Hearing impairment among workers exposed to excessive levels of noise in ginning industries

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Abstract
Cotton ginning workers have a risk of hearing loss due to excessive noise levels at the workplace environment. In this study, estimates of typical sound levels prevailing at the workplace environment and its effects on hearing ability of the exposed workers were made among cotton ginning workers. Data on self-reported health status was collected by a questionnaire survey at 10 cotton ginning industries located at Jalgaon district of Maharashtra state, India. The cotton ginning workers were exposed to continuous noise levels between 89 and 106 dBA. The hearing ability of the subjects was accessed by pure tone audiometry. The results of audiometry show mild, moderate and moderately severe degree of hearing impairment among the cotton ginning workers. The data generated during the study show that hearing loss was significantly associated with period of exposure to the workplace noise ($P < 0.0001$). The prevalence of audiometric hearing impairment defined as a threshold average greater than 25 dB hearing level was 96% for binaural low-frequency average, 97% for binaural mid frequency average and 94% for binaural high-frequency average in the cotton ginning workers. We recommend the compulsory use of personal protective equipment like ear plug by the cotton ginning workers at the workplace environment. A regular maintenance of ginning and pressing machineries will avoid the emission of excessive noise at the workplace environment of cotton gins. A regular periodic medical examination is necessary to measure the impact of workplace noise on the health of cotton ginning workers.

Keywords: Audiometry, cotton ginning, hearing impairment, workplace noise

Introduction
Industrial noise is one of the major sources of noise pollution. Worldwide, 16% of the disabling hearing loss in adults is attributed to the occupational noise.[1] Small scale industries like textile, sawmills, printing and mining etc. are also responsible for excessive noise and exposure of workers to the hazardous noise levels.[2] In India, there are large numbers of agro-based small scale industries. The workers in these industries are exposed to higher noise levels prevailing at the workplace environment during duty hours.[3–5]

Cotton ginning is an important group of small scale industry in India playing an important role in the national economic growth. India ranks third in the production of cotton in the world, accounting for about 14% of the world cotton production. In India, the area under cotton cultivation and total production has significantly increased during the last 10 years. In the year 2008–9, the area under cotton cultivation was increased to 92.6 lakh hectares, with a yield of 591 kg/hectares and total production of 322 lakh bales per annum.[3] Maharashtra is one of the major cotton ginning states in the country. The area under cultivation of cotton of this state in 2008–9 was 31.39 lakh hectares, with total production of 62 lakh bales per annum with yield of 336 kg/hectare.[4]

In developing countries, people working in industries are still not aware about the ill effects of exposure to high levels of noise due to insufficient knowledge and literacy.[6] Generally, high noise levels are prevalent at industrial workplaces in these countries. Exposure of the workers to such high noise leads to noise-induced hearing loss (NIHL).[7] The cotton processing workers in the study area are also not well aware of the health risks of exposure to the higher noise levels. Hearing ability can greatly be reduced by repeated or long-term exposure to high noise, and this permanent effect is known as NIHL. The damage to the human ear depends on the intensity and duration of noise exposure. Previous studies showed that people who were exposed to noise levels higher than 85 dB suffer from NIHL.[8] Studies conducted on industrial noise have reported higher levels of hearing loss among the workers exposed to high levels of workplace noise.
noise, and shows alarming signals of NIHL.\textsuperscript{[5]}

If hearing loss remains undetected, it may lead to impairment of an individual’s ability to function. Audiometric test is useful to detect the hearing impairment among the workers. The purpose of this study is to determine the noise levels in the cotton ginning and to identify the prevalence of hearing impairment among the workers. The outcome of the present study will raise the level of awareness among the industrialist and workers on the health risks of their workplace environment, and this will help to formulate the strategies for protection of workers from the hazardous noise levels prevailing in the industries.

**Methods**

**Study area**

Jalgaon is one of the major cotton growing districts of the state. The existence of favorable factors like availability of raw cotton, cheap labor and means of transport in Jalgaon district gave impetus to the development of the cotton ginning, pressing, spinning and weaving operations.\textsuperscript{[10]} Approximately 15000 workers are involved in the cotton processing industries in the district. During the process of cotton ginning and pressing, the gin mill workers are exposed to high levels of noise. Most of the ginning has only a day shift that runs for about 12 h, and the workers spend 8–12 h/day in the noisy workplace. The present study was conducted in 10 ginning industries located in the Chopda and Dharangaon tehsils of Jalgaon district. The ginning and pressing machines are the major source of noise in the ginning industries.

**Questionnaire survey**

The health survey was conducted at workplace environment in the ginning industries. A self-administered audiometric screening test (SAAST) survey among the subjects is most frequently used to assess health perceptions in epidemiological research.\textsuperscript{[9]}. Sindhusake et al.,\textsuperscript{[9]} reported that the questionnaire survey about hearing appeared to be sufficiently sensitive and specific to provide reasonable estimates of hearing loss prevalence among the workers. In the present study, a standard questionnaire administered by a team of trained interviewers was used for collection of data on hearing status of the subjects. The questionnaires were provided to the subjects in order to collect the information on work, age, their time of work, any other job with high noise levels, whether they suffered from any injury/trauma to the ears, weather they were exposed to ototoxic drugs or solvents for a long duration, etc.

**Selection of subjects**

We selected 200 workers aged between 19 and 55 years who had been working for at least 1 year in the cotton ginning industry. The average age of the sample was 35 years, and the participation rate of the workers for the study was 90%; others could not be involved in the study even after proper counseling by the authors. As there were female workers rarely involved in this occupation, only male workers are considered as the study subjects. These workers were not using any noise prevention aids for ear protection. The workers carry out their work for a period of 8–10 h daily and for 6–7 days in a week. All the workers in this study are younger than 55 years of age. Consequently, old workers were not included in the evaluation of hearing loss as many studies have reported the effect of aging on hearing thresholds. Nevertheless, there are some reports that use a limit of 55 years for an onset of detectable age-induced hearing loss.\textsuperscript{[10]} The workers were categorized as per exposure duration and age group. A group of 50 staff of the Jalgaon District Central Cooperative (JDCC) bank aged between 21 and 51 years was served as the control group. The average age of the control group was 31 years, with a standard deviation of 8.45. All the subjects from the target group and control group were tested in the morning, ensuring that subjects were not exposed to any type of high noise levels before the test. As per response to the SAAST survey, workers with a history of treatment with ototoxic drugs and trauma infection were excluded from the samples.\textsuperscript{[9]}

**Study instruments**

Questionnaire survey, noise level monitoring and audiometric tests of the ginning workers were the important steps of this study. Noise dosimeter (Type 4436; Bruel and Kjear, Denmark) is used for the measurement of cumulative exposure of subjects to noise over a period of time. Noise dose were determined as 90 dBA criteria for 8 h, with 3 dBA exchange rate. Noise dosimeter was calibrated by using a standard sound level calibrator (Optel, Bombay, India) at 1 kHz calibration frequency for 94 dB before each measurement. The instrument was attached to the body of the subjects as the guidelines provided in the manual of the instrument and allowed during duty hours.

The hearing threshold levels of the subjects were determined by using the clinical pure tone audiometer (EDA-3N3 Mille; Elkon Pvt. Ltd., Mumbai, India.) on wearing headphone (ELEGA, dynamic receiver, DR-59) with a red earphone on the right ear and black earphone on the left ear. The hearing threshold levels were measured by the ascending procedure at 250, 500, 1000, 1500, 2000, 3000, 4000, 6000 and 8000 Hz. Three successive tests were conducted subsequently on the same day for each subject and the best result was used for this study. Using a cut-off >25 dB, hearing threshold averages were calculated as the binaural as low (250, 500, 1000 and 1500 Hz), the binaural mid (1500, 2000, 3000 and 4000 Hz) and binaural high (3000, 4000, 6000 and 8000 Hz) frequencies.

**Calculation of monaural and binaural hearing impairment**

Monaural and binaural hearing impairment is expressed in
terms of percentage by using threshold average of frequencies 1000, 2000, 3000 and 4000 Hz. Hearing impairment was defined as a threshold average greater than 25 dB hearing level.

Monaural hearing impairment
Percentage of monaural hearing impairment was calculated as follows:

a. From the audiometric results, the average of thresholds of hearing for frequencies of 1000, 2000, 3000 and 4000 Hz was calculated.

b. Deduct from it 25 dB (as there is no impairment up to 25 dB).

c. Multiply it by 1.5. Formula for monaural hearing impairment is given below:

\[ \frac{(1000 \text{ Hz} + 2000 \text{ Hz} + 3000 \text{ Hz} + 4000 \text{ Hz})}{4} \times 1.5 = \% \text{ of loss.} \]

Binaural hearing impairment

a. From the percentage monaural impairment, multiply the percent of better ear by 5.

b. To this, add the percent of worse ear.

c. Divide it by 6. Formula for binaural hearing impairment is as follows:

\[ \frac{(\% \text{ better ear} \times 5) + (\% \text{ worse ear})}{6} = \% \text{ binaural hearing loss.} \]

Percentage of hearing impairment in different age groups was calculated by the National Institute of Occupational Safety and Health (NIOSH) handicap equation 1997 available online at www.occupationalhearingloss.com. It detects early effects of noise on inner ear function with respect to age and sex of an individual.

Risk assessment
The symptoms like hearing loss, unilateral hearing trouble and bilateral hearing trouble, reported by subjects during the questionnaire survey, were considered for risk assessment. The risk was calculated among the exposed (workers) and unexposed (control) subjects. The odds ratio is calculated by setting a simple 2 x 2 matrix such that the rows divide the subjects according to those who had been exposed (cotton ginning workers) and those who had not been exposed (control) to the risk factor.

Sensitivity and specificity
The agreement between self-reported hearing loss and audiometric sensitivity and specificity are statistical measures of the performance of a binary classification test. Sensitivity is the ability of self-report to detect the presence of hearing loss when it is present on audiometry. Specificity is the ability of self-report to detect the absence of hearing loss when it is absent in audiometry. Sensitivity and specificity for different exposure groups is calculated considering the exposure group as predictor and hearing impairment as the outcome. Specificity measures the proportion of negatives that are correctly identified (e.g., the percentage of normal) from the total number of samples.

Statistical analysis
The audiometric results in dB in each category were used for Analysis of Variance (ANOVA) using Microsoft Excel. The positive predictive value (PPV) of a test is the probability that the question would correctly identify a person having hearing impairment. The negative predictive value (NPV) of a test is the probability that the question would correctly identify a person whose hearing is not infected. PPV and NPV were calculated to determine accuracy of the hearing test. The data on percent of hearing impairment of the different exposure groups and age group was processed for mean, standard deviation and one-way ANOVA using Microsoft Excel.

Degree of hearing impairment
The criteria of Clarke (1981)\(^{11}\) was used for classification of degree of hearing loss as shown below. Audiometric values at 500, 1000, 2000 and 4000 Hz were averaged to determine the degree of hearing impairment.\(^{12}\)

<table>
<thead>
<tr>
<th>Degree of hearing loss</th>
<th>Hearing loss range (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Mild</td>
<td>26–40</td>
</tr>
<tr>
<td>Moderate</td>
<td>41–55</td>
</tr>
<tr>
<td>Moderately severe</td>
<td>56–70</td>
</tr>
<tr>
<td>Severe</td>
<td>71–90</td>
</tr>
<tr>
<td>Profound</td>
<td>91+</td>
</tr>
</tbody>
</table>

Results
The background characteristics of the workplace environment of cotton ginning workers show that the workers are exposed to unhealthy noise levels [Table 1]. The average age group for the target group was 35 years, and was 31 years for the control group. In the cotton ginning industries, the ambient noise levels were between 95 and 103 dBA and 89 and 106 dBA at the ginning and pressing units, respectively.

In Table 2, the data generated on audiometric analysis shows a comparison between the prevalence of degree of hearing impairment among ginning workers (target group) and control subjects. Average hearing impairment in the target was 96%, and only 22% for the control group. The prevalence of hearing loss was determined based on the hearing threshold levels, with a low fence of 25 dB. The prevalence of hearing impairment is 96% for the binaural low-frequency average, followed by 97% for the binaural mid frequency average and 94% for the binaural high-frequency average among the target group. The estimates of audiometric analysis show that more than 90% ginning workers are affected due to workplace noise at low, mid and high frequencies. The hearing status of control subjects
shows that in few subjects mild hearing impairment were observed at each low, mid and high frequency, which may be due to exposure of these subjects to noise prevailing during their daily routine activities such as traffic, loud music, etc. The average age of the control and exposed groups was 31 and 35 years, respectively. It was observed that 83% of the exposed workers having hearing impairment above 35 dB, whereas no hearing impairment above 35 dB was observed in the control subjects.

The data on noise levels, personal noise dose and hearing threshold level (dB) in the ginning and pressing units of the industry is presented in Tables 3 and 4. The average noise levels in the ginning unit are higher than that in the pressing unit of the ginning industries. The 8-h percentage of dose varied from 115.0% to 1223.0% in these ginning unit workers, which is higher than the percentage of noise dose observed from 100.0% to 1150.3% of the pressing unit workers. The hearing impairment was observed to be slightly higher in the workers of the ginning unit as compared with the pressing unit workers. Moderate (>35 to 50 dB) and moderately severe (>50 dB) hearing threshold level was higher in more percent of workers among the ginning unit as compared with the pressing unit in the present study area.

Table 3 shows the classification of hearing impairment in the cotton ginning workers with their period of exposure to workplace noise. Binaural hearing loss is a common major concern in the entire exposure group. Binaural hearing impairment was observed in above 86% of the studied cotton ginning workers. Percentage of binaural impairment is increasing with increase in the period of exposure to higher noise. Binaural impairment was observed among
96% of the workers who were exposed to workplace noise for more than 10 years as against 16% of the control subjects.

Table 6 shows the mean percentage of hearing impairment calculated by NIOSH 1997 of cotton ginning workers as per age group, average noise dose and exposure period. The data generated during this study show a significant relation between hearing impairment, noise dose and exposure period of the workers to the workplace noise in all the age groups. Hearing impairment among the workers is significantly associated with the period of exposure to workplace noise and noise dose ($P < 0.0001$).

Table 7 shows the results of the frequency-specific hearing loss, with a significant relationship ($P < 0.0001$) between noise dose, exposure duration and hearing loss. Hearing loss at the frequency range of 3000–6000 Hz was observed in more percent of workers who were exposed to the workplace noise for a long duration. NIHL was observed at the frequency range of 3000–6000 Hz among 100% workers exposed to an average noise dose 600% for more than 10 years in the age group above 49 years. The study shows that hearing loss was observed in 71–100% of the workers at higher frequencies (3000, 4000 and 2000 Hz), as shown in Table 7.

Table 8 shows the results on risk assessment from the self-reported hearing impairment data. Odd ratios are given for the symptoms of hearing loss, unilateral and bilateral hearing trouble in the different exposure groups. An Odds ratio greater than 1.0 indicates that there is positive association between exposure and risk. In the workers of ginning industry, the Odds ratio values are increasing with increase in the period of exposure to the workplace noise in the ginning industry. The highest value of Odds ratios for hearing loss, unilateral and bilateral hearing trouble were observed to be 46.00, 22.10 and 27.81, respectively, in the workers exposed to higher noise levels for more than 10 years. Table 8 also summarizes the agreement between self-reported hearing impairment and the period of exposure to workplace noise in all the age groups.
symptoms (hearing loss, unilateral and bilateral hearing loss) and audiometric impairment. The sensitivity more than 0.80 and specificity above 0.66 was observed for all symptoms in all exposure groups, which shows positive agreement between self-reported hearing loss and audiometric impairment. PPV among the exposure group was observed in the ranges of 0.66 to 0.80 for hearing loss symptom, 0.62 to 0.71 for unilateral hearing trouble symptom and was within 0.64 to 0.75 for bilateral hearing trouble. NPV of 0.90 was observed for unilateral and bilateral hearing trouble and 0.92 for hearing loss in all exposure groups. A high NPV shows a high probability of questions to correctly identify a person having no hearing impairment.

Figure 1 shows the prevalence of hearing impairment for binaural low, mid and high frequency average in the cotton ginning workers with respect to the exposure period. Above 95% hearing impairment for binaural low, mid and high frequency average was observed in the subjects exposed to 4–6 years, 7–9 and >10 years period.

Figures 2–6 show the degree of hearing impairment as normal, mild loss, moderate, moderately severe and severe hearing loss among the different exposure groups and control group. Hearing capacity of the control group is given in Figure 2, which shows mild hearing loss in both ears of the control group, i.e. 41% in the left and 46% in the right ear. In Figure 3, mild hearing loss is observed in 56% of the workers for both the ears and moderate hearing loss is observed in 41% and 38% for the left and right ear, respectively, in the ginning workers with period of exposure between 0 and 3 years to the workplace noise. In Figure 4, moderate hearing loss is observed in 74% and 64% for the left and right ear, respectively, in the ginning workers with period of exposure between 4 and 6 years to the workplace noise.

Figures 5 and 6 were shows moderate and moderately severe hearing loss in a higher percentage of workers in the exposure group of 7–9 years and above 10 years. Figure 5 shows moderate hearing loss in 72% of the workers of the 7–9 years of exposure group, whereas 11% workers suffered from moderately severe hearing loss in the right ear and 14% in the left ear. The workers exposed for more than 10 years period to the workplace noise had 75% moderate and 17% moderately severe hearing loss. This study shows that the degree of hearing impairment increases with increase in exposure period to the excessive noise levels prevailing at the workplace.

**Discussion**

In this study, it was observed that noise levels in the ginning industries exceeded the prescribed noise exposure limits of 90 dBA for industrial workers in India. Bhattacharya et al. reported similar higher noise levels (102–104 dBA) at the workplace of textile mill weavers. Michael Yhdego observed noise levels above 90 dB in the friendship textile mill in Ubongo. The results of this study indicate that the prevalence of hearing loss is greater among cotton ginning workers than in the control group, and it increases with increase in period of exposure to the workplace noise. Ginning workers with period of exposure above 4 years are more susceptible to the NIHL as compared with the control group. It was observed that 96% of the ginning workers involved in the study had developed hearing impairment. Ighoroje et al. observed the 5/5 subjects had hearing impairment among saw mill workers exposed for a period of 14 years in Nigeria.

The workers participating in the study spend 8–12 h/day in the ginning industry without using any personal protective equipment. Therefore, the risk of hearing impairment is observed to be greater in the study area workers as compared with the control subjects. The Odds ratios for the symptoms studied are increasing with increase in period of exposure to the workplace noise. Patel and Ingle reported a high risk among the dal mill workers during the study conducted at the Maharashtra Industrial Development Corporation (MIDC) Jalgaon. Sataloff and Sataloff also reported that occupational NIHL is one of the biggest industrial diseases.

The ambient noise levels prevailing at ginning and pressing units are above 90 dBA in the ginning industries. The previous studies showed that people exposed to noise levels higher than 85 dBA suffer from NIHL. Deborah reported sound levels in the range 102–104 dBA at the textile and weaving units in India. Degree of hearing impairment observed during this study shows that mild, moderate and moderately severe hearing loss is common among the cotton ginning workers. Folashade et al. observed mild (49%) and moderate hearing loss (6.4%) among mill workers in small-scale enterprises in southwest Nigeria.
This study shows that the hearing threshold value is increasing with increasing noise dose and exposure period; therefore, NIHL was more among the cotton ginning workers who were exposed to the workplace noise for a longer period. The prevalence of NIHL was observed to be more significant in carpet and textile workers exposed to the workplace noise.\cite{Nilsson17} Nilsson \textit{et al},\cite{Nilsson18} have reported a high prevalence of hearing impairment (58.1%), with severe impairment in 20.4% among the shipbuilding industry workers.

Hearing loss is observed at higher frequencies and also spreading lower frequencies in a large percentage of workers. Percentage of hearing loss is higher in the workers exposed to higher noise for a long duration, i.e. 7–9 years and above.
10 years. Previous studies showed that NIHL is bilateral and symmetrical, usually affecting the higher frequencies (3000, 4000 or 6000 Hz) and then spreading to the lower frequencies (500, 1000 or 2000 Hz).[12]

The results of this study indicate that occupational noise exposure has a significant impact on the hearing ability of cotton ginning workers in all age groups as compared with the control subjects. Krishnamurti[19] reported that occupational noise exposure has a greater impact on hearing sensitivity than the hearing sensitivity of the old age group. A more important finding of the study is the prevalence of high hearing impairment (above 90%) at binaural low, mid and high frequencies among the cotton ginning workers. Ingle et al.[20] observed the prevalence of high hearing impairment as 80% for the binaural low-frequency average, 70% for the binaural mid frequency average and 46% for the binaural high-frequency average in the traffic policemen.

The study shows the need of awareness about the occupational health hazards due to noise exposure. A regular medical examination, use of personal protective equipment and periodical maintenance of machines will be useful for protection of the workers from excessive noise prevailing at the workplace environment.

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References


How to cite this article: Dube KJ, Ingale LT, Ingale ST. Hearing impairment among workers exposed to excessive levels of noise in ginning industries. Noise Health 2011;13:348-55.

Source of Support: Nil, Conflict of Interest: None declared.

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