing protectors. Several behavioural models have been used to explain differences in their use such as the protection-motivation model (Melamed et al 1996) or the health promotion model (Lusk et al 1994). The revised health promotion model has been used more extensively. It looks at modifying factors (interpersonal and situational influences on HPD use) and cognitive-perceptual factors (benefits of, barriers to and self-efficacy of HPD use). In a study of construction workers based on this model, four main barriers to HPD use were identified: self-efficacy (belief in one's ability to use HPD correctly), perceived benefits of using HPD, perceived value in using HPD, and perceived barriers to using HPD (Lusk et al 1997).

Knowledge of the behavioural predictors of hearing protectors use can be used as a basis for development of an education program. Application of the health promotion model to an HPD use training intervention targeted toward construction workers resulted in a significant increase in use of HPDs, demonstrating that training developed to address the needs and beliefs of a particular group of exposed workers can be effective (Lusk et al 1999). Similarly, in factory workers, use of hearing protectors increased in the intervention tailored group versus non-tailored and control groups (Lusk 2004).

Research question and objectives

Qualitative research

The first step of the research would be aimed at identifying the barriers and enablers to the proper use of HPD, using a qualitative research method. In-depth interviews and focus groups including workers and management could give insight into the determinants for acceptance, wearing and effective attenuation of hearing protectors for inclusion in an intervention study.

The areas to be explored would include:

- Awareness about actual noise exposure and hearing prevention in the workplace
- Involvement of the management and workers in hearing protection policy
- Provision of hearing protectors: availability, variety, free of charge, maintenance
- Occupational and behavioural factors affecting the use/non-use of HPD
- Training programs, including their content.

The results of this phase 1 study could assist in developing effective interventions to be tested in higher risk groups such as construction and/or manufacturing industries and small to medium size workplaces.

Intervention study

An intervention study would be designed based on the qualitative research findings to test the effectiveness of different tailored approaches in improving the use of HPDs. This could be implemented in several workplaces, the number of participants to be calculated in accordance with standard sample size calculations, including the minimal effect we wish to detect.

Intervention studies are considered to be more conclusive than observational studies (Kristensen 2005), as randomised controlled trials have a greater likelihood to establish causality between an intervention and its outcome. However, few good quality studies using a randomised control trial design have tried to identify which factors affect the use of HPDs. In a recent systematic review on interventions to

promote the wearing of hearing protectors, only six studies met the minimal requirements to be included in the review (El Dib and Mathew 2009).

We propose that a randomised control trial be conducted amongst an intervention and a control group. The intervention would consist of tailored education and training on hearing loss and hearing protection measures based on information gathered by previous interviews in phase 1. A comparison group either receiving the usual approach to HPD use in their workplace or another intervention would also be used and participating workers randomly allocated to one of the groups. Several measures such as the percentage of workers wearing HPDs, level of comfort and level of understanding of the training materials will be developed to compare the two groups following the intervention over at least a 12 month period.

References

1. Thorne PR, Ameratunga SN, Stewart J, Reid N, Williams W, Purdy SC, Dood G, Wallaart J. Epidemiology of noise-induced hearing loss in New Zealand. NZMJ 2008:121:33-44.
2. Daniell W, Fulton-Kehoe D, Cohen M, Swan S, Franklin G. Increased reporting of occupational hearing loss: workers' compensation in Washington State, 1984-1998. Am J Ind Med 2002;42:502-10.
3. Verbeek JH, Kateman E, Morata TC, Dreschler W, Sorgdrager B. Interventions to prevent occupational noise induced hearingloss. Cochrane Database of Systematic Reviews 2009, Issue 3. Art No.: CD006396.
4. National Hazard Exposure Worker Surveillance: noise exposure and the provision of noise control measures in Australian workplaces. Safe Work Australia, January 2010.
5. Else D. A note on the protection afforded by hearing protectors: implications of the energy principle. Ann Occup Hyg 1973;16:81-3.
6. Daniell W, Swan S, McDaniel M, Camp J, Cohen M, Stebbins J. Noise exposure and hearing loss prevention programmes after 20 years of regulations in the United States. Occup Environ Med 2006;63:343–51.
7. Toivonen M, Paakkonen R, Savolainen S, Lehtomaki K. Noise attenuation and proper insertion of earplugs into ear canals. Ann Occup Hyg 2002;46:527-30.
8. Joseph A, Punch J, Stephenson M, Paneth N, Wolfe E, Murphy W. The effects of training format on earplug performance. Int J Audiol 2007;46:609-18.
9. Tsukada T, Sakakibara H. A trail of individual education for hearing protection with an instrument that measures the noise attenuation effect of wearing earplugs. Ind Health 2008;46:393-6.
10. Kock S, Andersen T, Kolstad HA, Kofoed-Nielsen B, Wiesler F, Bonde JP. Surveillance of noise exposure in the Danish workplace: a baseline survey. Occup Environ Med 2004;61:838–43.
11. Prince MM, Collingan MJ, Stephenson CM, Bischoff BJ. The contribution of focus groups in the evaluation of hearing conservation program (HCP) effectiveness. J Safety Res 2004;35:91-106.

12. Arezes PM, Miguel S. Hearing protectors acceptability in noisy environments. Ann Occup Hyg 2002;46:531-6.
13. Melamed S, Rabinowitz S, Feiner M, Weisber E, Ribak J. Usefulness of the protection motivation theory in explaining hearing protection device use among male industrial workers. Health Psychol 1996;15:209-15.
14. Lusk SL, Ronis DL, Kerr MJ, Atwood JR. Test of the Health Promotion Model as a causal model of workers' use of hearing protection. Nurs Res 1994;43:151-7.
15. Lusk S, Ronis D, Hogan M. Test of the health promotion model as a causal model of construction workers' use of hearing protection. Res Nurs Health 1997;20:183-94.
16. Lusk SL, Ronis DL, Kazanis AS, Eakin BL, Hong O, Raymond DM. Effectiveness of an intervention to increase construction workers' use of hearing protection. Hum Factors 1999;41:487-94.
17. Lusk SL, Eakin BL, Kazanis AS, McCullagh MC. Effects of booster interventions on factory workers' use of hearing protection. Nurs Res 2004;53:53-8.
18. Kristensen TS. Intervention studies in occupational epidemiology. Occup Environ Med 2005;62:205-10.
19. El Dib RP, Mathew JL. Interventions to promote the wearing of hearing protection. Cochrane Database of Systematic Reviews 2009, Issue 4, Art. No.: CD005234.