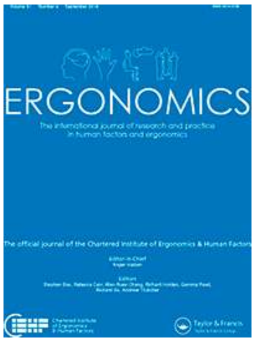



Ergonomics

ISSN: 0014-0139 (Print) 1366-5847 (Online) Journal homepage: http://www.tandfonline.com/loi/terg20

# Comparative assessment of shift in hearing threshold among handicraft operatives in India

Ashish Kumar Singh

ERGONOMICS
https://doi.org/10.1080/00140139.2018.1519121

Taylor & Francis
Taylor & Francis Group



# Comparative assessment of shift in hearing threshold among handicraft operatives in India

Ashish Kumar Singh

Department of Mechanical Engineering, Malaviya National Institute of Technology, Jaipur, India

**ABSTRACT**

This case-control exploratory study is first of its kind to assess the noise exposure and loss in hearing threshold (HT) due to the occupational use of hand tools used for handicraft work. Sixty male participants involved in different crafts trade and a reference group of 50 office workers were selected. The sound pressure levels under actual work conditions were measured as per the method outlined in IS 7194:1994. The mean equivalent sound pressure level was quite high (96.37 dB(A)), exceeding the exposure limit of 90 dB(A). Audiometric tests were conducted to compare the HT between both the groups. In agreement with dose consumed, the exposed workers exhibit moderate hearing impairment in the frequency range of 1500–6000 Hz. The association of HT at different frequencies among occupation were detected using *post-hoc* multiple comparisons. 95% of the workers showed hearing handicap at some level and noise-induced hearing loss increases with higher age and experience. Interventions in the hand tools, implementation of hearing conservation programmes and practice of personal protective equipments have been suggested.

**Practitioner Summary:** As the primary outcomes, comparative assessment of the shift in hearing threshold was analyzed in anticipation to develop a better work system. Results from the study report that the sound pressure level was fairly high and 95% of the handicraft operatives showed hearing handicap at some level.

**Abbreviations:** ANOVA: Analysis of variance; ANSI: American National Standards Institute; CPCB: Central Pollution Control Board; dB(A): Decibel A-weighting; dBHL: Decibel hearing level; HT: Hearing Threshold; IEC: International Electrotechnical Commission; IS: Indian Standard; Lex, 8 h: Equivalent sound pressure level; Lpeak: Peak sound pressure level; NIHL: Noise-induced hearing loss; NIOSH: National Institute of Occupational Safety and Health; OSHA: Occupational Safety and Health Administration; PTS: Permanent hearing threshold shift; SHT: Shift in hearing threshold

**ARTICLE HISTORY**
Received 31 January 2018
Revised 4 June 2018
Accepted 27 August 2018

**KEYWORDS**
Handicrafts; noise exposure; ergonomics; shift in hearing threshold; noise-induced hearing loss (NIHL)

## Introduction

Occupational noise is a significant problem as well as a hazardous industrial pollutant that may cause severe hearing loss among workers of every country in the world (Fernández et al. 2009; Nandi and Dhatrak, 2008). It has a considerable impact on individuals working in all types of industries. Studies carried out by the National Institute of Occupational Health, India, revealed that the sound pressure levels were extremely high in textile industries (ranging from 102 to 114 dB(A)) in India. Although it may be a problem in textile industries, it is also as much of a problem in other industrial sectors including informal sectors.

As per the current regulation in the Indian Standards about the hearing conservation of workers, the occupational permissible exposure limit is permitted to 90 dB(A) for 8 h per day and the workers shall not be exposed to noise level exceeding 115 dB(A) at any time (OSHA 3074:2002; CPCB 1948). If the noise exposure is chronic and exceeds these permissible levels, then both auditory and non-auditory adverse health outcomes can be seen (Basner et al. 2014). The National Institute of Occupational Safety and Health (NIOSH, 1996) recommends that the maximum sound pressure level should be 85 dB(A) for 8 h per day and the workers shall not be exposed to continuous, varying, intermittent, or impulsive noise exceeding 140 dB(A) at any time. As per Occupational Safety and Health Administration (OSHA) directives (OSHA 3074:2002), it is the action limit for which the

CONTACT Ashish Kumar Singh singh.mechanical@yahoo.com Department of Mechanical Engineering, Malaviya National Institute of Technology, J.L.N Marg, Malaviya Nagar, Jaipur, 302017, India

employer is required to enroll the employees in hearing conservation program.

Informal sector constitutes a significant part of the country's economy in the developing countries (Dianat and Salimi 2014). In the low-middle income country like India, handicraft industry is the major part of the informal sector where a large number of workers are employed (Mukhopadhyay and Srivastava 2010a). It generates employment for the largest constituency of local unorganized labor. Of the 46 crore workers, 14 crores are women (Thakur 2016). With the increasing global commercialization of craft products, the export of Indian handicrafts have shown exponential growth over the years (IBEF 2016; NSC 2012) and reached the point of US$335 billion in the year 2015–2016 (EPCH 2015a). Handicrafts account for 50% of the national product by informal sector and shown an increase of US$231.17 million with a growth rate of 13.5% from the preceding year (EPCH 2015b; NSC 2012).

Unfortunately, the handicraft industry is a high-risk occupation that may often lead to occupational injuries, respiratory disorders, eyesight problems, noise and vibration exposure, and skin problems (Mrunalini and Logeswari 2016; Singh et al. (in press (a)); Wang et al. 2011)). Despite the wide range of occupations involved in the handicraft sector, long static sitting, awkward posture, repetitive, sustained, or forceful movement of limbs, and dexterity are the characteristics that share a common ground. Consequently, make it extremely labor intensive when compared to other jobs.

For the past few years, it was found that the reports were mainly focused on the occupational health problems among handcrafting workers (Durlov et al. 2014; Habibi et al. 2013; Mukhopadhyay and Srivastava 2010b; Reddy 2014; Sahu et al. 2013). In a study, Dianat and Salimi (2014) concluded that the traditional methods of performing the handicrafts work require further developments to improve the working conditions of the craftsmen. Several studies reported on muscular and neurological examinations, palpation, range of motion, muscle strength tests and visual demand assessments in the imitation jewelry occupation (De et al. 2012; Salve 2015a, 2015b; Untimanon et al. 2006). Susanha and Sujitra (2007) opined that wood carving workers are highly prone to backache, asthma, gastric ulcer, eyesight problems and skin problems. Tangkittipaporn and Tangkittipaporn (2006) surveyed 979 handicraft home workers from 281 small-scale workshops in northern Thailand and argued that low competency mainly induce the occupational risks in health and safety management, which may risk workers' physical health. Another study on Thai handicraft workers in a laboratory setting was based on investigating the trunk discomfort due to the type of sitting posture (Areeudomwong et al. 2012).

A systematic review by Lie et al. (2016) presents the estimated risk of occupational noise exposure in different industrial trades (construction, automotive, aviation, metalworking, railway, shipyard, offshore and firefighting). Apart from these industries, commendable efforts were put forth by the investigators to comprehensively reviewing the risk of noise exposure among workers in informal sectors that include farmers, cotton workers, professional drivers, musicians, mining workers and other professions. It is necessary to study the audiometric effects on the hearing threshold in order to plan hearing conservation strategy for noise-exposed workers (Noweir and Zytoon 2013).

Several investigators (Hong et al. 2013; Sataloff and Sataloff 2006) opined that most of the audiometric patterns in noise-induced hearing loss (NIHL) are usually bilateral and symmetrical. Contrary to that, a recent review (Le et al. 2017) provided insights into the pathophysiology, clinical findings, social and economic impacts of asymmetric NIHL in noise-exposed individuals. Pieces of evidence from that review concluded that the incidence of hearing loss shows a trend towards increasing asymmetry among higher frequencies or with rising levels of hearing loss. Therefore, a reliable and comprehensive study of audiometry is essential to estimate the risk of NIHL associated with noise exposure to an action level of 85 dB or above (OSHA 3074:2002).

Clearly, it could be said that the major risk factor for occupational hearing loss depends on the excessive noise on the job. People with hearing impairments have an increased risk of industrial accidents (Robinson and Casali 1995) and find it harder to maintain interpersonal communication (Schifferstein and Desmet 2007). A few studies related to woodwork (Noweir, Bafail, and Jomoah 2014), hawkers (Chakraborty et al. 2005), jute weaving (Taylor et al. 1965), cotton work (Moselhi, El-Sadik, and El-Dakhakhny 1979) and paper pulp production (Bergström and Nyström 1986) have investigated long-term exposure to occupational noise. It has been pointed out by Fuente and Hickson (2011) that there is the limited contribution (<3%) of Indian authors on NIHL research from Asian countries. Countries like Japan, Israel, Taiwan, China and South Korea tops the list with the highest number of publications on NIHL. Furthermore, to the authors' knowledge and literature review, limited research has been carried out in the area of handicrafts in India, especially in noise perspective.

Estimates of the noise exposure from different types of equipment are documented in several studies (McBride 2004; Owoyemi, Falemara, and Owoyemi 2016; Skinner 2005). However, the noise is generated by the operational diversity in the process, and it could rise due to the non-compliance with basic safety practices. A little is known about the occurrence of noise exposure and the associated risk factors such as a shift in hearing threshold (SHT) among the handicraft workers. Therefore, it was sought to address this issue by assessing the occupational noise exposure and evaluating the SHT among several handicraft activities. This work examines and compares the SHT for nine frequencies between 250 and 8000 Hz in both ears between the exposed and control group of workers.

## Methods

### *Tasks involved in handicraft activities*

During this study, we have investigated the noise exposure and SHT among workers involved in six different crafts trades, viz. carpet alignment, carpet trimming, woodcarving, woodturning, pearl hole drilling/setting, and stone carving. The details of tasks involved in these occupations have been discussed later in the text.

In the carpet alignment, there is no preferential flow, which has to be followed for aligning the different parts of a carpet. It is done on what comes while inspecting. During alignment, hammering is done at the sides of the chisel. An inch tape is used to measure how much adjustment is needed. If something needs to be put straight, then a thread is tied for the direction and different chisels are used for setting the positions of figures and flowers. Hammering the rod against the chisel leads exposure to the high sound pressure levels (Singh et al. in press (a)).

Carpet trimming is the process of removing unwanted threads (silk and wool) while maintaining the uniformity in thickness of the carpet. Before trimming, the design of the carpet is indistinguishable, since its surface is covered with long, directionless piles. It levels the carpet to appropriate relative thickness. Trimming uses a shearing machine and the cutting is performed at the front of a carpet. This device has a cutter blade and a roller. It cuts up to a particular length, which could be set beforehand by setting the cutter and the roller of the device. During trimming, the workers sitting in a split squatting posture holds the machine in their dominant hand. They guide the device against the carpet to trim the threads into the carpet. Continuous and prolonged use of this machine tool also leads exposure to the hand-transmitted vibration and high sound pressure levels.

During woodcarving, the outlines of the final figure were first sketched on the wooden block. The woodcarver sits in a squat posture holding the wood block and carving it using different types of cutters. Highly precise works are done using these tools. They produce quick work by the ease in tracing the patterns and smooth transition in round edges. As the cutter head touches the wooden block, it carves with the vibration and noise against the wood. The final polishing was done by forcing the half round and square files against the semi-finished sculpture. The woodcarvers are exposed to hand vibration and noise during both the processes.

Woodturning involves wooden lathe machine to turn wooden blocks into different profiles or cylindrical shapes. It uses several hand-held tools to cut patterns symmetrical around the axis of the rotation of the block. The worker is exposed to high chattering noise and vibration due to the interaction of the moving block and tool edge during the operation (Toth 2017).

Pearl hole drilling/setting is a part of making imitation jewelry. The worker holds the pearl to be drilled and place it on the powered drill to make a hole. The drill bit of size larger than the size of the necklace thread is forced against the pearl creating hand vibration and noise exposure.

Stone carving is the process in which natural stones are shaped into sculptures by the controlled removal of stone. It involves marking, cutting, finishing and polishing activities. This study was focused on the finishing stage. The principal tools needed by the carver during finishing are pencil, markers, hammer (varying size), chisels (point and tooth), files, saw, and sandpaper (Baral, Crasto, and Kumar, 2017). Marble and limestone have been the most preferred stones for carving.

### *Selection of participants and study design*

The present case-control study was carried out from July 2017 to October 2017 in 9 workshops at different locations in Sadwa, Ramgarh, Sitapura and Sanganer regions within Jaipur district. The experimental group of 60 workers, aged between 21 and 46 (mean 31.68; SD 7.31) was divided into six equal groups as per their occupation, viz., carpet alignment, carpet trimming, wood carving, wood turning, imitation jewelry and stone carving workers. Every workshop had 5–10 workers and willingness of management to participate in the study were more of a concern. No participants were paid for their participation. This could be the only weaker dimension in approaching a large sample population for statistical data analysis.

The average work experience of the participants in the present occupation was 10.75 ± 6.53 years. Minimum three year of work experience in the same job was the inclusion criteria for this study. All the participants were having no history of upper extremity disorders and permanent hearing impairment. No participants underwent audiometry screening during the past and reported no documented sensorineural hearing loss. The description of subject selection with inclusion and exclusion criteria is provided in Figure 1. The University Institutional Review Board approved all experimental procedures and all male workers were provided written informed consent before the participation. The flowchart in Figure 2 allows depicting a little additional elaboration strategy of the experimental design of this study. The participants were divided into three groups according to the categories of age (≤25 years, 26–34 and ≥35 years) and experience (<5 years, 5–10 years and >10 years) from the questionnaire. The treatments/grouping categories were the age and experience while the participants with the hearing handicap (>5%) were considered under these treatments.

A control group of 50 asymptomatic male office workers, aged between 21 and 45 (mean 29.92; SD 6.04) was also selected within the institute and nearby offices. Their usual routine involves administrative work, daily computer work, mainly data entry and text editing. The demographic description for the exposed and control groups depicted in tabulated form in Table 1. Demographic characteristics (like mean age, BMI, BSA, experience) of the exposed group was statistically matched (at a *p*-value of less than .05) with the control group. Inclusion criteria for the control group included a hearing acuity threshold of at least 30 dB hearing level (dBHL) for 9 frequencies between 250 and 8000 kHz in both ears. Pomp et al. (2010) based on their case-control study reported that the differences in BMI arise from different lifestyles. Also, both exposed and control cohort adopt working in a single shift and most of the workers were working 48 hours per week (8 hours per day, 6 days a week). Sometimes, they work extra hours as overtime for earning additional income. Therefore, apart from the differences in their vocation, it can be said that the exposed and control groups were having more or less the same lifestyle.

## Noise exposure measurement

The outlines stipulated in IS 7194:1994 norms for the measurement of sound pressure levels were incorporated and followed with caution during the course of the study. The noise dosimeter (Make: NoisePro DLX□1; ANSI S1.25□1991), which monitors noise levels

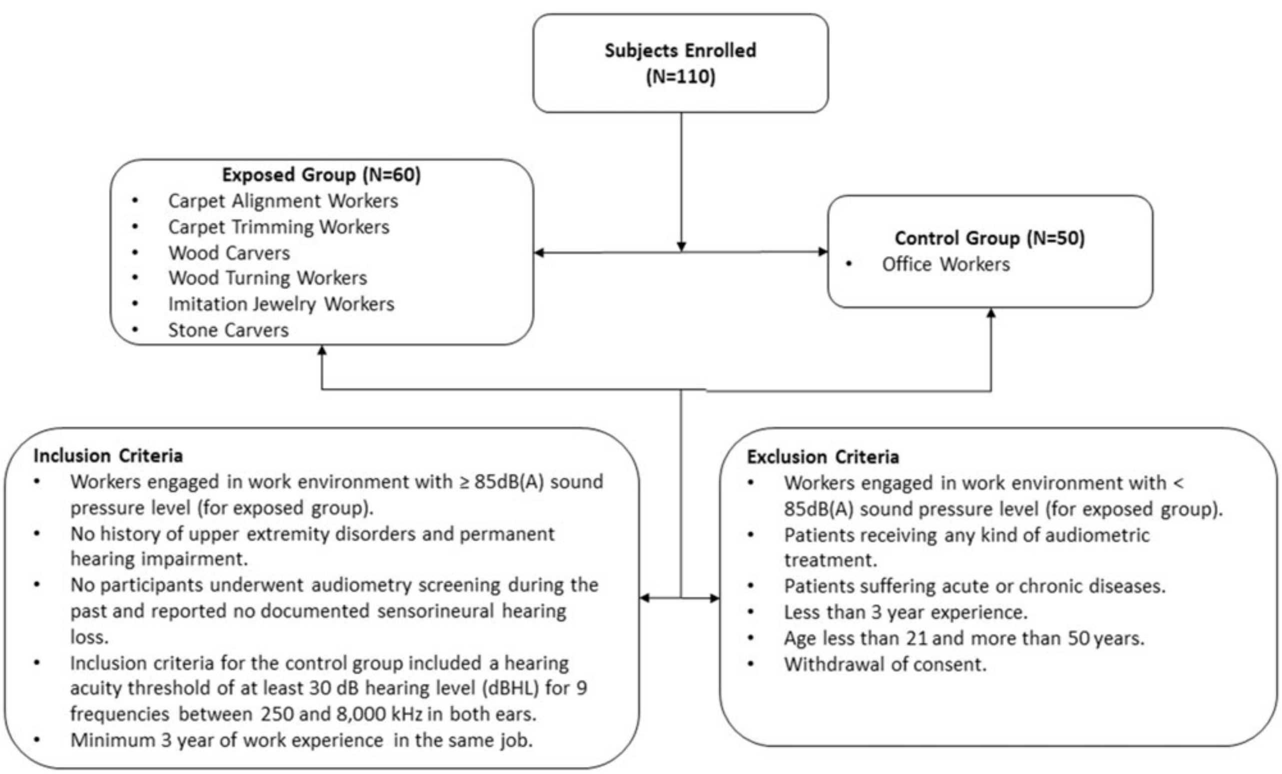



Figure 1. Subject selection with inclusion and exclusion criteria.

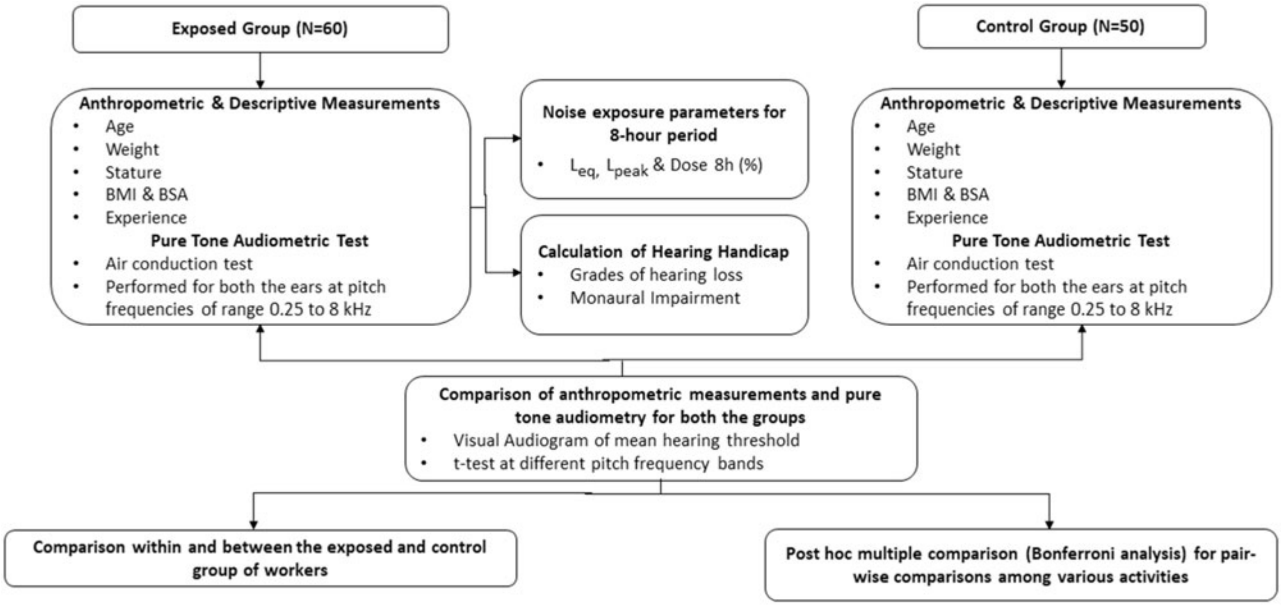



**Figure 2.** Elaborative flowchart of the experimental design.

**Table 1.** Demographic characteristics of exposed and control group of workers.

| | Mean ± SD | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Overall ($n = 110$) | Alignment workers ($n = 10$) | Trimming workers ($n = 10$) | Wood carvers ($n = 10$) | Wood turners ($n = 10$) | Jewelry workers ($n = 10$) | Stone carvers ($n = 10$) | Exposed group ($n = 60$) | Control group ($n = 50$) | $p$ Value |
| Age of subject (years) | 30.88 ± 6.79 | 32.2 ± 9.53 | 32.10 ± 5.82 | 33.10 ± 7.09 | 31.80 ± 5.27 | 30.60 ± 8.19 | 30.30 ± 8.62 | 31.68 ± 7.31 | 29.92 ± 6.04 | .176 |
| Weight of subject (Kg) | 59.99 ± 6.21 | 57.65 ± 5.95 | 58.98 ± 4.33 | 59.14 ± 6.88 | 61.87 ± 6.71 | 58.96 ± 3.82 | 58.75 ± 3.37 | 59.23 ± 5.29 | 60.90 ± 7.11 | .159 |
| Stature of subject (m) | 1.64 ± 0.05 | 1.62 ± 0.05 | 1.64 ± 0.04 | 1.63 ± 0.05 | 1.65 ± 0.04 | 1.64 ± 0.04 | 1.61 ± 0.06 | 1.63 ± 0.05 | 1.64 ± 0.05 | .396 |
| BMI (Kg/$m^2$) | 22.42 ± 1.95 | 21.85 ± 2.14 | 21.98 ± 1.47 | 22.18 ± 1.84 | 22.65 ± 1.91 | 22.10 ± 1.92 | 22.69 ± 1.12 | 22.24 ± 1.72 | 22.66 ± 2.22 | .29 |
| BSA ($m^2$) | 1.65 ± 0.10 | 1.61 ± 0.10 | 1.64 ± 0.07 | 1.64 ± 0.12 | 1.68 ± 0.11 | 1.65 ± 0.05 | 1.64 ± 0.06 | 1.64 ± 0.09 | 1.66 ± 0.11 | .278 |
| Experience (years) | 9.77 ± 6.03 | 11.80 ± 8.94 | 10.80 ± 5.45 | 11.40 ± 7.15 | 11.10 ± 4.07 | 10.00 ± 7.44 | 9.40 ± 6.54 | 10.75 ± 6.53 | 8.60 ± 5.19 | .062 |

as dB(A) was used for the measurement of equivalent ($L_{ex}$, 8 h) and peak ($L_{peak}$) noise exposure. The root mean square measurement range was set to from 70 to 140 dB (A) with a resolution of 0.1 dB increments for F/S response rate. Auto-scaling mode (4 digits) was selected for dose measurement and an exchange rate of 3 dB (A), criterion level at 90 dB (A), criterion time of 8 h, threshold level at 80 dB (A) were set in. Calibration was performed prior to and following each field study using Quest calibrator (3 M Quest QC-10) complying with ANSI S1.40-1984 and IEC 942:1988 Class 1 standards. The 3 M Quest field calibrator device was also recalibrated annually by the manufacturer's service engineer.

The 0.52-inch Electret Condenser Microphone (BK4936 Class/Type 1) was clipped to the dominant hand collar of the participant at a distance of 10 and 15 cm from the ear. Indexes such as the equivalent sound pressure level ($L_{ex}$, 8 h) and peak sound pressure level ($L_{peak}$) were measured and further downloaded into the spreadsheets for further analysis. Some of the handicraft workers were having working hours longer than 8 h. However, in most of the cases, their typical workday begins at 9:00 am and lasted until 5:00 pm. Therefore, the recording was done for 8 h starting from 9:00 am to 5:00 pm and the percentage of the time-weighted dose was calculated.

### Pure tone audiometric test

All the participants from the exposed and control groups were invited to perform the pure tone audiometric test using ARPHI PROTON DX5 portable pure tone audiometer. The air conduction measurement range was 0.25 kHz–8 kHz with −10 dBHL–120 dBHL steps. The continuous tone duration was controlled manually and DR 59 headset was used as hearing accessory for patient response. The calibration standards and procedures strictly followed as per the manufacturer's guidelines complying with IEC 60318-1:2009 and ANSI S3.6:2004. Routine calibration of the audiometer, its associated instrumentation are done on an annual basis and calibration certificates were properly documented.

The hearing threshold test was performed in an acoustically treated chamber at the institute laboratory. This was done to ensure better control over certain variables under study. Audiometry (ANSI, 2004; ASHA, 2005) was conducted before shift work (after 12–14 h without exposure to noise) to avoid transient hearing loss. The test was performed for both the ears at low pitch frequencies of range 0.25–1 kHz, moderate pitch frequencies of range 1–4 kHz and higher pitch frequencies of range 4–8 kHz. Their hearing thresholds determined the degree of hearing loss. The method followed reducing the level of tone by 10 dB step until no response obtained. Thereafter, increasing the step by 5 dB until they respond and so-on for other frequency ranges. The participant's response to test frequency and tone were documented on the audiological evaluation sheet shown in Figure A1 (online Appendix) and later on replicated into the spreadsheets for further analysis.

### *Statistical analysis*

A Shapiro–Wilk's test ($p > .05$) (Razali and Wah 2011; Shapiro and Wilk 1965) and a visual inspection of their histograms, normal Q–Q plots and box plots showed that the hearing threshold values were normally distributed for both exposed and control cases. Therefore, we opted for parametric tests, as it was verified that the error variance for the data obtained was same across the group.

Student's *t*-test was conducted to test the Hypothesis H1 (a) "significantly high hearing threshold (dB (A)) within the exposed group as compared to the control group." ANOVA was performed to test the Hypothesis H1 (b) "significant difference in the hearing threshold at different frequencies among different occupation." A Bonferroni adjustment was used to test the multiple comparisons among various occupations. It was used to control the family-wise error rate in determining whether ANOVA analysis was significant (Day and Quinn 1989).

The statistical information of individuals was presented as mean value (SD). These data were analyzed using the Statistical Package for Social Science (SPSS) for Windows version 22.0 (IBM SPSS Statistics for Windows Version 22, Armonk, NY: IBM Corp). The outcomes of results from the analyses were checked for significance at 95 and 99% confidence intervals.

## Results and discussion

A total of 110 samples were collected, including 50 participants working in trades other than those targeted for the study. The results of the study present the evidence that the hearing threshold may be influenced due to repetitive, continuous and intermittent noise exposure for a prolonged period, albeit to a moderate degree. This is the first case-control study of its kind to investigate the SHT among different handicraft operatives in India.

The noise level at all the work locations was above 85 dB(A), i.e. the NIOSH recommended a limit for an 8 h period. The mean exposure level only among carpet trimming workers was found below 90 dB(A), i.e. OSHA-mandated permissible limits. Table 2 shows the mean equivalent sound pressure level ($L_{ex}$, 8 h), and peak sound pressure level ($L_{peak}$) of 8 h. In the carpet trimming and woodturning workshops, the noise level was continuous while workers in carpet alignment and stone carving were exposed to the impulsive noise level. The workers engaged in the precise artistic activities like wood carving and imitation jewelry tasks were exposed to an intermittent level of noise occurring at irregular intervals. However, it should be noted that the imitation jewelry workers experienced a high level of sound pressure (105.60 dB(A)) among all the other groups.

The earlier studies showed that the prolonged exposure to higher noise may have long-term effects on the nervous system (Dewangan, Kumar, and Tewari 2005) and could cause contraction of blood vessels in the toes, fingers, skin and abdominal organs (Jansen 2003). In fact, the contraction in blood vessels affects the static muscle strength (Singh et al. in press (a)). A recent case-control study (Singh et al., in press (b)) revealed that there was a decrement in the static handgrip and pinch grip strength among female handicraft operatives including imitation jewelry workers.

Table 2. Noise exposure parameters among the handicraft workers for 8-hour period.

| Occupation | Mean (SD) $L_{ex}$, 8 h dB(A) | Range $L_{ex}$, 8 h dB(A) | Mean (SD) $L_{peak}$ dB(A) |
|---|---|---|---|
| Carpet alignment | 97.62 (1.59) | 95.7–100.4 | 108.48 (3.12) |
| Carpet trimming | 89.55 (1.72) | 87.2–91.8 | 101.46 (2.70) |
| Wood carving | 93.19 (2.95) | 89.9–98.5 | 108.2 (6.36) |
| Wood turning | 99.85 (1.81) | 97.3–102.6 | 108.6 (2.8) |
| Imitation jewelry | 105.60 (1.65) | 103.3–107.8 | 111.1 (2.6) |
| Stone carving | 92.39 (2.70) | 89.5–95.6 | 104.96 (3.19) |

The equivalent sound pressure level ($L_{ex}$, 8 h) was consistently found to be a better predictor for the assessment of NIHL in populations with similar exposure characteristics (Roberts et al. 2018). The results from the measurement revealed that $L_{ex}$, 8 h, and $L_{peak}$ under study ranged from 87.2 dB(A) to 107.8 dB(A) (mean 96.37 dB(A) SD 5.76) and 98.3 dB(A) to 114.1 dB(A) (mean 107.15 dB(A) SD 4.73) for the exposed group. It implies that immediate action needs to be taken according to the current regulation. No workers were found to be exposed to noise level exceeding 115 dB(A) $L_{peak}$ at any time complying with the existing regulation.

The participants from the exposed and control group received the air conduction audiometric treatment in the institute laboratory. The results from the independent samples *t*-test were in agreement with the amount of dose consumed. The exposure to the high sound pressure level in the exposed group caused higher hearing threshold in all the moderate pitch (1–4 kHz) and higher pitch (4–8 kHz) frequency bands than the control group (Table 3). Statistical analysis of the data of these groups in 1–8 kHz frequency revealed a high significant difference ($p < .01$) in the outcome. However, a marginal significance was observed in low-frequency band among the groups.

Based on the literature reported for the occupational hearing loss, the pattern of the auditory effects of the handicraft workers examined in this study showed the similar trend. In regard to the known pattern of NIHL progress, the first sign is a V-shape notch at 4 kHz or 6 kHz in the audiogram (Hong et al. 2013), which deepen and spread to other neighbouring frequencies with continuous exposure to noise (Aybek, Kamer, and Arslan 2010; Hong 2005; Noweir and Zytoon 2013). With continued exposure to noise for a more extended period, the notch can eventually spread wider and deeper to lower frequencies (3 kHz, 2 kHz, 1 kHz, and 0.5 kHz) (Hong et al. 2013; Le et al. 2017). Audiometric profiles in NIHL shows a sharp depression at higher frequencies between 3 and 6 kHz but some hearing recovery at 8 kHz. This recovery due to excessive noise exposure is still a matter of debate (Ali, Morgan, and Ali 2015).

Task-wise audiograms for the left and right ear in the exposed group of workers shows a mild hearing loss in the frequency range of 0.25–1.5 kHz and moderate impairment in the frequency range of 2–6 kHz (Figure 3). Most of the workers showed similar patterns in the audiogram except carpet trimming workers. It is noteworthy that they showed lower mean equivalent sound pressure level as compared to other groups. The results are in line with some previous studies, which suggested that the loss in the hearing abilities has been positively associated with the intensity and duration of the noise exposure (Pettersson 2013; Pettersson, Burström, and Nilsson 2011; Pyykkö, Pekkarinen, and Starck 1987). Figure 4 depicts the audiograms of the mean hearing threshold for right

Table 3. Descriptive and hearing threshold parameters in exposed and control group of workers for right and left ear at different pitch frequency bands.

| Parameters | Experimental group | Control group | *p*-Value |
|---|---|---|---|
| Frequency at right ear | | | |
| 250 | 24.9 (5.2) | 24.0 (5.9) | .387 |
| 500 | 25.8 (5.5) | 23.5 (5.1) | .023* |
| 1000 | 27.8 (6.1) | 20.0 (5.5) | .000** |
| 1500 | 27.4 (6.1) | 23.5 (5.6) | .001** |
| 2000 | 32.7 (6.5) | 21.0 (4.4) | .000** |
| 3000 | 39.3 (7.2) | 22.5 (5.6) | .000** |
| 4000 | 41.9 (7.7) | 21.5 (6.8) | .000** |
| 6000 | 46.4 (7.9) | 24.5 (6.6) | .000** |
| 8000 | 29.0 (4.8) | 19.0 (5.9) | .001** |
| Frequency at left ear | | | |
| 250 | 24.6 (6.1) | 22.5 (5.6) | .067† |
| 500 | 25.8 (5.5) | 24.0 (5.1) | .075† |
| 1000 | 28.4 (6.7) | 21.0 (5.4) | .000** |
| 1500 | 28.3 (6.7) | 24.0 (4.7) | .000** |
| 2000 | 32.3 (6.5) | 22.0 (4.6) | .000** |
| 3000 | 38.7 (7.6) | 21.5 (6.8) | .000** |
| 4000 | 41.5 (6.3) | 23.0 (6.5) | .000** |
| 6000 | 44.3 (7.0) | 23.5 (6.4) | .000** |
| 8000 | 30.2 (6.2) | 18.5 (5.1) | .000** |

*($p < .05$).
**($p < .01$).
†(slight but not significant).

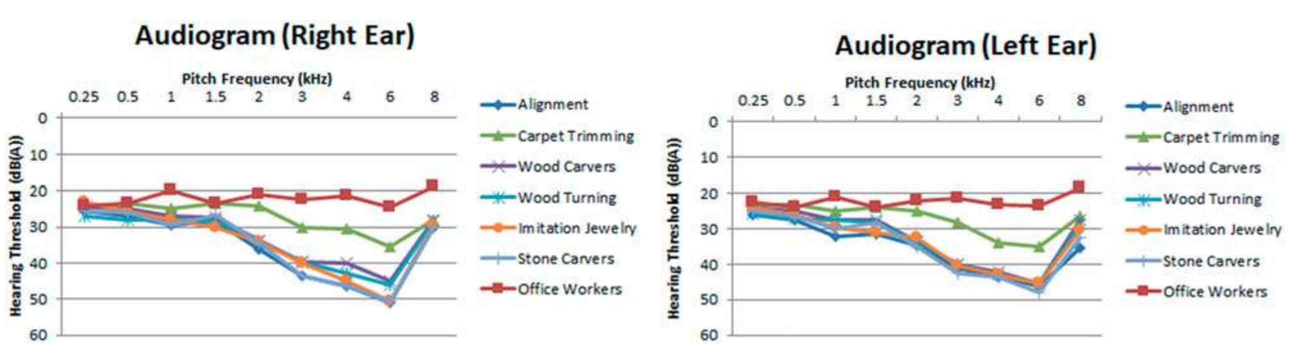



Figure 3. Audiogram of the mean hearing threshold for right and left ear in exposed subjects engaged in various handicraft activities and control group.

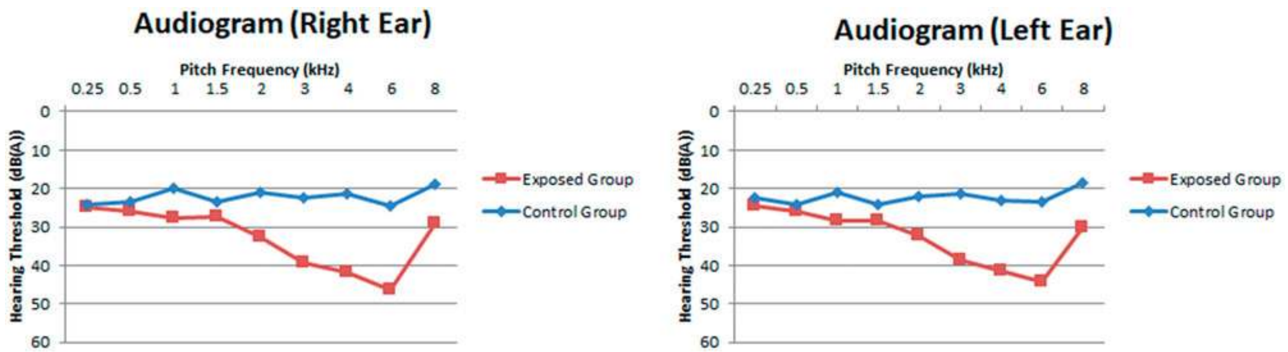



Figure 4. Audiogram of the mean hearing threshold for right and left ear in exposed and control group.

Table 4. Grades of hearing loss in the exposed group.

| | | Frequency (%) ($n = 60$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Grade of hearing level | Ear | 250 | 500 | 1000 | 1500 | 2000 | 3000 | 4000 | 6000 | 8000 |
| Normal (<25 dB(A)) | Left ear | 23 (38.33) | 18 (30%) | 15 (25%) | 13 (21.67%) | 5 (8.33%) | 1 (1.67%) | 0 | 0 | 6 (10%) |
| | Right ear | 21 (35%) | 14 (23.33%) | 15 (25%) | 14 (23.33%) | 4 (6.67%) | 1 (1.67%) | 1 (1.67%) | 0 | 6 (10%) |
| Mild hearing loss | Left ear | 37 (61.67%) | 42 (70%) | 45 (75%) | 46 (76.67%) | 51 (85%) | 41 (68.33%) | 35 (58.33%) | 24 (40%) | 53 (88.33%) |
| (25–40 dB(A)) | Right ear | 39 (65%) | 46 (76.67%) | 45 (75%) | 45 (75%) | 52 (86.67%) | 40 (66.67) | 29 (48.33%) | 18 (30%) | 54 (90%) |
| Moderate hearing | Left ear | 0 | 0 | 0 | 1 (1.67%) | 4 (6.67%) | 18 (30%) | 25 (41.67%) | 36 (60%) | 1 (1.67%) |
| loss (41–60 dB(A)) | Right ear | 0 | 0 | 0 | 1 (1.67%) | 4 (6.67%) | 19 (31.67%) | 30 (50%) | 41 (68.33%) | 0 |
| Severe hearing loss | Left ear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (61–80 dB(A)) | Right ear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 (1.67%) | 0 |

and left ear in overall exposed subjects involved in craft activities and control group.

Table 4 shows the grading of hearing impairment. The treatments/grouping category was the subjective rating of grading of hearing loss (Nandi and Dhatrak 2008) while the frequency of participants was considered under these treatments from the sample collected. Hearing handicap among the exposed workers was calculated including the hearing threshold levels at 500 Hz, 1000 Hz, 2000 Hz, 3000, 4000 Hz and 6000 Hz (Nandi and Dhatrak 2008; Ruikar, Motghare, and Vasudeo 1997). Different professional bodies adopted various methods for calculating the hearing impairment. Few of them did not include the 3000 Hz frequency band. Though the Committee on Hearing and Equilibrium of the American Academy of Ophthalmology and Otolaryngology included 3000 Hz in the calculation of hearing handicap to provide more accurate measurement information (Gurgel et al. 2012; GEHH 1979). Therefore, we sought to adopt the formula that includes 3000 Hz pitch frequency band.

Table 5 shows the frequency of participants for different levels of hearing threshold level and monaural impairment in both ears. The percentage of the hearing handicap of individuals was calculated (Table 6) and it was found that most of the participants (48.33%) lies in the range of 11–20% handicap. Quite surprisingly, only three workers (5%) were not having any kind of hearing handicap, which signifies that the workers were at significant risk of developing the permanent hearing threshold shift (PTS).

A 5% hearing handicap criteria could be considered as an industrial injury and act as a model based on the measurement of the larger ear with pure-tone audiometry (Ivarsson, Bennrup, and Toremalm 1992). Therefore, we have compiled a summary of the number of exposed workers, who had hearing handicap

Table 5. Frequency of hearing threshold level (for 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz) and monaural impairment in exposed participants.

| Ear | Hearing threshold level dB(A) | Frequency | Monaural impairment (%) | Frequency |
|---|---|---|---|---|
| Right | 0–10 | 0 | 0 | 14 |
| | 11–20 | 1 | 1–10 | 33 |
| | 21–30 | 11 | 11–20 | 11 |
| | 30–40 | 36 | 21–30 | 2 |
| | >40 | 12 | >30 | 0 |
| Left | 0–10 | 0 | 0 | 15 |
| | 11–20 | 1 | 1–10 | 28 |
| | 21–30 | 8 | 11–20 | 16 |
| | 30–40 | 37 | 21–30 | 1 |
| | >40 | 14 | >30 | 0 |

Table 6. Calculation of hearing handicap in exposed participants with NIHL.

| | NIHL present | |
|---|---|---|
| Hearing handicap (%) | Number | Percentage (%) |
| 0 | 3 | 5 |
| 1–10 | 15 | 25 |
| 11–20 | 29 | 48.33 |
| 21–30 | 13 | 21.67 |
| >30 | 0 | 0 |

more than 5% under three categories of age and experience (Table 7). It could be seen that hearing deterioration in the noise-exposed groups increases with age and experience. The majority of participants experienced NIHL were in the age group of ≥35 years, followed by 26–34 years. 40% of the craftsmen falling in the classification of >10 years' experience suffered a higher risk of hearing handicap as compared to the less experienced workers.

Surprisingly, the jewelry workers were highly exposed to the risk of NIHL as all the workers participated were having a hearing handicap more than 5%. Carpet trimmers and stone carvers were the least exposed to noise for the 8 h period (Table 2). The same pattern could be seen in Table 7, as they were having a hearing handicap (>5%) in the largest grouping categories, which reveals that the chances of occurring NIHL are higher after the age and experience of 35 and 10 years.

Chronic exposure to high-intensity noise ranging from 88 to 107 dB (A) (6–8 h/day) for more than 10 years can cause biochemical changes and acute myocardial infarction among workers (Davies et al. 2005). Pyykkö, Pekkarinen, and Starck (1987) identified age as one of the individual risk factors for the loss of the hearing abilities. Our results are also consistent and found that hearing ability decreases with the progressive age and length of service. Singh et al. (2009) demonstrated a higher prevalence of hearing loss among the industrial workers exposed to continuous, intermittent and impulsive noise (ranging 80–130 dB (A)). In their later study (Singh, Bhardwaj, and Deepak 2013), they found that the prolonged exposure to impulsive and impact noise proved to be more hazardous to hearing as compared with continuous noise for the length of service for more than 10 years.

The mean values of occupational hearing threshold (dB (A)) of the workers for both ears at different levels of frequency bands are shown in Table 8. The empirical evidence from the descriptive statistics suggests that the workers exposed to impulsive noise level (carpet alignment and stone carving) suffer a higher loss in the hearing threshold for both ears as compared to the other groups. Although the workers engaged in the wood carving and imitation jewelry tasks were exposed to intermittent noise levels, the latter suffered higher loss due to high dose during work. To support the preceding results, ANOVA

**Table 7.** Number of exposed participants with a minimum 5% hearing handicap in various age and experience groups in six different occupations.

| | Age | | | Experience | | |
|---|---|---|---|---|---|---|
| Job type/Category | ≤25 years | 26–34 years | ≥35 years | <5 years | 5–10 years | >10 years |
| Alignment workers | 1 | 4 | 4 | 1 | 3 | 5 |
| Trimming workers | – | 2 | 3 | 1 | 1 | 3 |
| Wood carvers | 2 | 3 | 3 | 1 | 3 | 4 |
| Wood turners | – | 4 | 5 | 1 | 4 | 4 |
| Jewelry workers | 2 | 4 | 4 | 2 | 3 | 5 |
| Stone carvers | – | 2 | 4 | 1 | 2 | 3 |

**Table 8.** ANOVA statistics for comparison within and between the exposed groups of workers.

| Parameters | Carpet alignment | Carpet trimming | Wood carving | Wood turning | Imitation jewelry | Stone carving | F value | *p* Value |
|---|---|---|---|---|---|---|---|---|
| Frequency at right ear | | | | | | | | |
| 250 | 25.0 (4.4) | 24.0 (3.9) | 24.5 (3.7) | 27.0 (5.4) | 23.0 (6.7) | 25.5 (6.4) | 0.71 | .619 |
| 500 | 27 (4.2) | 23.5 (5.8) | 25.0 (4.7) | 28.0 (5.4) | 25.5 (6.4) | 26.0 (6.1) | 0.81 | .544 |
| 1000 | 29.5 (6.4) | 25.0 (6.2) | 27.0 (5.4) | 28.0 (6.7) | 28.0 (5.4) | 29.5 (6.4) | 0.76 | .579 |
| 1500 | 28.5 (5.8) | 23.5 (4.7) | 27.5 (4.9) | 28.5 (6.7) | 30.0 (7.8) | 26.5 (5.8) | 1.38 | .246 |
| 2000 | 36 (5.2) | 24.0 (5.2) | 33.5 (5.3) | 34.0 (4.6) | 34.0 (7.0) | 34.5 (4.4) | 6.60 | .000* |
| 3000 | 43.5 (4.7) | 30.0 (5.8) | 39.5 (5.0) | 39.5 (5.0) | 40.0 (8.2) | 43.5 (5.3) | 7.34 | .000* |
| 4000 | 46.5 (5.3) | 30.5 (6.0) | 40.0 (5.3) | 43.0 (4.8) | 45.0 (5.3) | 46.5 (5.8) | 12.70 | .000* |
| 6000 | 51 (6.6) | 35.5 (6.0) | 45.0 (5.3) | 46.0 (7.0) | 50.5 (5.5) | 50.5 (5.5) | 9.74 | .000* |
| 8000 | 30 (3.3) | 28.0 (4.2) | 28.0 (5.9) | 28.5 (4.7) | 29.5 (5.5) | 30.0 (5.3) | 0.38 | .863 |
| Frequency at left ear | | | | | | | | |
| 250 | 26.0 (6.6) | 23.0 (5.9) | 24.0 (6.6) | 25.5 (6.0) | 24.0 (6.1) | 25.0 (6.2) | 0.32 | .899 |
| 500 | 27.5 (6.3) | 23.0 (5.9) | 25.0 (5.3) | 27.0 (4.2) | 26.0 (6.1) | 26.5 (5.3) | 0.86 | .514 |
| 1000 | 32.0 (7.9) | 24.0 (6.1) | 27.5 (6.3) | 27.5 (6.3) | 29.5 (6.0) | 30.0 (6.2) | 1.77 | .134 |
| 1500 | 31.5 (8.5) | 24.0 (5.2) | 27.5 (5.4) | 28.0 (6.3) | 31.0 (7.7) | 28.0 (4.8) | 1.76 | .138 |
| 2000 | 34.5 (9.6) | 25.0 (4.7) | 33.5 (3.4) | 33.5 (4.1) | 32.5 (6.8) | 35.0 (4.1) | 4.01 | .004* |
| 3000 | 41.0 (9.4) | 28.0 (4.2) | 40.0 (4.7) | 40.0 (5.3) | 40.5 (6.9) | 42.5 (4.9) | 7.47 | .000* |
| 4000 | 43.5 (7.8) | 34.0 (4.6) | 42.0 (4.2) | 43.0 (5.9) | 43.0 (5.4) | 43.5 (4.7) | 4.45 | .002* |
| 6000 | 46.0 (5.7) | 35.0 (5.3) | 45.5 (4.4) | 45.5 (6.4) | 45.5 (6.4) | 48.0 (5.9) | 6.38 | .000* |
| 8000 | 35.5 (6.0) | 26.5 (4.7) | 27.5 (6.3) | 28.5 (4.1) | 30.5 (5.0) | 32.5 (7.2) | 3.59 | .007* |

*($p < .05$).

multiple comparison tests were used to show the significance later in the text.

A one-way between subjects ANOVA was conducted to find the significance of independent variable and the interaction of those independent variables. It was carried out to compare the effect of occupation on the hearing threshold at different frequencies, for both ears (Table 8). The confidence intervals are constructed using bootstrap re-sampling based on function type set to percentile and variations at 1000 bootstrap subset samples. The results from the analyses translate that with 95% confidence, the true mean hearing threshold of workers is somewhere between the upper and lower confidence limits. The analysis was significant in the frequency band ranging from 2000 to 6000 Hz for both ears. However, hearing threshold among the participants found to be significantly different for 8000 Hz in the left ear ($F(6, 103) = 3.59$, $p = .007$). Altogether, these results suggest that moderate and higher pitch frequency bands (2000–6000 Hz) do affect SHT. Furthermore, it should be noted that the higher pitch frequency bands do not appear to have a significant effect on SHT.

A *post hoc* Bonferroni adjustment to ANOVA was used to test the multiple comparisons and control the family-wise error rate among different occupations (Table 9). As it could be seen that carpet alignment workers, stone carvers and imitation jewelry workers

**Table 9.** ANOVA *post hoc* multiple comparison (Bonferroni analysis) to explore all possible pair-wise comparisons among various activities.

| | | | Significance at 95% and 99% confidence interval | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Group (I) | Group (J) | Frequency at right ear | 1000 | 1500 | 2000 | 3000 | 4000 | 6000 | 8000 |
| 1 | 2 | | | | ** | ** | ** | ** | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |
| | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | ** | | ** | ** | ** | ** | ** |
| 2 | 3 | | | | ** | ** | ** | * | |
| | 4 | | | | ** | ** | ** | ** | |
| | 5 | | | | ** | ** | ** | ** | |
| | 6 | | | | ** | ** | ** | ** | |
| | 7 | | | | | ** | ** | ** | ** |
| 3 | 4 | | | | | | | | |
| | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | ** | | ** | ** | ** | ** | ** |
| 4 | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | ** | | ** | ** | ** | ** | ** |
| 5 | 6 | | | | | | | | |
| | 7 | | ** | ** | ** | ** | ** | ** | ** |
| 6 | 7 | | ** | | ** | ** | ** | ** | ** |
| | | Frequency at left ear | | | | | | | |
| 1 | 2 | | | | ** | ** | ** | ** | * |
| | 3 | | | | | | | | * |
| | 4 | | | | | | | | |
| | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | ** | ** | ** | ** | ** | ** | ** |
| 2 | 3 | | | | * | ** | * | ** | |
| | 4 | | | | * | ** | ** | ** | |
| | 5 | | | | † | ** | ** | ** | |
| | 6 | | | | ** | ** | ** | ** | |
| | 7 | | | | | † | ** | ** | ** |
| 3 | 4 | | | | | | | ** | |
| | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | † | | ** | ** | ** | ** | ** |
| 4 | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | † | | ** | ** | ** | ** | ** |
| 5 | 6 | | | | | | | | |
| | 7 | | ** | ** | ** | ** | ** | ** | ** |
| 6 | 7 | | ** | | ** | ** | ** | ** | ** |

*($p < .05$).
**($p < .01$).
†(slight but not significant).
*Note*: Group 1: Carpet alignment; Group 2: Carpet trimming; Group 3: Wood carving; Group 4: Wood turning; Group 5: Imitation jewelry; Group 6: Stone carving; Group 7: Control group.

suffer a higher loss in the hearing threshold for both ears when compared with the control group. All of them showed more or less the same behavior for each frequency band as evident in Figure 3. It was apparent that carpet trimming workers had significantly less loss in the hearing threshold for the frequency ranging from 2000 to 6000 Hz when compared to other exposed group.

The exposure to noise more than the exposure limit for 8 h workday can cause health problems to the workers in the long run (Dewangan, Kumar, and Tewari 2005). Van Kempen et al. (2002) verified through meta-analysis that occupational noise is associated with an increase in cardiovascular disease risk. Singh and Khan (2014) recognized that in India, contractors are not ready to use expensive measures to mitigate occupational risks. Therefore, it is challenging to find cheaper ways to address these problems. Few low cost but practical solutions were proposed in a recent study (Akter et al. 2018) that can reduce the amount of noise that gets through to the ears. They recommended using self-forming and reusable earplugs made up of waxed cotton, foam, silicone rubber or fiberglass wool. These inexpensive yet effective solutions may temporarily prevail over noise exposure. Future directions include the assessment of cardiovascular risks associated with occupational noise among handicraft workers. The results from this study can be helpful in designing hand tools that may reduce the sound pressure level within the acceptable limits. Further research is hence needed for improving the ergonomics of hand tool interventions and work system that could curtail the risk of NIHL. A higher propensity to hearing impairment was observed in the handicraft workers. Indeed, the empirical evidence also suggests that the Indian industries should be encouraged to implement hearing conservation programmes and the workers should be motivated to use personal protective equipment (Singh, Bhardwaj, and Deepak 2013; Singh et al. 2009).

## Conclusion

The goal of this study was to assess the noise exposure and loss in hearing threshold among the handicraft workers due to the occupational use of hand tools. From the results and discussion, the following conclusions have been drawn from the present investigation:

1. The equivalent sound pressure level ($L_{ex}$, 8 h) (mean 96.37 dB(A) SD 5.76) among the exposed group implies that immediate action needs to be taken according to the current regulation. Although no workers were exposed to noise level exceeding 115 dB(A) $L_{peak}$ at any time complying with the existing regulation.
2. The SHT of carpet trimmers was lower than other handicraft operatives may be because the loss in the hearing abilities has been positively associated with the intensity and duration of noise exposure.
3. The exposed workers showed mild–to-moderate hearing loss in all the frequency bands. Most of the workers showed similar patterns in the audiogram. The comparative results suggest that the workers exposed to impulsive noise level suffer a higher loss in the hearing threshold for both ears as compared to the other groups experiencing continuous noise level.
4. Surprisingly, the majority of workers (95%) had a hearing handicap at some level (1–30%), which corresponds to a significant risk of developing PTS. The moderate and higher pitch frequency bands directly influence SHT. Control measures or hearing protection to reduce noise should be provided to the workers against excessive SHT.

## Limitations and future scope

It must be borne in mind that this study was only conducted on a small exposed group of workers. The study demonstrates the potential noise-induced risk factors and tries to relate SHT in several handicrafts occupations. Furthermore, we have not measured the noise exposure for same environmental settings and SHT before and after the work shifts among the groups. Future directions include repeatability assessment over multiple work shifts. Further longitudinal work is needed to explore the design ergonomics of work system that may reduce sound pressure level within the acceptable limits.

## Acknowledgments

The author expresses his deepest gratitude to all the workers who participated in this study. The author acknowledges the encouragement and cooperation extended by Dr. Makkhan Lal Meena without whom this independent research would not have been possible. I am thankful to him for facilitating all the requirements, going out of the way, and allowing me to work in activities outside my Ph.D. work. All the anonymous reviewers are thanked for very useful comments on this study.

## ORCID

Ashish Kumar Singh http://orcid.org/0000-0001-7390-4498

## References


Akter, S., A. Hasan, F. Fardous, and A. M. Bhouyain. 2018. “Effect of Noise Pollution on Hearing Capacity of Workers in Jute Mills of Chittagong City.” *African Journal of Environmental Science and Technology* 12 (1): 15–20. doi:10.5897/AJEST2017.2432.

Ali, S., M. Morgan, and U. I. Ali. 2015. “Is It Reasonable to Use 1 and 8 kHz Anchor Points in the Medico-Legal Diagnosis and Estimation of Noise-Induced Hearing Loss?” *Clinical Otolaryngology* 40 (3): 255–259. doi:10.1111/coa.12362

American National Standards Institute. 2004. *Specifications for Audiometers (ANSI S3.6-2004)*. New York: ANSI.

American Speech-Language-Hearing Association (ASHA). 2005. “Guidelines for manual pure-tone threshold audiometry [Guidelines].” Accessed March 07 2017. www.asha.org/policy.

Areeudomwong, P., R. Puntumetakul, D. B. Kaber, S. Wanpen, N. Leelayuwat, and U. Chatchawan. 2012. “Effects of Handicraft Sitting Postures on Lower Trunk Muscle Fatigue.” *Ergonomics* 55 (6): 693–703. doi:10.1080/00140139.2012.658086.

Aybek, A., H. A. Kamer, and S. Arslan. 2010. “Personal Noise Exposures of Operators of Agricultural Tractors.” *Applied Ergonomics* 41 (2): 274–281. doi:10.1016/j.apergo.2009.07.006.

Basner, M., W. Babisch, A. Davis, M. Brink, C. Clark, S. Janssen, and S. Stansfeld. 2014. “Auditory and Non-Auditory Effects of Noise on Health.” *Lancet (London, England)* 383 (9925): 1325–32. doi:10.1016/S0140-6736(13)61613-X.

Baral, B.,. A. Crasto, and A. Kumar. 2017. “Jaipur Stone Carving.” Published September 4, 2015. Accessed November 12 2017. http://www.dsource.in/resource/jaipur-stone-carving/tools-and-raw-materials.

Bergström, B., and B. Nyström. 1986. “Development of Hearing Loss during Long-Term Exposure to Occupational Noise a 20-Year Follow-up Study.” *Scandinavian Audiology* 15 (4):227–234. doi:10.3109/01050398609042148.

Central Pollution Control Board (CPCB). 1948. “Noise Pollution Norms – Model Rules of the Factories Act.” *Ministry of Environment and Forests*. http://envfor.nic.in/citizen/specinfo/noise.html. Accessed November 19 2016

Chakraborty, M. R., H. S. Khan, M. A. Samad, and M. N. Amin. 2005. “Noise Level in Different Places of Dhaka Metropolitan City (DMC) and Noise-Induced Hearing Loss (NIHL) in Dhaka City Dwellers.” *Bangladesh Medical Research Council Bulletin* 31 (2): 68–74. PMID: 16967812.

Davies, H. W., K. Teschke, S. M. Kennedy, M. R. Hodgson, C. Hertzman, and P. A. Demers. 2005. “Occupational Exposure to Noise and Mortality from Acute Myocardial Infarction.” *Epidemiology* 16 (1): 25–32. doi:10.1097/01.ede.0000147121.13399.bf.

Day, R. W., and G. P. Quinn. 1989. “Comparisons of Treatments after an Analysis of Variance in Ecology.” *Ecological Monographs* 59 (4): 433–463. doi:10.2307/1943075.

De, A., U. Dhar, T. Virkar, C. Altekar, W. Mishra, V. Parmar, M. Mutakekar, R. Iqbal, and A. M. Chandra. 2012. “A Study of Subjective Visual Disturbances in Jewellery Manufacturing.” *Work* 41 (Supplement 1):3404–3411. doi:10.3233/WOR-2012-0616-3404..

Dewangan, K. N., G. P. Kumar, and V. K. Tewari. 2005. “Noise Characteristics of Tractors and Health Effect on Farmers.” *Applied Acoustics* 66 (9): 1049–1062. doi:10.1016/j.apacoust.2005.01.002.

Dianat, I., and A. Salimi. 2014. “Working Conditions of Iranian Hand-Sewn Shoe Workers and Associations with Musculoskeletal Symptoms.” *Ergonomics* 57 (4):602–611. doi:10.1080/00140139.2014.891053.

Durlov, S., S. Chakrabarty, A. Chatterjee, T. Das, S. Dev, S. Gangopadhyay, P. Haldar, S. G. Maity, K. Sarkar, and S. Sahu. 2014. “Prevalence of Low Back Pain among Handloom Weavers in West Bengal, India.” *International Journal of Occupational and Environmental Health* 20 (4): 333–339. doi:10.1179/2049396714Y.0000000082.

Export Promotion Council for Handicrafts (EPCH). 2015a. “Country wise export’s share of handicrafts during 2015–2016, New Delhi [online].” Published 2015a. Accessed September 10 2016. http://www.epch.in/moreDetails.htm.

Export Promotion Council for Handicrafts (EPCH). 2015b. “Review exports during 2015–2016, New Delhi [online].” Published 2015b. Accessed September 10 2016. http://www.epch.in/policies/exportdata.pdf.

Fernández, M. D., S. Quintana, N. Chavarría, and J. A. Ballesteros. 2009. “Noise Exposure of Workers of the Construction Sector.” *Applied Acoustics* 70 (5): 753–760. doi:10.1016/j.apacoust.2008.07.014.

Fuente, A., and L. Hickson. 2011. “Noise-Induced Hearing Loss in Asia.” *International Journal of Audiology* 50 (sup1): S3–S10. doi:10.3109/14992027.2010.540584.

Guide for the Evaluation of Hearing Handicap (GEHH). 1979. “American Academy of Otolaryngology Committee on Hearing and Equilibrium and the American. Council of Otolaryngology Committee on the Medical Aspects of Noise.” *JAMA: The Journal of the American Medical Association* 241 (19): 2055–2059. PMID: 159424.

Gurgel, R. K., R. K. Jackler, R. A. Dobie, and G. R. Popelka. 2012. “A New Standardized Format for Reporting Hearing Outcome in Clinical Trials.” *Otolaryngology-Head and Neck Surgery* 147 (5):803–807. doi:10.1177/0194599812458401.

Habibi, E., M. Zare, A. Haghi, P. Habibi, and A. Hassanzadeh. 2013. “Assessment of Physical Risk Factors among Artisans Using Occupational Repetitive Actions and Nordic Questionnaire.” *International Journal of Environmental Health Engineering* 2 (1): 14. doi:10.4103/2277-9183.110158.

Hong, O. 2005. “Hearing Loss among Operating Engineers in American Construction Industry.” *International Archives of Occupational and Environmental Health* 78 (7): 565–574. doi:10.1007/s00420-005-0623-9.

Hong, O., M. J. Kerr, G. L. Poling, and S. Dhar. 2013. “Understanding and Preventing Noise-Induced Hearing Loss.” *Disease-a-Month* 59 (4): 110–118. doi:10.1016/j.disamonth.2013.01.002.

India, India Brand Equity Foundation (IBEF). 2016. “Indian Handicrafts Industry and Exports.” Published November, 2016. Accessed March 15 2017. http://www.ibef.org/exports/handicrafts-industry-india.aspx and http://www.ibef.org/OldWebsite22022016/EEPC/Handicrafts/2014/files/assets/basic-html/index.html#1.

Ivarsson, A., S. Bennrup, and N. G. Toremalm. 1992. “Models for Studying the Progression of Hearing Loss Caused by

Noise." *Scandinavian Audiology* 21 (2): 79–86. doi:10.3109/01050399209045986.

Jansen, G. 2003. "Noise Pollution behind the Bedford Place Mall." *A Report Presented to the Councial in Halifax Nova Scotia*. Accessed on 18 November 2017. http://fundywritersretreat.blogspot.com/.

Le, T. N., L. V. Straatman, J. Lea, and B. Westerberg. 2017. "Current Insights in Noise-Induced Hearing Loss: A Literature Review of the Underlying Mechanism, Pathophysiology, Asymmetry, and Management Options." *Journal of Otolaryngology – Head and Neck Surgery* 46 (1): 41. doi:10.1186/s40463-017-0219-x.

Lie, A., M. Skogstad, H. A. Johannessen, T. Tynes, I. S. Mehlum, K. C. Nordby, B. Engdahl, and K. Tambs. 2016. "Occupational Noise Exposure and Hearing: A Systematic Review." *International Archives of Occupational and Environmental Health* 89 (3): 351–372. doi:10.1007/s00420-015-1083-5.

McBride, D. I. 2004. "Noise-Induced Hearing Loss and Hearing Conservation in Mining." *Occupational Medicine* 54 (5): 290–296. doi:10.1093/occmed/kqh075.

Moselhi, M., Y. M. El-Sadik, and A. El-Dakhakhny. 1979. "A Six-Year Follow up Study for Evaluation of the 85 dBA Safe Criterion for Noise Exposure." *American Industrial Hygiene Association Journal* 40 (5): 424–426. doi:10.1080/15298667991429778.

Mrunalini, A., and S. Logeswari. 2016. "Musculoskeletal Problems of Artisans in Informal Sector – a Review Study." *International Journal of Environment, Ecology, Family and Urban Studies* 6 (1):163–170.

Mukhopadhyay, P., and S. Srivastava. 2010a. "Evaluating Ergonomic Risk Factors in Non-Regulated Stone Carving Units of Jaipur." *Work (Reading, Mass.)* 35 (1):87–99. doi:10.3233/WOR-2010-0960.

Mukhopadhyay, P., and S. Srivastava. 2010b. "Ergonomic Design Issues in Some Craft Sectors of Jaipur." *The Design Journal* 13 (1): 99–124. doi:10.2752/146069210X12580336766446.

Nandi, S. S., and S. V. Dhatrak. 2008. "Occupational Noise-Induced Hearing Loss in India." *Indian Journal of Occupational and Environmental Medicine* 12 (2): 53. doi:10.4103/0019-5278.43260.

National Statistical Commission (NSC). 2012. "Report of the Committee on Unorganized Sector Statistics [online]." Published 2012. Accessed July 14, 2016. http://www.lmis.gov.in/sites/default/files/NSC-report-unorg-sector-statistics.pdf.

National Institute for Occupational Safety and Health. 1996. Preventing occupational hearing loss – a practical guide; DHHS (NIOSH); Publication No. 96-110. Accessed July 15 2017. https://www.cdc.gov/niosh/docs/96-110/pdfs/96-110.pdf?id=10.26616/NIOSHPUB96110.

Noweir, M. H., and M. A. Zytoon. 2013. "Occupational Exposure to Noise and Hearing Thresholds among Civilian Aircraft Maintenance Workers." *International Journal of Industrial Ergonomics* 43 (6): 495–502. doi:10.1016/j.ergon.2013.04.001.

Noweir, M. H., A. O. Bafail, and I. M. Jomoah. 2014. "Noise Pollution in Metalwork and Woodwork Industries in the Kingdom of Saudi Arabia." *International Journal of Occupational Safety and Ergonomics* 20 (4): 661–670. doi:10.1080/10803548.2014.11077068.

Occupational Safety and Health Administration (OSHA 3074). 2002. "Hearing Conservation", Accessed May 25 2018. https://www.osha.gov/Publications/osha3074.pdf.

Occupational Safety and Health Administration (OSHA). 2016. "Technical Manual Noise Measurement. Regulations and Standards, Section III: Chapter 5." Accessed November 18 2016 https://www.osha.gov/dts/osta/otm/new_noise/.

Owoyemi, M. J., B. Falemara, and A. J. Owoyemi. 2016. "Noise Pollution and Control in Wood Mechanical Processing Wood Industries." Doi: 10.20944/preprints201608.0236.v11

Pettersson, H. 2013. "Risk of hearing loss from combined exposure to hand-arm vibrations and noise." Doctoral dissertation, Umeå universitet. Accessed June 26 2016. https://www.diva-portal.org/smash/get/diva2:589455/FULLTEXT01.pdf.

Pettersson, H., L. Burström, and T. Nilsson. 2011. "The Effect on the Temporary Threshold Shift in Hearing Acuity from Combined Exposure to Authentic Noise and Hand-Arm Vibration." *International Archives of Occupational and Environmental Health* 84 (8): 951–957. doi:10.1007/s00420-011-0635-6.

Pomp, E. R., K. J. Van Stralen, S. Le Cessie, J. P. Vandenbroucke, F. R. Rosendaal, and C. J. M. Doggen. 2010. "Experience with Multiple Control Groups in a Large Population-Based Case–Control Study on Genetic and Environmental Risk Factors." *European Journal of Epidemiology* 25 (7): 459–466. doi:10.1007/s10654-010-9475-z.

Pyykko, I., J. Pekkarinen, and J. Starck. 1987. "Sensory-Neural Hearing Loss during Combined Noise and Vibration Exposure." *International Archives of Occupational and Environmental Health* 59 (5): 439–454. PMID: 3653989.

Razali, N. M., and Y. B. Wah. 2011. "Power Comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling Tests." *Journal of Statistical Modeling and Analytics* 2 (1):21–33.

Reddy, G. C. 2014. "Environmental Friendliness in Manufacturing of Traditional Handicrafts: A new Perspective." Unpublished Craft Documentation Report. http://14.139.111.26/jspui/bitstream/1/496/1/2.%20ENVIRONMENTAL%20FRIENDLINESS%20IN%20MANUFACTURING%20OF%20TRADITIONAL%20HANDICRAFTS%20A%20NEW%20PERSPECTIVE.pdf1

Roberts, B., N. S. Seixas, B. Mukherjee, and R. L. Neitzel. 2018. "Evaluating the Risk of Noise-Induced Hearing Loss Using Different Noise Measurement Criteria." *Annals of Work Exposures and Health*. 62 (3): 295–306. doi: 10.1093/annweh/wxy001

Robinson, G. S., and J. G. Casali. 1995. "Audibility of Reverse Alarms under Hearing Protectors for Normal and Hearing-Impaired Listeners." *Ergonomics* 38 (11): 2281–2299. doi:10.1080/00140139508925268.

Ruikar, M. M., D. D. Motghare, and N. D. Vasudeo. 1997. "Evaluation of Hearing Handicap in Textile Mill Employees with Noise Induced Hearing Loss." *Indian Journal of Otolaryngology and Head and Neck Surgery* 49 (2): 97–100. doi:10.1007/BF03023782.

Sahu, S.,. S. Moitra, S. Maity, A. K. Pandit, and B. Roy. 2013. "A Comparative Ergonomics Postural Assessment of Potters and Sculptors in the Unorganized Sector in West Bengal, India." *International Journal of Occupational Safety and Ergonomics* 19 (3): 455–462. doi:10.1080/10803548.2013.11077001.

Salve, U. R. 2015a. "Prevalence of Musculoskeletal Discomfort among the Workers Engaged in Jewelry Manufacturing." *Indian Journal of Occupational and Environmental Medicine* 19 (1): 44–55. doi:10.4103/0019-5278.157008.

Salve, U. R. 2015b. "Vision-Related Problems among the Workers Engaged in Jewellery Manufacturing." *Indian Journal of Occupational and Environmental Medicine* 19 (1): 30–35. doi:10.4103/0019-5278.157004.

Sataloff, J., and R. T. Sataloff. 2006. *Occupational hearing loss*. Boca Raton, FL: CRC Press.

Schifferstein, H. N., and P. M. Desmet. 2007. "The Effects of Sensory Impairments on Product Experience and Personal well-being." *Ergonomics* 50 (12):2026–2048. doi:10.1080/00140130701524056.

Shapiro, S. S., and M. B. Wilk. 1965. "An Analysis of Variance Test for Normality (Complete Samples)." *Biometrika* 52 (3/4): 591–611. doi:10.2307/2333709.

Skinner, C. M. 2005. "Noise Reduction Techniques in the Design of a Pneumatic-Driven Hand Held Power Tool." *The Journal of the Acoustical Society of America* 118 (3): 1918. doi:10.1121/1.4780427.

Singh, A. K., M. L. Meena, and H. Chaudhary. in press (a). "Assessment of Low Cost Tool Intervention among Carpet Alignment Workers Exposed to Hand-Arm Vibration and Shift in Hearing Threshold." *International Journal of Human Factors and Ergonomics*. http://www.inderscience.com/info/ingeneral/forthcoming.php?jcode=ijhfe.

Singh, A. K., M. L. Meena, H. Chaudhary, and G. S. Dangayach. in press (b). "A Comparative Assessment of Static Muscular Strength among Female Operatives' Working in Different Handicraft Occupations in India." *Health Care for Women International*. doi:10.1080/07399332.2018.1484468.

Singh, J., and A. A. Khan. 2014. "Effect of Coating over the Handle of a Drill Machine on Vibration Transmissibility." *Applied Ergonomics* 45 (2): 239–246. doi:10.1016/j.apergo.2013.04.007.

Singh, L. P., A. Bhardwaj, K. K. Deepak, and R. Bedi. 2009. "Occupational Noise Exposure in Small Scale Hand Tools Manufacturing (Forging) Industry (SSI) in Northern India." *Industrial Health* 47 (4):423–430. doi:10.2486/indhealth.47.423.

Singh, L. P., A. Bhardwaj, and K. K. Deepak. 2013. "Occupational Noise-Induced Hearing Loss in Indian Steel Industry Workers: An Exploratory Study." *Human Factors: The Journal of the Human Factors and Ergonomics Society* 55 (2): 411–424. doi:10.1177/0018720812457175.

Susanha, Y., and T. Sujitra. 2007. "Self-Care Health Behaviors among Woodcarving Workers." *Nursing Journal* 34:58–59.

Tangkittipaporn, J., and N. Tangkittipaporn. 2006. "Evidence-Based Investigation of Safety Management Competency, Occupational Risks and Physical Injuries in the Thai Informal Sector." *In International Congress Series* 1294: 39–42. doi:10.1016/j.ics.2006.03.074.

Taylor, W., J. Pearson, A. Mair, and W. Burns. 1965. "Study of Noise and Hearing in Jute Weaving." *The Journal of the Acoustical Society of America* 38 (1): 113–120. doi:10.1121/1.1909580.

Thakur, T. S. 2016. "Workers in unorganised sector — challenges and way forward." *The Indian Express*, April 12 2015. Accessed May 19, 2016. http://indianexpress.com/article/cities/chandigarh/90-indian-workforce-in-unorganised-sector-deprived-of-welfare-schemes-says-justice-t-s-thakur/.

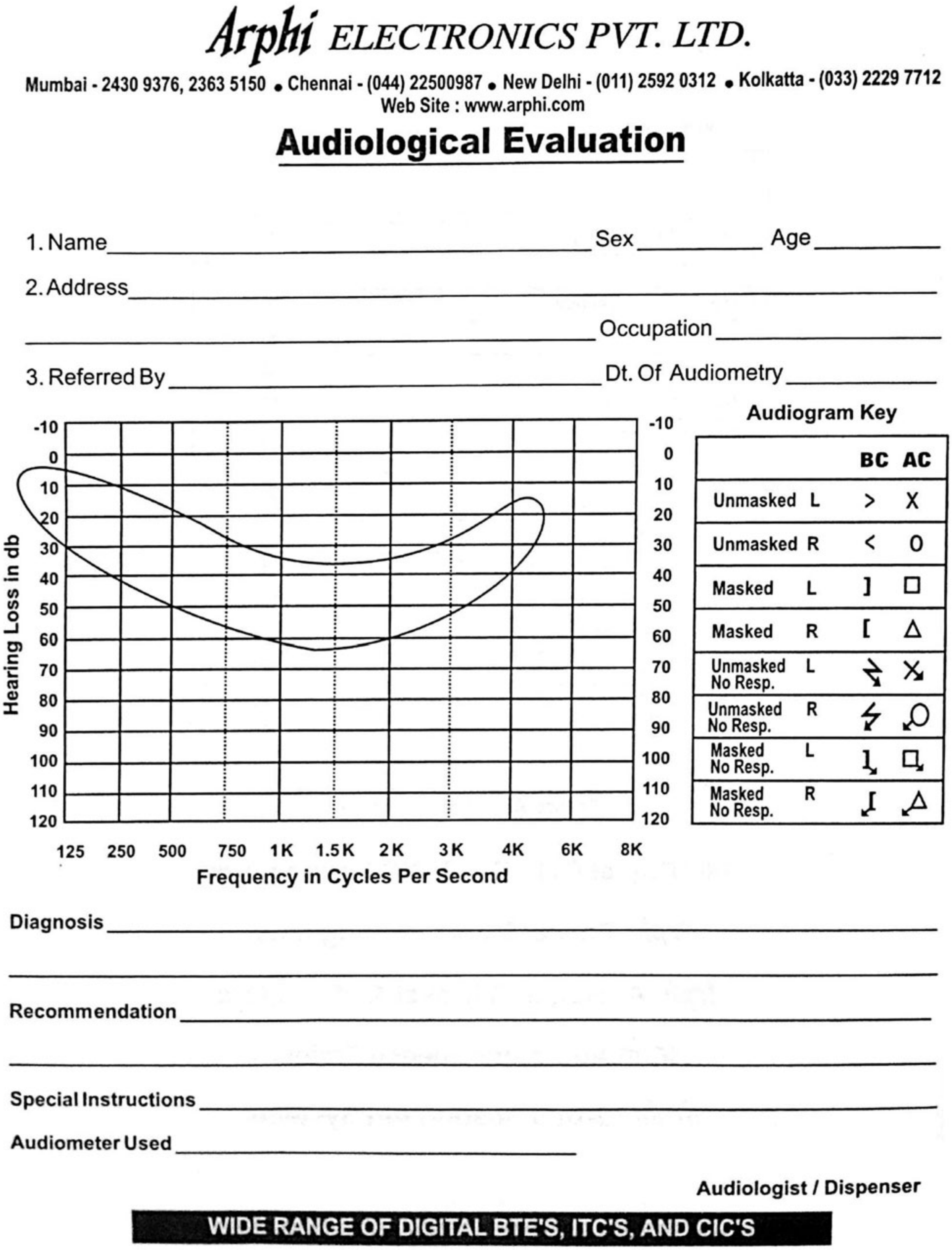
Toth, J. 2017. "Tips to Prevent Chatter in Your Woodturning." Published May 18 2015. Accessed November 13 2017. http://www.woodturnersjournal.com/tips-to-prevent-chatter-in-your-woodturning/.

Untimanon, O., W. Pacharatrakul, K. Boonmeepong, L. Thammagarun, N. Laemun, S. Taptagaporn, and V. Chongsuvivatwong. 2006. "Visual Problems among Electronic and Jewelry Workers in Thailand." *Journal of Occupational Health* 48 (5): 407–412. doi:10.1539/joh.48.407.

Van Kempen, E. E., H. Kruize, H. C. Boshuizen, C. B. Ameling, B. A. Staatsen, and A. E. de Hollander. 2002. "The Association between Noise Exposure and Blood Pressure and Ischemic Heart Disease: A Meta-Analysis." *Environmental Health Perspectives* 110 (3): 307. doi:10.1289/ehp.02110307.

Wang, C. Y., F. Wang, H. M. Wang, R. J. Chen, and W. L. Yu. 2011. "Occupational Health Status of Migrant Female Workers of Artificial Gem Manufacturing Cottages in Guangxi. "*Zhonghua Lao Dong Wei Sheng Zhi ye Bing za Zhi = Zhonghua Laodong Weisheng Zhiyebing Zazhi =*." *Chinese Journal of Industrial Hygiene and Occupational Diseases* 29 (9): 646–649. doi:10.3760/cma.j.issn.1001-9391.2011.09.003.

## Appendix



Arphi ELECTRONICS PVT. LTD.

Mumbai - 2430 9376, 2363 5150 • Chennai - (044) 22500987 • New Delhi - (011) 2592 0312 • Kolkatta - (033) 2229 7712
Web Site : www.arphi.com

**Audiological Evaluation**

1. Name ____________ Sex ______ Age ______
2. Address ____________
____________ Occupation ______
3. Referred By ____________ Dt. Of Audiometry ______



**Audiogram Key**

| | | BC | AC |
|---|---|---|---|
| Unmasked | L | > | X |
| Unmasked | R | < | O |
| Masked | L | ] | □ |
| Masked | R | [ | △ |
| Unmasked No Resp. | L | | |
| Unmasked No Resp. | R | | |
| Masked No Resp. | L | | |
| Masked No Resp. | R | | |

Diagnosis ____________
____________
Recommendation ____________
____________
Special Instructions ____________
Audiometer Used ____________

Audiologist / Dispenser

WIDE RANGE OF DIGITAL BTE'S, ITC'S, AND CIC'S

Figure A1. Audiological evaluation sheet to document participant's response to test frequency and tone.