Noise-induced hearing loss in the wood industry: A cross-sectional prevalence study based in Kaski District, Nepal

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Key words
Noise-induced hearing loss, noise exposure, occupational health, Nepal, woodworkers

Acronyms and abbreviations
BSA British Society of Audiology
CBSN Central Bureau of Statistics, Nepal
CI Confidence interval
DALY Disability-adjusted life year
dBA Decibel (A-weighted)
dBHL Decibels hearing loss
GDP Gross domestic product
HCP Hearing conservation programme
HTL Hearing threshold level
IEC International Electrotechnical Commission
ILO International Labour Organisation
IQR Inter-quartile range
kHz Thousand hertz
L_{Aeq} Equivalent noise level (A-weighted)
NIHL Noise-induced hearing loss
NIOSH National Institute for Occupational Safety and Health
OHS Occupational health and safety
PEL Permissible exposure level
SPSS Statistical Package for Social Sciences
TWA Time-weighted average
VIF Variance inflation factor
WHO World Health Organisation
Abstract

Objective: To describe the prevalence of occupational noise-induced hearing loss (NIHL) among woodworkers in Nepal; to measure noise levels in the wood industry; to inform the generation of legislations relating to permissible exposure level (PEL) and hearing conservation programmes (HCPs) in Nepal.

Design: A cross-sectional prevalence study.

Study Sample: 125 participants (89 carpenters, 36 log cutters) representing 234 ears (170 and 64 respectively), recruited through convenience sampling in Pokhara.

Results: Prevalence of NIHL was 26.5% (95% confidence interval (CI): 20.4–33.6) and 43.8% (95% CI: 32.3–55.9) among carpenters and log cutters respectively. Equivalent noise levels ranged from 71.2–93.3 dBA and 74.9–93.9 dBA for the respective groups. Hearing threshold level (HTL) was significantly greater among log cutters at 3 (p=0.015), 4 (p<0.001), 6 (p<0.001) and 8 (p<0.001) kHz on pure-tone air-conduction audiometry. When data for all participants were combined in binary logistic regression analysis, age and time in occupation were significant predictors for NIHL (p=0.002 and p=0.014 respectively).

Conclusions: Woodworkers in Nepal are at a substantial risk of occupational NIHL. Further research is required to describe this problem in more depth so that measures to protect workers’ hearing can be successfully implemented.
Introduction

Hearing loss is the most common sensory deficit and a significant cause of worldwide morbidity (Mathers et al, 2000). Over 180 million people develop a disabling hearing impairment during adulthood (Mathers et al, 2000), and noise-induced hearing loss (NIHL) is estimated to account for 16% of such cases (Nelson et al, 2005) – second only to presbycusis (age-associated hearing loss). In 2000, 4.1 million disability-adjusted life years (DALYs) were lost to occupational NIHL (Nelson et al, 2005). The majority of these were in developing countries, where the economic and social burdens of a hearing impairment are compounded by lack of access to appropriate healthcare facilities (World Health Organisation (WHO), 2012).

Noise, or unwanted sound, has numerous adverse effects. These include irritability, hypertension and NIHL (Concha-Barrientos et al, 2004) – a sensorineural hearing impairment resulting from damage to the hair cells of the cochlea (Jones, 1996). Occupational noise represents the most common cause (Alberti, 1992), and research in developed countries has shown that workers in the wood industry are among those at risk (Meyer et al, 2002; Koehncke et al, 2003).

Initial exposure to excessive noise causes a transient reduction in hearing acuity (temporary threshold shift) which returns to normal a matter of hours after the noise source is withdrawn (Alberti, 2001). Prolonged exposure, however, causes hair cell death, leading to a permanent threshold shift. Audiometrically this often manifests as a dip, or notch, between 3–6 kHz with subsequent recovery at 8 kHz (Irwin, 1994; Coles et al, 2000; McBride & Williams, 2001). Hearing loss tends to be most rapid at 4 kHz during the first 10–15 years of noise exposure before spreading to surrounding frequencies (Luxon, 1998), including those corresponding to human voices. Individuals with NIHL therefore notice a loss in clarity of perceived speech and an inability to distinguish words (Jones, 1996; Rabinowitz, 2000). The consequences of such a disability are widespread and include impaired communication, social isolation, anxiety and poorer job performance (Hétu et al, 1988; Concha-Barrientos et al, 2004).
In addition to length of time exposed, noise intensity is influential on the progression and severity of NIHL. The equivalent noise level, \( L_{\text{Aeq}} \) (using A-weighted decibels sensitive to human hearing), denotes noise over a particular period of time, taking into account any fluctuations which may occur. This can be used to calculate an individual’s time-weighted average (TWA), which represents noise exposure over an 8 hour working day. It is generally accepted that the risk of developing NIHL with a TWA below 85 dBA is negligible (National Institute for Occupational Safety and Health (NIOSH), 1998; Lutman, 2000). Levels above this, however, are considered hazardous to hearing (NIOSH, 1998). Consequently, many developed countries have legislations which set the workplace noise permissible exposure level (PEL) at 85 dBA. Moreover, hearing conservation programmes (HCPs) are often in operation, and function to protect workers from NIHL through education, provision of hearing protective devices and regular audiometric assessment.

Rapid industrialisation and economic growth in many developing countries, especially those in Asia, have been accompanied by increasing challenges relating to occupational health and safety (OHS) (Fuente & Hickson, 2011). In Nepal – one of the least developed nations in the world (United Nations Development Programme) – the vast majority of the population (96.2%) work informally (International Labour Organisation (ILO), 2010). Occupational health services cover less than 5% of those employed (WHO, 2008), and working conditions are often poor (Joshi & Dahal, 2008). The combination of limited human resources and a poorly-educated workforce make implementing OHS standards particularly difficult (Carter, 2010). With respect to occupational NIHL, criteria for its diagnosis, laws regarding workplace noise PEL and guidelines for HCPs are lacking (Fuente & Hickson, 2011). As a result, a substantial proportion of workers are at risk of developing a lifelong, yet preventable, hearing impairment.

Literature on occupational NIHL in developing countries is scarce; even more so when specific trades are considered. A PubMed search combining “noise-induced hearing loss” with each of the terms “wood”, “saw mill” and “carpenters” revealed only one study on NIHL in the wood industry in Asia. Based in India, it involved 250 saw mill and 170 printing press workers from a total of 20 workplaces (Dhere et al, 2009). The average noise level, measured 6 times at each site, was significantly greater
among saw mill workers than printing press workers (90.2 dBA vs. 79.3 dBA; \( p=0.005 \)) while the prevalence of NIHL, based on audiometric findings, was 28% and 13% respectively.

The results of this study should be treated with caution when being applied to Nepal. The methodology was not described in sufficient detail to be able to make informed judgements on its reliability – for example, no mention was given to the procedure of audiometry or the inclusion and exclusion criteria. In addition, OHS measures are more advanced in India, where compensation is available for those with occupational NIHL and a PEL of 90 dBA enforced (Nandi & Dhatrak, 2008; Fuente & Hickson, 2011). Although it is questionable how universally these measures are carried out, it is still likely that they lessen the damaging effects of noise on workers’ hearing.

Dhere et al (2009) demonstrated that those employed in the wood industry are regularly exposed to hazardous noise levels, presenting a substantial risk to their hearing. Given the current paucity of epidemiological data on occupational NIHL in many Asian nations including Nepal, not to mention the global burden of such an impairment, future research has the potential to make a significant impact on an area of growing public health concern; reducing disability, increasing quality of life and leading to safer working environments for millions worldwide. Thus, the aims of this study were:

- To describe the prevalence of occupational NIHL among woodworkers in Nepal.
- To measure noise levels in the wood industry and compare these to internationally recognised standards.
- To inform the generation of legislations relating to PEL and HCPs in Nepal.

**Methods**

**Setting and Population**

This was a cross-sectional prevalence study based in Pokhara, Kaski District. As the second largest city in Nepal, a wide range of small- and medium-scale businesses operate in the surrounding area including rice mills, saw mills, metal workshops and factories manufacturing concrete, gravel, plastic, food and furniture. For the purposes of this investigation saw mills and furniture factories were identified in advance as places with potentially hazardous noise levels. Permission was gained from
the managers of these establishments for their employees’ participation. Owing to time and resource constraints, workplaces were recruited through convenience sampling. While the limitations of this are later acknowledged, it represented a strategy which would allow more rapid collection of data in the time available. After being provided with information on the nature of the study, employees at the selected workplaces were given the option to take part. Ethical approval for the project was obtained from the Nepal Health Research Council and the Internal Ethics Review Committee at the University of Birmingham, UK. Informed consent was sought from all participants, and referrals to secondary care arranged when necessary.

Other than managers’ acquiescence, no inclusion or exclusion criteria applied to saw mills or furniture factories. Regarding participants, the following criteria applied:

**Inclusion Criteria**

- Noise-exposed woodworkers based in the Kaski District:
  - Aged ≥15 years, in accordance with the Minimum Age Convention, 1973 (ILO, 1973).
  - Working in current occupation for ≥6 months. Hearing impairment progresses with length of time exposed to a hazardous noise, and Alberti (2001) suggests that a permanent hearing loss may be detected as an audiometric notch within 6 months.

**Exclusion Criteria**

- As this study sought to investigate the cause-effect relationship between noise and hearing impairment, those participants with a bilateral hearing impairment unrelated to noise were excluded. Specifically:
  - Hearing loss before age 15 or preceding occupational noise exposure, ascertained on direct questioning.
  - Conductive hearing loss, indicated by an air-bone gap >20 decibels hearing loss (dBHL) at two or more adjacent frequencies on pure-tone audiometry.
- Participants with a unilateral pathology meeting exclusion criteria were only excluded for that ear. The contralateral (healthy) ear was still included in the final analysis.
Workers in both saw mills and furniture factories were predominantly exposed to continuous noise. For the former (henceforth referred to as log cutters) this was principally in the form of band saws, which were used to cut timber. Grinding wheels for sharpening saw blades were another noise source, although they were used less frequently. Noise exposure in the latter group (henceforth referred to as carpenters) was more varied. Typical machines included circular saws, planers, sanders, drills and wood lathes. In addition, these workers were subjected to impact noise, for example when hammering.

The criteria used to define NIHL were a dip on pure-tone air-conduction audiometry between 3–6 kHz and a hearing threshold level (HTL) >25 dBHL at any of the frequencies 3, 4 or 6 kHz. These measures were favoured over the WHO definition of disabling hearing impairment (permanent unaided HTL for the better ear ≥41 dBHL, averaged for the frequencies 0.5, 1, 2, and 4 kHz) (WHO, 1991), as the latter was not thought to fully reflect the high-frequency hearing loss typically seen with long-term noise exposure. It should also be noted that the WHO definition applies to all forms of hearing loss, and is therefore relatively non-specific with respect to NIHL.

Those meeting the study’s criteria for NIHL were further classified according to severity of their hearing impairment. Mild, moderate and severe NIHL were defined as peak HTLs of 26–40, 41–60 and 61–80 dBHL respectively, between 3–6 kHz. Ears were classified individually, meaning someone with bilateral NIHL represented two separate cases. This decision was taken to account for those with unilateral NIHL which, although rare (Alberti, 2001), would artificially elevate the true prevalence of NIHL if analysis were performed per participant rather than per ear. Furthermore, it was anticipated that some woodworkers may be more susceptible to unilateral NIHL than other occupations given their regular use of handheld machines, which could result in one ear being exposed to proportionally more noise, depending on handedness.

**Data Collection**

**Hearing Assessment**

Those participants meeting inclusion criteria completed a verbal questionnaire with the aid of a translator fluent in Nepali and English. Information on demographics, occupational and otological history, average working hours, use of hearing protection and previous exposure to noise were
gathered. Otoscopic examination was performed to identify those with potential pathologies warranting exclusion.

Pure-tone audiometry was performed in two steps, adhering as closely as possible to the most recent British Society of Audiology (BSA) guidelines (BSA, 2011). An Amplivox 260 portable diagnostic audiometer, meeting International Electrotechnical Commission (IEC) 60645-1 standards and fitted with TDH-39 circum-aural headphones, was used. For every participant, air-conduction hearing thresholds were determined in each ear at the frequencies 0.5, 1, 2, 3, 4, 6 and 8 kHz. In addition, bone-conduction thresholds at the frequencies 0.5, 1, 2 and 4 kHz were tested. The purpose of the latter procedure was to identify those with a conductive hearing loss (i.e. not due to noise), who were subsequently excluded as outlined above. All audiometric assessments were conducted in conditions where ambient noise did not exceed 50 dBA.

**Noise Assessment**

Noise levels were measured using a Sinometer SL-812 class II sound level meter conforming to IEC 61672-1 standards. For every workplace, 3 $L_{Aeq}$ readings were taken, each for a period of 1 hour, and from these the mean $L_{Aeq}$ calculated. Readings were recorded on separate days so as to account for random variability in noise. A participant's TWA was calculated as follows:

$$TWA = L_{Aeq} + 10\log_{10}(T/8)$$

$L_{Aeq}$ = equivalent noise level, in dBA. In this case it corresponds to the mean noise level at a particular workplace.

$T$ = typical working time, in hours.

This equation was adapted from the Health and Safety Executive (2005), and recognises the fact that TWA is greater for those working longer than 8 hours per day.

**Statistical Analysis**

Statistical Package for Social Sciences (SPSS) version 19 was used to analyse the data. This was initially done separately for the two populations (carpenters and log cutters) as the nature of their work, and therefore noise exposure, differed. Distributions for all continuous variables were non-normal, so
medians and inter-quartile ranges (IQR) were used to describe central tendencies. All audiometric data were positively skewed, so ln-transformations were applied in an attempt to normalise the distributions.

The prevalence of mild, moderate and severe NIHL, with 95% confidence intervals (CI), was calculated for each group; Chi-squared testing compared the overall prevalence of NIHL between the two groups. Mann-Whitney U tests were employed at each audiometric frequency to look for differences in HTL among carpenters and log cutters. All participants were then combined, and, after excluding for potentially confounding sources of noise exposure, multiple linear and binary logistic regression analyses carried out to determine the predictors for HTL at each frequency, and presence of NIHL, respectively.

Results

Population Demographics

161 woodworkers from 15 workplaces were recruited, of whom 132 met inclusion criteria. Data were collected from 125 participants; 89 worked as carpenters and 36 as log cutters. 16 participants had a unilateral pathology meeting exclusion criteria, so a total of 234 ears (170 for carpenters, 64 for log cutters) were included in the final analysis. All participants were male, reflecting the low number of women employed in the wood industry in Nepal rather than any active exclusions.

Differences in demographic characteristics were apparent between the two groups (Table 1). Age ($p=0.001$) and time in occupation ($p=0.034$) were significantly greater among log cutters (Mann-Whitney U test). Meanwhile, among carpenters in particular, age and time in occupation were positively skewed: 52.8% were aged 15–24, with the same percentage working 5 years or less. For log cutters, these proportions were 27.8% and 30.6% respectively. 27.0% of carpenters were current smokers compared to 44.4% of log cutters, although median pack-year history was 0 in both groups.

No log cutters, and only 1 carpenter, reported wearing hearing protection when working.

NIHL prevalence
The overall prevalence of NIHL was 26.5% (95% CI: 20.4–33.6) in carpenters and 43.8% (95% CI: 32.3–55.9) in log cutters (Figure 1). The difference in prevalence between the groups was statistically significant on Chi-squared testing ($p=0.011$), with an unadjusted odds ratio (OR) of 2.2 (95% CI: 1.2–3.9). However, the fact that 95% CIs for overall prevalence overlapped, reduces the degree to which these differences hold true in the wider population of woodworkers. NIHL prevalence by levels of severity for carpenters were as follows: mild, 14.1% (95% CI: 9.7–20.2); moderate, 10.0% (95% CI: 6.3–15.4); severe, 2.4% (95% CI: 0.9–5.9). In comparison, NIHL prevalence for log cutters were as follows: mild, 17.2% (95% CI: 9.9–28.2); moderate, 21.9% (95% CI: 13.5–33.4); severe, 4.7% (95% CI: 1.6–12.9). Thus, at all levels of severity, prevalence of NIHL appeared to be higher in log cutters (Figure 1).

**Noise levels**

Due to time restrictions, noise levels were only measured at 10 workplaces – 5 furniture factories (employing carpenters), and 5 saw mills (employing log cutters). Workplace $L_{Aeq}$ values over 1 hour ranged from 71.2–93.3 dBA at the former, and 74.9–93.9 dBA at the latter (Tables 2(a) and 2(b)).

TWAs were calculated for 70 participants (50 carpenters, 20 log cutters). Median (IQR) TWA was 83.1 dBA (82.1–85.4) in the former and 87.1 dBA (86.9–87.5) in the latter, with Mann-Whitney $U$ testing showing a significant difference in TWA distribution among the populations ($p<0.001$). 37 participants (52.9%) had a TWA $\geq85$ dBA. Median working times were 9 h 30/day, 6.0 days/week in carpenters and 9 h 00/day, 6.5 days/week in log cutters.

**Audiometry**

There were no significant differences between right and left ears at any of the frequencies tested (Wilcoxon signed-rank test, $p>0.05$), so audiometric data were combined. Comparisons between pure-tone HTL at each frequency were made using the Mann-Whitney $U$ test. There were significant differences in HTL distribution among carpenters and log cutters at 3 ($p=0.015$), 4 ($p<0.001$), 6 ($p<0.001$) and 8 kHz ($p<0.001$), as shown in Figure 2, which plots the median HTL of the respective populations at the seven frequencies tested. This also demonstrates the high-frequency notch
configuration, typical with NIHL, observed among the study subjects; being particularly pronounced for log cutters.

Regression Analysis

Before proceeding, a number of adjustments were made to the handling of data so as to get a more accurate representation of the factors influencing hearing. Firstly, the analysis was combined for the study populations. In order to ensure any differences between these remained accounted for, occupation (carpenter/log cutter) was inputted into the analysis as an independent binary variable. Secondly, missing data for TWA were replaced by the population median. Thirdly, due to the extremely low pack-year history reported by participants, smoking status was entered into analyses as a binary variable (ex- and current-smokers/non-smokers). Lastly, those participants reporting past exposure to loud noise including bomb blasts, explosions, hobbies and previous occupations were excluded from the analysis. This attempted to account for causes of NIHL other than working in the wood industry, and thus strengthen any association found by the regression models. After excluding such cases, data were available for 191 ears.

Multiple linear regression

Forwards multiple linear regression analyses were performed on ln-transformed audiometric data to determine the predictors for HTL at each frequency. The independent variables entered were: age, time in occupation, TWA, smoking status and current occupation. Tolerance and variance inflation factor (VIF) showed no evidence of multicollinearity in any of the models, and Cook’s distance did not suggest any influential cases.

Time in occupation was a significant predictor for HTL at all frequencies except 6 and 8 kHz (Table 3). Age was a significant predictor at 4, 6 and 8 kHz, which is not unexpected given the natural history of presbycusis. The only other significant predictor was TWA, although this was at 1 kHz rather than the higher frequencies one would expect, and, counter-intuitively, was inversely associated with HTL. All models were fairly weak in their abilities to predict HTL – adjusted $R^2$ did not exceed 0.3 at any
frequency. However, $R^2$ was greater at the higher frequencies (3–8 kHz), suggesting that time in occupation and age explained a greater degree of the respective models’ variability. This would be consistent with the high-frequency hearing impairment seen in both NIHL and presbycusis.

**Binary logistic regression**

Forwards likelihood ratio logistic regression was undertaken, with NIHL as the dependent variable and the same independent variables as those used in multiple regression analyses. Age and time in occupation were both significant predictors of NIHL status, with $p$-values of 0.002 and 0.014 respectively. These accounted for almost 30% of the model’s variability in predicting NIHL (Nagelkerke $R^2 = 0.296$). ORs were 1.067 (95% CI: 1.024–1.112) and 1.080 (95% CI: 1.016–1.148) for age and time in occupation respectively.

**Discussion**

**Study findings**

The results of this study showed a high prevalence of occupational NIHL in the wood industry in Nepal. This appeared to be greater in log cutters than carpenters (43.8% vs. 26.5%), although drawing definitive conclusions is difficult due to the small sample size of the former. Noise levels among both populations were notably high – mean $L_{Aeq}$ exceeded 85 dBA in 5 of the 10 workplaces tested – and over half of all woodworkers were exposed to hazardous levels of noise during a typical 8 hour working day. It is well-established that noise intensity and duration of exposure contribute towards a person’s risk of developing NIHL (Luxon, 1998). Both were significantly greater among log cutters, and represent the most likely explanation for their higher prevalence of NIHL. However, there are other factors which should also be taken into account.

Presbycusis refers to the sensorineural hearing loss occurring with age. Whereas NIHL tends to cause a notch configuration on audiogram between 3–6 kHz, presbycusis is characterised by a downward-sloping pattern at high frequencies, with HTL normally maximal at 8 kHz (Gates & Mills, 2005). For the combined population of woodworkers, the effect of age on hearing was highlighted by
its significance as a predictor for HTL at 4, 6 and 8 kHz, and NIHL status, on multiple and binary logistic regression analyses respectively. Regarding HTLs within the two groups, these were significantly greater for log cutters at 3, 4, 6 and 8 kHz. While increased noise exposure may explain this to some degree, age is also a likely contributor and must be borne in mind. The same applies when interpreting the higher prevalence of NIHL in log cutters, although attempts to account for this were made by defining NIHL on the basis of a notch configuration. This meant those with a progressive high-frequency hearing loss, such as occurs in presbyacousis, did not meet criteria for NIHL.

Cigarette smoking is another factor which may affect hearing. A study in a metal processing factory in Brazil (Ferrite & Santana, 2005) showed that, in noise exposed workers, the effects of smoking and age on hearing loss are synergistic; while Mizoue et al (2003) found a dose-response relationship between smoking and high-frequency hearing loss in Japanese steel workers. In this particular study, a higher proportion of log cutters were current smokers, although Chi-squared testing showed this difference to be non-significant (p=0.058). The extremely low pack-year history among both carpenters and log cutters is likely a reflection of social norms, and the effects of smoking on hearing are most probably negligible. Supporting this was the fact that smoking status was not a significant predictor of HTL or NIHL on either multiple or logistic regression analyses.

It is worth noting that susceptibility to NIHL can vary widely between individuals (Alberti, 2001). The higher prevalence among log cutters in this study could be due, in part, to the chance inclusion of more people naturally predisposed to NIHL.

To summarise, greater noise exposure and time in occupation represent the most probable reasons for the higher prevalence of NIHL among log cutters. However, other explanations to consider include their increased age, potential differences in susceptibility to noise, and, although unlikely, a greater proportion of smokers.

Limitations
The author believes that this study is the first to describe workplace noise exposure and occupational NIHL prevalence in Nepal. However, a number of methodological weaknesses should be taken into consideration before making informed judgements on the findings.

The main limitation of this study was the use of convenience (i.e. non-random) sampling. As stated earlier, this was done for practical reasons and to allow more data to be collected in the short time available. However, with this came a compromise in the reliability of data and the degree to which it represents woodworkers throughout Nepal. Although variability was observed between the workplaces (in terms of number of employees, machines used and working conditions) and employees (in terms of age, ethnicity and education level), the non-random sampling method reduces the external validity of the data. Responder bias, for example, could have influenced the willingness of managers or employees to take part. The former, if aware that noise in their establishment was particularly high, could have declined for fear of personal repercussions, while the latter may have been more inclined to participate if they had a history of hearing loss resulting from long-term noise exposure. Although there is no guarantee that random sampling would reduce this bias, it would at least give a wider pool of potential participants, selected in an impartial manner.

The lack of control group also represents a methodological shortcoming. While this study describes the prevalence of occupational NIHL, there is no reference group of subjects not exposed to noise with which to compare the findings. Therefore, it is unclear if this study represents a real reflection of noise damage to hearing, or whether it is due to other underlying factors inherent in the population. A control group, ideally similar for all factors other than noise exposure, would give more power to the supposition that hearing loss is indeed noise-induced.

It was disappointing that due to time constraints, noise levels were not measured at all participating workplaces and, as a result, data on TWA not available for every participant. In a sense, the rigorous method of measuring noise hindered the complete collection of these data. Taking 3 separate hour-long noise readings at each site was time-consuming, but allowed accurate estimation of participants’ noise exposures. This was reflected by the narrow IQR in TWA for both carpenters and log cutters. A similar study on saw mill workers in Ghana (Boateng & Amedofu, 2004) took 5 noise measurements
for a period of 20–30 seconds at each selected machine. Adopting this method for the present study would have enabled noise readings for every workplace to have been taken, although due to their shorter duration they may have been less representative of workers’ true noise exposures.

The heterogeneous nature of the populations can be thought of as both a strength and weakness. It enables a broader description of NIHL prevalence and noise exposure in the wood industry. However, due to the resulting smaller sample sizes, especially amongst log cutters, it reduces the degree to which findings can be applied to the wider population of woodworkers. This is of particular importance given the study’s non-random sampling strategy, which already lessens its generalisability.

**Comparison with other research**

Several studies support this one’s findings that those in the wood industry in a developing country are at risk of NIHL. Both Dhere et al (2009) and Boateng & Amedofu (2004) found NIHL prevalence among saw mill workers of 20% or above. Noise levels at workplaces were often in excess of 85 dBA; a finding corroborated by Minja et al (2003) for carpenters.

It is encouraging that this study is not alone in reporting such findings, although the extent to which studies in Africa (Minja et al, 2003; Boateng & Amedofu, 2004) can be applied to Nepal is questionable. There remains a lack of good quality epidemiological research on occupational NIHL, with different definitions frequently used and varying methods employed. Moreover, given the contrasting political, social and economic conditions in many developing counties, care should be taken when making comparisons.

**Implications and further research**

Future industrial growth and development in Nepal presents many favourable opportunities, but with these come challenges relating to workers’ health. Although agriculture remains the dominant sector in Nepal, representing 73.9% of all employed persons (Central Bureau of Statistics, Nepal (CBSN), 2009), its share in gross domestic product (GDP) has declined from approximately 70% in the 1970s to 33% in 2009 (ILO, 2010). Meanwhile, sectors such as manufacturing and construction are gaining in prominence, and in 2008 represented 14.0% and 4.9% respectively of all those working in urban...
Noise-induced hearing loss in Nepal (CBSN, 2009). An increasing number of people are migrating from rural to urban areas in search of work (ILO, 2010) – a trend that looks set to continue in the future. Linked to this is a growing population, particularly the economically active population (aged 15–59 years), which is expected to represent over 60% of the total population in 2021 (ILO, 2010).

Recent studies suggest OHS in Nepal is ill-equipped to meet such an increasing need (Joshi & Dahal, 2008; Carter, 2010; Joshi et al., 2011). Steps need to be taken imminently to recognise this situation and implement a strategy to address the health and safety demands of the workforce. With particular respect to occupational NIHL, this study represents one of these early steps. It is hoped that providing evidence of the current state of NIHL in the wood industry can go some way towards informing guidelines to better protect the hearing of Nepali workers. However, further research to support these findings is prerequisite for this to be a realistic outcome.

Initial research on occupational NIHL should focus on other at-risk industries in Nepal, such as construction and transport, so as to represent a wider scope of workers and their health requirements. This study has shown that it is feasible to conduct research in these settings, and provides a foundation from which larger-scale studies may follow. These can employ more systematic methodologies such as cluster sampling of workplaces, and add weight to the argument for the generation of workplace noise PEL guidelines and the need to implement HCPs in workplaces.

Also necessary is research into the knowledge, attitudes and practices of both employees and managers on occupational NIHL. In order for HCPs to be successful, it is useful to ascertain how receptive those concerned would be. Pilot studies on, for example, provision of hearing protective devices, could be carried out to assess the possibility of, and potential barriers to implementing larger-scale interventions.

**Conclusion**

Occupational NIHL is an increasing problem in developing countries, where noise levels are often uncontrolled and OHS measures lacking. This study, the first of its kind, found a substantial proportion of woodworkers in Nepal to be at risk of NIHL. Further research is required to support this study’s
findings and guide the development of measures to protect the needs of a growing workforce. This in turn can alleviate the debilitating effects of a widespread, yet preventable, hearing loss.

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Declaration of interest

This study was funded by the University of Birmingham. The author reports no declarations of interest.
Figure 1: Prevalence of noise-induced hearing loss (percentage with 95% confidence intervals) by levels of severity among carpenters and log cutters.
Figure 2: Median hearing threshold level among carpenters and log cutters.
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<td>2–12</td>
<td>4–16</td>
<td></td>
</tr>
<tr>
<td><strong>Smoking status [n (%)]</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>89</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Current-smoker</td>
<td>24 (27.0)</td>
<td>16 (44.4)</td>
<td></td>
</tr>
<tr>
<td>Non-smoker</td>
<td>57 (64.0)</td>
<td>19 (52.8)</td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>8 (9.0)</td>
<td>1 (2.8)</td>
<td></td>
</tr>
<tr>
<td><strong>TWA (dBA)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>50</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>83.1</td>
<td>87.1</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>IQR</td>
<td>82.1–85.4</td>
<td>86.9–87.5</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Mann Whitney U test  
<sup>b</sup> Inter-quartile range  
<sup>*</sup> Indicates statistical significance

*Table 1: Comparison of demographic and occupational variables among carpenters and log cutters.*
### Table 2(a): Noise levels at furniture factories (employing carpenters).

<table>
<thead>
<tr>
<th>Workplace ID</th>
<th>$L_{Aeq}$ 1 (dBA)</th>
<th>$L_{Aeq}$ 2 (dBA)</th>
<th>$L_{Aeq}$ 3 (dBA)</th>
<th>Mean $L_{Aeq}$ (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82.8</td>
<td>85.6</td>
<td>86.0</td>
<td>84.8</td>
</tr>
<tr>
<td>2</td>
<td>85.0</td>
<td>73.2</td>
<td>83.9</td>
<td>80.7</td>
</tr>
<tr>
<td>3</td>
<td>71.2</td>
<td>76.9</td>
<td>85.5</td>
<td>77.9</td>
</tr>
<tr>
<td>4</td>
<td>75.1</td>
<td>84.2</td>
<td>84.0</td>
<td>81.1</td>
</tr>
<tr>
<td>5</td>
<td>83.1</td>
<td>93.3</td>
<td>81.2</td>
<td>85.9</td>
</tr>
</tbody>
</table>

### Table 2(b): Noise levels at saw mills (employing log cutters).

<table>
<thead>
<tr>
<th>Workplace ID</th>
<th>$L_{Aeq}$ 1 (dBA)</th>
<th>$L_{Aeq}$ 2 (dBA)</th>
<th>$L_{Aeq}$ 3 (dBA)</th>
<th>Mean $L_{Aeq}$ (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>74.9</td>
<td>87.6</td>
<td>84.1</td>
<td>82.2</td>
</tr>
<tr>
<td>7</td>
<td>86.8</td>
<td>86.3</td>
<td>86.2</td>
<td>86.4</td>
</tr>
<tr>
<td>8</td>
<td>81.7</td>
<td>84.2</td>
<td>93.9</td>
<td>86.6</td>
</tr>
<tr>
<td>9</td>
<td>85.7</td>
<td>86.9</td>
<td>86.7</td>
<td>86.4</td>
</tr>
<tr>
<td>10</td>
<td>81.8</td>
<td>90.3</td>
<td>87.5</td>
<td>86.5</td>
</tr>
</tbody>
</table>