Noise-Induced Hearing Loss Still a Problem in Shipbuilders: A Cross-Sectional Study in Goa, India

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Introduction

Noise-induced hearing loss (NIHL) is the most prevalent and preventable occupational disease in most Asian countries,¹ and occupational noise is the most common cause of NIHL in adults.² Studies of noise-exposed workforce have found NIHL in about 40% of the workers, the prevalence ranging between 19% and 56%.³,⁴ It is seen largely in the manufacturing industry, particularly the shipbuilding industry; the latter is notoriously known to be one of the noisiest.⁵ The Indian Factories Act (1996 amendment) lists NIHL as a notifiable and compensatable disease.⁶

Subjects and Methods

Study subjects

A cross-sectional study was conducted involving 552 workers employed in the shipbuilding industry in Goa, India, from June 2008 to March 2009. All subjects were males. The required sample size was 266, taking prevalence of NIHL among noise-exposed populations as 40%,⁴ absolute precision of 6%, and at the 95% confidence level (the calculation is as follows: 

\[ n = \left[ \frac{4pq}{D^2} \right] \times 100 \approx \left[ 4 \times 0.4 \times 0.6/(0.6)^2 \right] \times 100 = 266 \].

Because this paper is a part of a bigger study focussing on the health of welders, the subject selection criterion was occupation of
welding. All welders were exposed to noise at the shipyard. The total number of welders employed in this industry was 276. All 276 welders participated in this study (participation rate = 100% [276/276]). The welders worked 44 h a week on an average. A noise survey of the shipyard measured levels beyond 90 dB in some pockets where noise-generating processes like hammering, gouging, riveting and cutting of metal sheets took place, while the noise level in places where noisy machinery like generators and blowers were positioned were in the range of 70-80 dB. The average noise level of the shipyard was 65 dB (SD: 15 dB). It is important to note, however, that this value was obtained during the course of the noise survey, and that the noise levels tend to differ significantly with time depending on factors such as how many ships are being worked on at a given time in the shipyard, each ship is at which stage of construction (which dictates the types of noise-generating process that would be required), etc.

The comparison group comprised of 276 members of the office staff working in the same shipbuilding industry matched to the shipbuilders in terms of age, sex and socio-economic status. They were not exposed to noise during the course of work in the offices, which were located away from the shipyard. The average noise level at the office was 35 dB. Informed consent was obtained from all subjects prior to inclusion in the study. The study protocol was approved by the institutional ethics committee.

Data collection methods

An interviewer-administered questionnaire was used to record patient details, history of diminished hearing (Do you feel you have a hearing loss? [12]), ototoxic drug intake, current or past middle-ear disease, smoking habits [13] and consistency of use of earplugs. Because the members of the shipbuilders’ group were welders by occupation, history of exposure to hot metal fragments entering the ear was also asked in view of the possibility of “welder’s ear,” [14-16] which may range from non-symptomatic tympanic perforation to trans-tympanic injury to the facial nerve [14,15] causing middle-ear disease and conductive hearing loss [16].

This was followed by otoscopic examination of each subject to detect cerumen (which warranted softening and cleaning before audiometry), tympanic perforation and signs of active middle-ear disease. The study subjects underwent pure tone audiometry testing at the beginning of the shift following a minimum 12-h mandatory noise-free period. This was performed by an experienced technician using the Modified Hughson-Westlake procedure on a regularly calibrated instrument (Arphi Digital Diagnostic Audiometer Model 2001 V6, Arphi Electronics Pvt. Ltd, Prabhadevi, Mumbai, India). Air conduction was assessed for pure tones of 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz of sound levels between -10 dB and 110 dB. Pure tone thresholds for bone conduction were also determined.

Definition of NIHL and grades

Audiometric diagnostic criteria for NIHL included all of the following observations on the audiogram: The impairment is predominantly sensorineural (air–bone gap average at 1, 2 and 4 kHz is less than 15 dB), the boilermaker’s notch present in the 3-6 kHz range and hearing loss is bilateral and symmetrical (less than 25 dB at 500 Hz and less than 40 dB at 1000 Hz) in both ears [5,9,17,18]. Hearing loss based on the audiometric value taken as average of 500, 1000, 2000 and 4000 Hz was graded as given in Table 1. [19] Odds ratio (OR) and its 95% confidence interval (CI) (Woolfe’s method [20]) calculated manually were used to determine the presence and strength of association between the variables. Fisher’s exact test and binary logistic regression were also used. P value of less than 0.05 was taken as statistically significant. SPSS version 16 (Chicago, IL, USA) was used for the purpose of data analysis.

Results

This cross-sectional study was conducted from 9th June 2008 to 26th February 2009.

Characteristics of both study groups

The shipbuilders were comparable to the office staff in terms of age, duration of employment and smoking habit [Table 2].

Hearing loss

The prevalence of hearing loss detected by audiology (undifferentiated as NIHL or other) was clearly greater (7.6% [21/276]) among shipbuilders compared with office staff (1 in 276), as seen in Table 3. All the 22 subjects found to have hearing impairment on audiology gave positive history of diminished hearing.

NIHL

OR and its 95% CI were used to determine the presence and strength of association between variables. The audiograms of 6% (17/276) shipbuilders were found to conform to the audiometric diagnostic criteria for NIHL, while no office staff was detected to have this condition (OR = 37.29, 95% CI 22.42-62.18) [Table 4].

The remaining four shipbuilders had conductive type of hearing loss. Of these, one was a case of congenital deafness with Grade IV hearing loss while three had middle-ear disease (two with Grade I and one with Grade II hearing loss). The member of the office staff who had Grade I hearing loss of conductive type was a case of chronic suppurative otitis media. The association between NIHL and age, duration of employment and use of earplugs was statistically significant, as shown in Table 5.

Characteristics of NIHL cases

The mean age of shipbuilders with NIHL was 52.5 years,
with a standard deviation of 4.12 years, and they had been employed for an average of 30.4 years (standard deviation 4.89 years). Five of them were smokers, one was an ex-smoker and the rest were non-smokers; the OR for smoking and NIHL was 2.09 (95% CI 0.70-1.09). Of the 17 cases of NIHL, none were found to use earplugs regularly; 65% (11/17) reported using them “sometimes” and 35% (6/17) “never” used them, despite the earplugs being freely available at the workplace.

**Non-compliance with earplugs and reasons**

Of the 276 shipbuilders, 24% (66/276) were consistent earplug users, 66% (182/276) used them “sometimes” while the remaining 10% (28/276) were “never” users. When the 210 (76% [210/276]) inconsistent users (182 “sometimes” and 28 “never”) were asked to state their principal reason, 50% (104/210) said that earplugs interfered with communication, jeopardising coordination in work and decreasing perception of warning signals. Discomfort was cited by 33% (69/210), while the rest said they perceived no need to use hearing protection as they did not feel that noise levels were high enough to warrant such use. However, binary logistic regression showed that the duration of employment was a stronger predictor of hearing loss among welders (OR = 1.162, 95% CI 1.063-1.271, P = 0.001) than earplug use (OR = 0.956, 95% CI 0.326-2.806, P = 0.935).

**Related factors**

None of the subjects in either group had auditory problems before employment. While 34 shipbuilders and 19 office staff gave history of ototoxic drug intake, none of these reported diminished hearing or were found to have auditory morbidity on audiometry.

Thirty-three shipbuilders gave positive history of diminished hearing, of which 64% (21/33) were found to have hearing loss on audiometry while the remaining 12 had temporary threshold shift (which recovers in the 12-h mandatory period of quiet that is required before audiometric testing). The only member of the office staff who reported diminished hearing was found to have Grade I hearing loss on audiometry.

Three shipbuilders and four office staff gave history of middle-ear disease ever and, although none of them had active disease at the time of the study, the three shipbuilders were found to have hearing loss on audiometry (two Grade I and one Grade II). Eighteen shipbuilders admitted to have ever had welding sparks or hot metal fragments entering their ears, of which three had minor central perforations of the tympanic membrane, although none of them had hearing impairment on audiometry.

**Discussion**

The Directorate General of Factories Advisory Services and Labour Institutes, India, has recommended a maximum of 90 dB (A) as the permissible limit for 8 h continuous noise exposure. A recent noise survey of this shipyard in

**Table 1: Grading of hearing loss**

<table>
<thead>
<tr>
<th>Grade of hearing impairment</th>
<th>Audiology ISO value* (better ear)</th>
<th>Performance value* (better ear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 No impairment</td>
<td>≤25 dB</td>
<td>No, or very slight, hearing problems. Able to hear whispers</td>
</tr>
<tr>
<td>1 Slight impairment</td>
<td>26-40 dB</td>
<td>Able to hear and repeat words spoken in normal voice at 1 m</td>
</tr>
<tr>
<td>2 Moderate impairment</td>
<td>41-60 dB</td>
<td>Able to hear and repeat words using raised voice at 1 m</td>
</tr>
<tr>
<td>3 Severe impairment</td>
<td>61-80 dB</td>
<td>Able to hear some words when shouted into better ear</td>
</tr>
<tr>
<td>4 Profound impairment including deafness</td>
<td>≥81 dB</td>
<td>Unable to hear and understand even a shouted voice</td>
</tr>
</tbody>
</table>

*International Organization for Standardization, average of 500, 1000, 2000, 4000 Hz.

**Table 2: Characteristics of shipbuilders and office staff with respect to relevant factors**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Shipbuilders</th>
<th>Office staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (completed years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>43.2 (11.37)</td>
<td>42.2 (11.16)</td>
</tr>
<tr>
<td>Range</td>
<td>19-59</td>
<td>21-59</td>
</tr>
<tr>
<td>Duration of employment (completed years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>19.9 (11.5)</td>
<td>19.1 (10.38)</td>
</tr>
<tr>
<td>Range</td>
<td>1-40</td>
<td>1-40</td>
</tr>
<tr>
<td>Smoking habit n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoker</td>
<td>48 (17)</td>
<td>37 (13)</td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>16 (6)</td>
<td>10 (4)</td>
</tr>
<tr>
<td>Non-smoker</td>
<td>212 (77)</td>
<td>229 (83)</td>
</tr>
<tr>
<td>Age of smokers (completed years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>45.5 (9.57)</td>
<td>43.2 (10.27)</td>
</tr>
</tbody>
</table>

**Table 3: Hearing loss in shipbuilders and office staff**

<table>
<thead>
<tr>
<th>Hearing loss</th>
<th>Shipbuilders</th>
<th>Office staff</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I</td>
<td>19</td>
<td>6.8</td>
<td>1</td>
</tr>
<tr>
<td>Grade II</td>
<td>1</td>
<td>0.4</td>
<td>1</td>
</tr>
<tr>
<td>Grade III</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>Grade IV</td>
<td>1</td>
<td>0.4</td>
<td>0</td>
</tr>
<tr>
<td>None</td>
<td>255</td>
<td>92.4</td>
<td>275</td>
</tr>
<tr>
<td>Total</td>
<td>276</td>
<td>100</td>
<td>276</td>
</tr>
</tbody>
</table>

**Table 4: NIHL in shipbuilders and office staff**

<table>
<thead>
<tr>
<th>NIHL</th>
<th>Shipbuilders</th>
<th>Office staff</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>17</td>
<td>6.2</td>
<td>0</td>
</tr>
<tr>
<td>Absent</td>
<td>259</td>
<td>93.8</td>
<td>276</td>
</tr>
<tr>
<td>Total</td>
<td>276</td>
<td>100</td>
<td>276</td>
</tr>
</tbody>
</table>
In the current study, none of the consistent users of earplugs work in the workplace. Protecting hearing, but using them “sometimes” is in practice found to have NIHL. The fact that “always” use of earplugs “sometimes” users and 21% were found to have NIHL, while 6% had already developed a temporary threshold shift, which is the precursor of NIHL.

Earlier cross-sectional studies of noise-exposed workforces have found hearing protection as the most feasible means of NIHL prevention, although plagued by a number of issues. Inconsistent use of hearing protection is an issue not limited to developing countries where poor availability of such protection compounds the problem, but is also observed in the developed world despite easy availability at the workplace.

In the current study, none of the consistent users of earplugs were found to have NIHL, while 6% (11/182) of the “sometimes” users and 21% (6/28) of the “never” users were found to have NIHL. The fact that “always” use of earplugs protects hearing, but using them “sometimes” is in practice similar to non-use explaining the prevalence of NIHL in such settings where any level of compliance less than complete is unlikely to confer protection from auditory effects of noise. The reasons for non-compliance uncovered by our study, which mainly include discomfort and interference in effective communication, are similar to those reported by other studies. An additional reason for non-compliance is the component of temporary threshold shift; when workers get through the first few weeks of exposure, they often feel as though they have “got used” to the noise. But, what has most likely happened is that they have started to incur a temporary hearing loss, which impairs their hearing during the workday and usually subsides during the night, but which, upon repeated exposures, leads to NIHL. This study however has found that the duration of employment is a stronger predictor of NIHL as compared with non-regular use of earplugs, suggesting that duration of employment should be a preferred criterion for screening for NIHL among these workers, irrespective of a worker’s compliance to earplug use.

The current study found that the workers with NIHL were on average over 50 years of age, and had been employed in the industry for over 30 years. The role of age and experience in the aetiology of NIHL is acknowledged to be ambiguous, with some sources reporting that hearing deteriorates with age and NIHL occurs in addition to this, and others believe that it is the “young and tender” ear of the younger worker that is more susceptible to effects of noise compared with the “trained and resilient” ear of the older employee.

NIHL has been studied in relation to a number of factors, including ototoxic drugs, middle-ear disease and smoking habits. While the relationship between ototoxic drugs and NIHL is known to be synergistic, middle-ear disease reduces the flow of energy to the cochlea and therefore diminishes the amount of NIHL produced by a given noise. The relationship...
of smoking and NIHL is biologically plausible in view of the effects of nicotine on the vascular system; however, some authors do not concur to this. This study did not find a statistically significant association between either of these factors and NIHL, which may be attributed to the relatively small number of cases of NIHL found in this study.

The strengths of this study lie in the sound scientific study question that seeks to study a relatively neglected condition, adequate sample size and detailed analysis. However, this study has been carried out within the constraints commonly observed among researchers from developing countries, such as non-availability of state-of-art technology, namely noise dosimeters for accurate measurement of ambient noise at the level of every individual worker. Despite the study being of a cross-sectional design (and thereby obviating possibilities to explore temporal relations between exposures and outcomes), the association of NIHL with occupation as a shipbuilder despite regular use of earplugs has clearly emerged.

The findings of this study have been of use in alerting the authorities to the still-prevalent problem of NIHL in Goa. The authors recommend similar studies, especially in developing countries, in settings involving significant noise exposure even if safety regulations are in place. An augmented worker-awareness and education program must be supplemented by providing them with an enabling environment that is only possible by enforcing stringent regulations rendered powerful by means of strong policy decisions in this direction.

References
25. Leinster P, Baum J, Tong D, Whitehead C. Management and motivational factors in the control of noise induced hearing


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