Prevalence of noise-induced hearing loss among woodworkers in Nepal: a pilot study

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Background: The woodworking industry represents an important cause of occupational noise-induced hearing loss (NIHL), a significant yet underappreciated problem in many developing countries.

Objectives: To describe the prevalence of occupational NIHL among woodworkers in Nepal and measure noise levels at workplaces.

Methods: We conducted a cross-sectional study with 124 woodworkers (88 carpenters, 36 sawyers), recruited through convenience sampling from 26 workplaces. Pure-tone audiometry between the frequencies 0.5 and 8 kHz ascertained participants' hearing status, and noise readings were taken at selected workplaces.

Results: In all, 31% of carpenters and 44% of sawyers met criteria for NIHL, with 7 and 17% meeting World Health Organization (WHO) criteria for hearing impairment (HI), respectively. Noise levels at various workplaces ranged from 71.2 to 93.9 dBA.

Conclusions: Woodworkers in Nepal are at risk of occupational NIHL. As the industry develops, this problem will likely become more extensive, highlighting the need for workplace interventions and additional research.

Keywords: Nepal, Noise-induced hearing loss, Occupational health and safety, Prevalence, Wood industry

Introduction

Hearing loss is the most common sensory deficit and a significant cause of worldwide morbidity.¹ Over 180 million people develop a disabling hearing impairment (HI) during adulthood,¹ with occupational noise-induced hearing loss (NIHL) estimated to account for 16% of these cases.² In 2000, 4.1 million disability-adjusted life years were lost to occupational NIHL.² The majority of these were in developing countries, where the economic and social burdens of HI, including reduced earnings, limitations in career choice, stigmatization, abuse, and depression, are compounded by lack of access to appropriate healthcare facilities.^{3–5}

Noise has numerous adverse health effects including irritability, hypertension, and NIHL – a sensorineural HI resulting from irreversible damage to the hair cells of the cochlea.^{6–8} Initial exposure to excessive noise causes a transient reduction in hearing acuity, or temporary threshold shift, which returns to normal hours after the noise ceases. Prolonged exposure can eventually result in a permanent

threshold shift i.e. NIHL.⁹ On an audiogram, this typically manifests as a dip or notch between 3 and 6 kHz with subsequent recovery at 8 kHz.^{10–12} Hearing loss tends to be most rapid at 4 kHz during the first 10–15 years of noise exposure before spreading to surrounding frequencies.¹³ In normal adults, human speech is heard between 0.25 and 6 kHz, with lower frequencies corresponding to vowels and higher frequencies representing consonants. Individuals with NIHL therefore notice a loss in clarity of perceived speech and an inability to distinguish particular words.^{8,14} The consequences of such a disability are widespread and include impaired communication, social isolation, anxiety, and poorer job performance.^{7,15}

Noise intensity, in addition to duration of exposure, can influence the progression and severity of NIHL. The equivalent noise level, L_{Aeq} , denotes the average noise over a particular period of time, taking into account any fluctuations. It is generally accepted that the risk of developing NIHL is negligible when the L_{Aeq} during a typical shift is <85 dBA,^{16,17} while levels above this are considered hazardous to hearing.¹⁶ Consequently, many developed countries

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have legislation setting the workplace noise permissible exposure level at 85 dBA. Moreover, such countries also have hearing conservation programs to protect workers from occupational NIHL through education, provision of hearing protective devices, and regular audiometric assessment.

Nepal is one of the least developed nations in the world,¹⁸ and here occupational health and safety (OHS) coverage is inadequate for the working population.^{19–21} Of particular concern is the overwhelming proportion (96%) of the workforce engaged in the informal sector.²² Such employment lacks social security and OHS legislation, and is characterized by unsatisfactory working conditions, unpredictable job opportunities, and long working hours.²³ The Labor Act of 1992 stipulates basic requirements relating to working conditions, remuneration, and welfare of workers;²⁴ however, implementation of these standards is made especially difficult by limited human resources and poor education of the workforce.²⁵ In addition, laws regarding permissible noise exposure levels in the workplace, guidelines for hearing conservation programs, and criteria for the diagnosis of occupational NIHL are nonexistent. As a result, a substantial proportion of workers are at risk of lifelong, yet preventable HI.

Occupational NIHL has been reasonably well described in high- and middle-income Asian countries.²⁶ Literature from low-income countries such as Nepal is scarce; even more so when specific trades are considered. We identified only three studies pertaining to NIHL in the wood industry in Asia, none of which were conducted in low-income countries. The first, based in India, found NIHL prevalence among 250 saw mill workers to be 28% and average noise exposure 90.2 dBA.²⁷ In an investigation of health outcomes among workers in 120 wooden furniture factories in south-east Asia, Ratnasingam *et al.* describe a noise-induced permanent threshold shift in 34.7% of participants and noise levels up to 130 dBA.²⁸ Wittayapun and Tanasirirug report a NIHL prevalence of 52.1% among 303 wood factory workers in Thailand, with an average sound pressure level of 91.9 dBA.²⁹

Applying these results to Nepal should be undertaken with caution for a number of reasons. Various definitions for NIHL exist in the literature, and methods to determine an individual's hearing status or noise exposure frequently differ. Added to this are economic, social, and political factors, which are markedly contrasting. These studies nonetheless demonstrate that those employed in the wood industry are regularly exposed to hazardous noise levels, presenting a significant risk to their hearing. Given the current paucity of epidemiological data on occupational NIHL in many developing Asian countries, not to mention the far-reaching burden

Figure 1 A band saw being used to cut timber.

of this 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.

The primary aim of this study is to describe the prevalence of occupational NIHL and HI among woodworkers in Nepal. The secondary aim is to measure noise levels in the wood industry and compare these to internationally recognized standards.

Methods

Setting and population

This is a cross-sectional prevalence study based in Pokhara, Kaski District, Nepal. A range of small-scale businesses operate in Pokhara and the surrounding area, with saw mills and furniture factories being among the most common. For the purposes of this investigation, these enterprises were identified in advance as having potentially hazardous noise levels on the basis of previous research in other countries and anecdotal reports from Pokhara. Twenty-six workplaces were recruited through convenience sampling. All were small-scale enterprises employing between 2 and 20 persons. From these workplaces, 161 people consented to take part in the study.

Working activities reflected the availability of electricity (scheduled power cuts, usually lasting between 4 and 6 hours, are commonplace throughout Nepal). Saw mill workers (hereafter referred to as sawyers) were almost exclusively dependent on power for productivity, using band saws and circular saws to cut timber (Fig. 1). Furniture factory workers (hereafter referred to as carpenters) were able to perform a variety of jobs with or without power. Typical machines used during periods with electricity included circular saws, planers, drills, and wood lathes (Fig. 2). During power cuts, workers usually performed manual tasks such as sanding or hammering wood.

Figure 2 A wood lathe being used in the production of furniture.

Working environments were generally cramped and dusty, often with employees in close proximity to hazardous machines. Other than masks, which were occasionally worn, personal protective equipment such as gloves, hard hats, and earmuffs were rarely utilized. Shifts lasted approximately 10 hours including a 30-minute lunch break, 6 days per week. Employment was casual, relying on verbal contracts forged through family and personal associations rather than formal, written agreements. Wages were low, and workers were usually paid by piece rate. Little, if any, social protection was provided by employers.

Other than managers' acquiescence, there were no workplace inclusion or exclusion criteria. The inclusion and exclusion criteria for participants were as follows.

Inclusion criteria

- Woodworkers based in Kaski District aged ≥ 15 years employed in their current occupation for ≥ 6 months.

Exclusion criteria

- Current bilateral outer or middle ear pathology, including otitis externa, impacted cerumen, perforated tympanic membrane, acute otitis media, otitis media with effusion, chronic suppurative otitis media, and cholesteatoma.
- Bilateral hearing loss unrelated to noise, specifically:
 - hearing loss before age 15 or preceding occupational noise exposure and/or
 - conductive hearing loss, indicated by an air-bone gap >20 dBHL at two or more adjacent frequencies on pure-tone audiometry.
- Asymmetry, indicated by an average hearing threshold level (HTL) over the frequencies 0.5–4 kHz on pure-tone air-conduction audiometry (see below) differing by >20 dB hearing loss (dBHL) between left and right ears.

Note that participants with a unilateral pathology meeting these criteria were only excluded for that ear. The contralateral (healthy) ear was included in the final analysis.

Data collection

Hearing assessment

Participants completed an oral questionnaire (Appendix 1) with the aid of a translator fluent in both Nepali and English. Information on demographics, occupational and otological history, average working hours, use of hearing protection, and past exposure to occupational and/or recreational noise were gathered. Otoscopic examination was performed, and any participants in whom current bilateral outer or middle ear pathology was noted (see above) were referred to an ENT specialist (author: DS) for diagnostic confirmation and subsequent treatment if necessary. Pure-tone audiometry was performed in two steps, adhering to British Society of Audiology guidelines.³⁰ An Amplivox 260 portable diagnostic audiometer (manufactured in UK), meeting International Electrotechnical Commission (IEC) 60645-1 standards and fitted with TDH-39 circumaural headphones, was used. Air-conduction hearing thresholds were determined in each ear at the frequencies 0.5, 1, 2, 3, 4, 6, and 8 kHz, followed by bone-conduction thresholds at 0.5, 1, 2, and 4 kHz. The purpose of the latter procedure was to identify those with a conductive hearing loss (i.e. not caused by noise), who were subsequently excluded as outlined above. All audiometric assessments took place in a quiet room at or adjacent to an individual's workplace. Background noise was continually monitored using a CEM DT-8852 sound level meter (manufactured in China) conforming to IEC 61672-1 standards, and testing was temporarily halted if noise exceeded 50 dBA.

An individual was classified as having NIHL if, in either ear, the following findings on pure-tone air-conduction audiometry applied:

- hearing threshold level between 3 and 6 kHz greater than predicted for age, as set out in the guidelines by Coles *et al.*¹¹ (modified from ISO 7029) and
- a notch configuration between 3 and 6 kHz, with a peak HTL >25 dBHL within these frequencies.

Those meeting these conditions were further categorized according to the severity of NIHL. Mild, moderate, and severe NIHL were thus defined as a peak HTL between 3 and 6 kHz, in either one or both ears, of 26–40, 41–60, and 61–80 dBHL, respectively. In addition, participants' hearing was classified according to the World Health Organization (WHO) definition of HI.³¹ HTL for the better ear was averaged over the frequencies 0.5, 1, 2, and 4 kHz, with 26–40 dBHL representing mild impairment and 41–60 dBHL moderate impairment. This provided an objective and widely recognized method by which to quantify hearing loss.

Noise assessment

To establish the average noise level throughout the study area, noise readings were taken from a

Figure 3 Participant recruitment procedure.

subsample of 10 workplaces using a Sinometer SL-812 class II sound level meter (manufactured in China) conforming to IEC 61672-1 standards. Three L_{Aeq} readings of 1 hour each were obtained from the selected workplaces; from these, the mean L_{Aeq} for a particular workplace was calculated. Measurements were taken at a fixed point 1 m away from a given noise source and were recorded on three non-consecutive days to account for random variability in noise. Owing to practical constraints, workplaces were not selected randomly. For reasons discussed above, noise readings at saw mills were taken only during periods of electricity; at furniture factories, at least one reading was taken during a scheduled power cut.

Statistical analysis

SPSS version 19 was used to analyze data. This was initially performed separately for the two populations (carpenters and sawyers) as the nature of their work, and therefore noise exposure differed. Distributions of continuous variables were initially analyzed for normality using Shapiro–Wilk tests. Medians and interquartile ranges (IQRs) described central tendencies of nonparametric data, while means and standard deviations (SDs) described data following a

normal distribution. The prevalence of both NIHL and HI were calculated for each group and compared for any significant differences using Chi-squared tests. Mann-Whitney U tests were used to compare nonparametric, continuous data between the two populations of woodworkers. In all instances, a P value < 0.050 indicated statistical significance. Multiple linear and binary logistic regression analyses were carried out on the combined population of woodworkers to determine factors influencing HTL at each frequency, and the presence of NIHL and HI, respectively.

Ethical approval

Ethical approval was obtained from the Nepal Health Research Council and the Internal Ethics Review Committee at the University of Birmingham, UK. All participants provided informed consent.

Results

Population demographics

One hundred and twenty-nine participants were eligible for inclusion in the study. Data were collected from 124 participants; 88 worked as carpenters and 36 as sawyers (Fig. 3). All participants were male, reflecting the low number of females employed in the wood industry in Nepal. Age ($P=0.001$) and time in occupation ($P=0.036$) were significantly greater among sawyers (Table 1). These variables were positively skewed among all participants, particularly carpenters, of whom 52% (46/88) were aged 15–24 with the same percentage working for 5 years or less. These proportions were 28% (10/36) and 31% (11/36), respectively, among sawyers. Self-reported past exposure to noise was significantly higher among sawyers (31%) than carpenters (14%) ($P=0.041$).

Prevalence of NIHL and HI

In all, 31% (27/88) of carpenters and 44% (16/36) of sawyers met the criteria for NIHL (Table 2). There was no significant difference between these groups in terms of NIHL prevalence ($P=0.152$). Median age among all participants with NIHL was 35 years, compared to 23 years among those not classified with NIHL ($P<0.001$); while the former had worked for a median of 14 years compared to 3.5 years among the latter ($P<0.001$).

Among both populations, the proportion of participants meeting the WHO criteria for HI was considerably lower than that of NIHL, being 7% (6/88) in carpenters and 17% (6/36) in sawyers (Table 2). There was no significant difference in prevalence of HI between the respective populations ($P=0.105$). Median age among all participants with HI was 39.5 years, compared to 25 years among those not classified with HI ($P=0.002$); while the former had worked for a median of 17 years compared to 6 years among the latter ($P=0.007$).

Figure 4 Comparison of median HTL between carpenters and sawyers.

Audiometry

Eight carpenters and eight sawyers had a unilateral pathology meeting exclusion criteria; hence, a total of 232 ears (168 for carpenters, 64 for sawyers) were eligible for inclusion in the study. There were no significant differences between right and left ears at any frequency (Wilcoxon signed-rank test, $P > 0.050$). Audiometric data were therefore combined to give the mean HTL across both ears for each participant. There were significant differences in median HTL among carpenters and sawyers at 4 ($P = 0.005$), 6 ($P = 0.002$), and 8 kHz ($P = 0.010$) (Fig. 4). The characteristic notch pattern typically seen on the audiogram of an individual with NIHL is illustrated in Fig. 4, and is particularly pronounced for sawyers.

To further demonstrate the progression of hearing loss over time, participants were categorized according

to years of employment in the wood industry: 0.5–5 years (46 carpenters, 11 sawyers), 6–10 years (16 carpenters, 7 sawyers), 11–15 years (12 carpenters, 6 sawyers), 16–20 years (7 carpenters, 8 sawyers), and >20 years (7 carpenters, 4 sawyers). Figure 5(a) and (b) plots median HTL for these respective categories in each occupational group, and demonstrates the reduction in hearing acuity with increased time in the wood trade. Hearing loss appears mild among both populations in the early stages of employment, although inconsistent signs of a notch are found at 4 and 6 kHz. Beyond 15 years of work, this notch becomes more conspicuous and begins to affect hearing at the surrounding frequencies.

Noise levels

Noise readings were taken from five furniture factories and five saw mills. Hour-long L_{Aeq} values ranged from 71.2 to 93.3 dBA at the former and 74.9 to 93.9 dBA at the latter. Mean L_{Aeq} exceeded 85 dBA at five workplaces (four saw mills and one furniture factory) (Table 3).

Regression analyses

Multiple linear regression

As all audiometric data were positively skewed, In-transformations were applied to normalize the distributions. Forward multiple linear regression analyses were performed on this In-transformed data to determine the factors influencing HTL at each frequency. Seven models were constructed (one for each frequency tested), with HTL at a given frequency acting as the dependent variable in each respective model. The independent variables entered were age, time in occupation, smoking status (non-smokers/ex-smokers and current smokers), occupation (carpenter/sawyer), and past exposure to loud noise (yes/no). Time in occupation was significantly

Table 1 Demographics and working patterns by occupation

		Carpenters, n=88 (%)	Sawyers, n=36 (%)	P value*
Age (years)	Median	23	30	0.001 [†]
	IQR [‡]	20–31	24–44.5	
Time in occupation (years)	Median	5	10	0.036 [†]
	IQR	2–12	4–16	
Hours/day	Median	9:30	9:00	0.220 [†]
	IQR	8:00–11:00	8:30–10:00	
Days/week	Median	6	6.5	0.979 [†]
	IQR	6–7	6–6.5	
Past exposure to loud noise	Yes	12 (14)	11 (31)	0.041 [§]
	No	76 (86)	25 (69)	
Use of ear protection	Yes	1 (1)	0 (0)	1.000 [§]
	No	87 (99)	36 (100)	
Smoking status	Current smoker	24 (27)	16 (44)	0.120 [§]
	Non-smoker	56 (64)	19 (53)	
	Ex-smoker	8 (9)	1 (3)	

* $P < 0.050$ indicates statistical significance.

[†]Mann-Whitney U test.

[‡]Interquartile range.

[§]Chi-squared test.

Figure 5 Progression of median HTL with years in occupation: (a) carpenters and (b) sawyers.

associated with HTL at 1, 2, 3, and 4 kHz (Table 4), while age was significantly associated with HTL at 4, 6, and 8 kHz. The models were strongest in their association with HTL at higher frequencies, particularly at 4 kHz, where time in occupation and age explained approximately 37% of variability.

Table 2 Comparison of NIHL and HI prevalence, by levels of severity, between carpenters and sawyers

	Carpenters, <i>n</i> =88	Sawyers, <i>n</i> =36
NIHL*	<i>n</i> (%)	<i>n</i> (%)
Mild	12 (14)	4 (11)
Moderate	12 (14)	10 (28)
Severe	3 (3)	2 (5)
Overall	27 (31)	16 (44)
HI†	<i>n</i> (%)	<i>n</i> (%)
Mild	4 (5)	5 (14)
Moderate	2 (2)	1 (3)
Overall	6 (7)	6 (17)

*Noise-induced hearing loss.

†Hearing impairment.

Binary logistic regression

Forwards likelihood ratio logistic regression was undertaken, first with NIHL and then HI, as the dependent variables, with the same independent variables as entered above. Time in occupation was significantly associated with both NIHL (odds ratio (OR): 1.184, 95% CI: 1.110–1.264; $P<0.001$) and HI (OR: 1.134, 95% CI: 1.046–1.229; $P=0.002$).

Discussion

Study findings

The results of this study showed a high prevalence of NIHL in the wood industry in Pokhara, Nepal. This appeared to be greater in sawyers than carpenters, although drawing definitive conclusions is difficult due to the small sample size of the former. Hearing impairment was similarly more prevalent among sawyers, although rates were notably lower than those corresponding to NIHL among both populations.

There are a number of possible explanations for these disparities. The WHO definition for HI accounts for hearing in the better ear, and may therefore underestimate the impact – although uncommon – of unilateral NIHL. Furthermore, it applies to all causes of hearing loss, and is based on the average HTL at low and middle frequencies (0.5–4 kHz) rather than the higher frequency hearing loss, which affects those with NIHL.

It should also be noted that NIHL is an insidious condition with a long latency period, and only if noise exposure is prolonged (e.g. >10 years) will hearing loss progress to frequencies where it is more disabling to the individual. In this study, 70% of carpenters (62/88) and 50% of sawyers (18/36) had worked in the wood industry for 10 years or less, while nearly half of all participants (56/124) were aged <25 years. This could be the result of several factors: the current population demographic in Nepal, whereby those aged 15–19 years represent the largest cohort; migration trends, specifically internal urban migration and international migration to India and the Middle East among younger generations; and the precarious and transient nature of informal employment. Thus, despite being regularly exposed to hazardous noise, participants in this study had not been working in such an environment for a sufficient period of time for the effects to manifest as a global loss of hearing. Consequently, a large proportion of study participants who met the criteria for NIHL do not meet those for HI. We think the former classification most accurately reflects the real status of NIHL in the study population, although the associated disability was most likely minimal due to the short length of time most participants had been exposed to occupational noise.

The primary findings of this study are consistent with previous research on the wood industry in Asia, which describe NIHL in a considerable proportion of workers.^{24–26} Noise levels in the present study were lower than those reported both in Asia and comparable low-income countries in Africa. Mbuligwe describes a mean equivalent noise level of 102.6 dBA at five wood processing small-scale industries in Tanzania, with a mean peak noise level of 124.4 dBA;³² while noise emissions from a number of machines at saw mills in Ghana have been reported to exceed 90 dBA.³³ Possible reasons why noise readings in the present study differ to those referenced above include the method of measuring noise levels (over 1 hour as opposed to a whole shift); the mobile nature of woodwork, which may not be accounted for by a fixed sound level meter; and the unpredictable power supply in Nepal which, for carpenters in particular, somewhat reduced their use of electricity-dependent tools, and therefore noise exposure. This study nevertheless provides evidence that wood factories in Nepal operate at or above the internationally recognized L_{Aeq} limit of 85 dBA, thus posing a substantial risk to workers' hearing.

Limitations

This study provides valuable data on an occupational hazard prevalent in many developing countries. However, the methodological shortcomings should be taken into consideration before making further judgments on the findings.

Though we describe the prevalence of occupational NIHL in woodworkers, there is no control group of subjects not exposed to workplace noise with which to compare findings. Therefore, it is unclear if these results represent a real reflection of hearing damage due to noise or whether there are other causative factors inherent in the Nepalese population affecting participants' hearing. Schmitz *et al.* investigated the prevalence of HI (of any cause) among 3635 persons aged 15–23 years in rural southern Nepal. It was found that 1.5% of participants met criteria for middle-frequency HI, defined as a pure-tone air-conduction average at 0.5, 1, 2, and 4 kHz in the better ear ≥ 30 dBHL (this closely corresponds to the WHO definition of HI used in the present study).³⁴ Acknowledging differences in participant demographics and the methods used, this relatively low proportion in comparison to 7% of carpenters

Table 3 Noise levels at selected workplaces

Workplace ID	Workplace type	Noise level (dBA)			Mean L_{Aeq} (SD)
		L_{Aeq} 1	L_{Aeq} 2	L_{Aeq} 3	
1	Furniture factory	82.8	85.6*	86.0	84.8 (1.7)
2	Furniture factory	85.0	73.2*	83.9	80.7 (6.5)
4	Furniture factory	71.2*	76.9	85.5	77.9 (7.2)
6	Saw mill	74.9	87.6	84.1	82.2 (6.6)
8	Saw mill	86.8	86.3	86.2	86.4 (0.3)
9	Furniture factory	75.1*	84.2	84.0	81.1 (5.2)
11	Saw mill	81.7	84.2	93.9	86.6 (6.4)
13	Saw mill	85.7	86.9	86.7	86.4 (0.6)
14	Furniture factory	83.1	93.3	81.2*	85.9 (6.5)
15	Saw mill	81.8	90.3	87.5	86.5 (4.3)

SD: standard deviation.

*Noise reading taken during scheduled power cut.

Table 4 Significant variables for hearing threshold level (HTL) at each frequency, following multiple linear regression analyses of ln-transformed data

Frequency (kHz)	Significant variables	Regression coefficient (B) (dBHL)	95% CI	Standard error	P value*	R ²
0.5	–	–	–	–	–	–
1	Constant	3.367	3.305–3.429	0.031	<0.001	0.067
	Time in occupation	0.008	0.003–0.014	0.003	0.004	
2	Constant	3.289	3.219–3.358	0.035	<0.001	0.075
	Time in occupation	0.010	0.004–0.016	0.003	0.002	
3	Constant	3.295	3.217–3.373	0.039	<0.001	0.216
	Time in occupation	0.020	0.013–0.027	0.003	<0.001	
4	Constant	3.089	2.913–3.264	0.089	<0.001	0.367
	Time in occupation	0.021	0.011–0.032	0.005	<0.001	
	Age	0.010	0.002–0.017	0.004	0.012	
6	Constant	3.030	2.866–3.194	0.083	<0.001	0.299
	Age	0.020	0.014–0.025	0.003	<0.001	
8	Constant	3.108	2.935–3.281	0.087	<0.001	0.180
	Age	0.015	0.009–0.020	0.003	<0.001	

dBHL: dB hearing loss.

* $P < 0.050$ indicates statistical significance

and 17% of sawyers in the present study meeting WHO criteria for HI suggests that we are correct in asserting that the hearing loss observed among woodworkers is most likely attributable to noise.

In meeting this study's secondary aim, the mean noise levels at 10 workplaces are reported. Data collected were guided by resource availability and practical limitations, as alluded to above, and should therefore be interpreted with these in mind. We hypothesize that the results obtained in the present study underestimate the true noise levels to which Nepalese woodworkers are subjected. It should be emphasized that these noise measurements serve to complement the study's principal findings, while providing a general impression of noise levels in the wood industry in Nepal; more detailed conclusions regarding the association between magnitude of noise exposure and severity of NIHL cannot be drawn.

Lastly, the use of convenience (i.e. non-random) sampling reduces the degree to which this study's results represent woodworkers throughout Nepal. This sampling method was undertaken for logistical reasons, and although variations were observed between workplaces (in terms of number of employees, machines used, and working conditions) and employees (in terms of age, ethnicity, and education level), it is accepted to be open to potential biases.

Implications and recommendations

Predicted industrial growth presents favorable opportunities to workers in Nepal, but with these come challenges relating to occupational health. Agriculture remains the country's dominant sector, representing 74% of all employed persons,³⁵ although its share in gross domestic product has declined from approximately 70% in the 1970s to 33% in 2009.²² Meanwhile, sectors such as manufacturing and construction are gaining prominence, and in 2008 represented 14% and 5%, respectively, of those working in urban areas.³⁵ An increasing number of people are migrating from rural to urban areas in search of work²² – a trend that looks set to continue. The population is also on the rise, particularly economically active people (aged 15–59 years), who are expected to represent over 60% of the Nepalese population in 2021.²² The results of this study suggest that the disability associated with NIHL is currently minimal; however, as the number of working people increases and becomes older, it is likely that the long-term effects of noise on hearing will become more evident.

Recent studies suggest services in Nepal are ill-equipped to meet this growing need.^{19–21,25} Common to many developing countries, the itinerant nature of the workforce, lack of job security, high proportion of informal employment, and preponderance of small-scale industries all contribute to this

problem.^{36–38} Steps need to be taken imminently to recognize this situation and implement a strategy to address the health and safety demands of the population. With particular respect to occupational NIHL, this study represents one of these early steps. It is hoped that providing evidence for the current state of NIHL in the wood industry can go some way toward informing guidelines to better protect the hearing of woodworkers not only in Nepal but also in other low-income countries of Asia. However, further research to support these findings is prerequisite for this to be a realistic outcome.

First, more robust and thorough measurements of noise exposure among woodworkers are necessary. Personal noise dosimetry, which has been shown to be more accurate than sound level meters at estimating individual noise exposure,³⁹ is the ideal method and could be applied to a randomly selected sample of workers before being extrapolated to the wider population. Research in other at-risk industries in Nepal, such as construction and transport, should also be a priority and would allow a broader scope of workers and their health requirements to be represented. 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 studies can employ more systematic methodologies such as random sampling of participants or workplaces, and will add weight to the argument for permissible exposure level guidelines and hearing conservation programs to be implemented more universally. Also necessary is research into the knowledge, attitudes, and practices of both managers and employees regarding occupational NIHL. In order for hearing conservation programs to be successful, it is important to ascertain how those at whom they are aimed would receive them. Pilot studies on small-scale interventions, such as the provision of hearing protective devices to staff, should be carried out to assess the possibility of and potential barriers to implementing more substantial measures.

Conclusion

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

Disclosure

We declare no conflicts of interest.

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