Hearing Threshold and its Concomitants Among Santal Stone Mine Workers of Birbhum District, West Bengal, India

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Abstract: Background: Hearing impairment is one of the major health problems under the paradigm of occupational health. Mine workers are vulnerable to hearing impairment due to the nature of work, inadequate knowledge of sound hazards and limited access to protective devices. However, the cause of such health problems in India have rarely been explored. Present study aimed to find out hearing threshold of the study population, the level of noise in the mine areas and the relationship of different concomitants on hearing thresholds of the workers. Methods: Cross-sectional data on audiometric measurements, age and work duration in stone mining work were collected from 189 adult Santal stone mine workers (i.e. Group I = working and residing in stone mines and Group II = working in stone mines but residing outside stone mines) of Birbhum district, West Bengal. Data on noise pollution level were also collected. All the data were collected following standard techniques and instruments. Descriptive statistics, cross-tabulation and multivariate logistic regression analysis were performed. Results: Hearing threshold was higher in Group I than Group II; in aged workers than younger workers and working for long duration than short duration in mines. The level of noise pollution inside the stone mine area was above the recommended limit. The most important concomitants of hearing threshold were residence and work in stone mines. Conclusion: The workers engaged in stone mine work and residing inside mine area were more susceptible to hearing impairment. The intensity of the risk further increases with the advancement of age.

Key Words: Hearing loss, Multivariate logistic regression, Noise pollution, Occupational Health, Santals

Introduction:
Sound at high intensity at workplace remains a problem in all regions of the world that attributes to 16% of hearing loss cases among workers (1). Available evidences suggest that average noise levels at workplace in most of the developing countries were above the standard limit (2). Moreover, inadequate protective devices from high intensity sounds, lack of education and unawareness of sound hazards in workplace among workers aggravate the situation more complicated (3). Exposure to noise for prolonged duration causes hearing loss (4), alternates normal sleep pattern (5), changes in blood pressure and pulse rate (6) and affects work performance (7). Therefore, assessment of human health risk at workplace, particularly the health risk of noise at workplace and its concomitants are essential for the sustainable development and welfare of the workers (8).

Prevalence of hearing impairment was reported from several occupational sectors e.g. among policeman (9), military (10) and naval personnel (11); some reported hearing impairment among industrial workers of Saudi Arabia (12), Indonesia (13) and Africa (14,15). Hearing loss among construction workers of China (16), USA (17) and among public transportation drivers of Pakistan (18) were also reported. Agricultural workers were also occasionally exposed to high noise levels above the recommended limit (19-21). Tengku-Hanidza et al. reported that grass cutting workers of Malaysia showed mild to moderate hearing impairment (22). However, highest risk of occupational hearing loss was found among mine workers (23-25). Studies conducted among mine workers of USA (26), South Africa (27), Zimbabwe (28), Tanzania (29) and China (30) reported that around 40% of workers had hearing impairment. The risk was more prominent among underground miners than open pit miners (29). Besides, noise pollution due to vehicles in mine areas was also reported by some other studies (31,32).

In India, literature revealed that hearing loss due to noise at workplace was common among the mine workers (33,34). Hearing loss among air force personnel (35), truck drivers (36) and among textile workers (37,38) were also reported. Studies conducted among miners (39,40) found that hearing loss of the workers was associated with exposure to high noise and
inadequate use of protective devices. Again, many studies (41-45) reported that the overall noise levels in Indian mines were much higher than the recommended limit. However, available literatures on hearing threshold of stone mine workers and noise pollution in stone mine areas of West Bengal are scanty. In view of above, present study was conducted among the Santal stone mine workers of Birbhum district of West Bengal. The aim was to a) find out hearing threshold of the study population, b) the level of noise in the mine areas and c) to see the relationship of different concomitants on hearing threshold of the workers.

Materials and Methods
Present data were collected as a part of a larger bio-medical project conducted on two Santal laborer groups of Suri sub-division of Birbhum district, West Bengal. ‘Group I’ is Santal laborers working and residing inside the stone mine (i.e. quarry/crusher) area and ‘Group II’ is Santal laborers working outside the stone mine (i.e. quarry/crusher) area but residing outside the stone mine area. Thus, it was presumed that the effect of noise pollution would be different between/among groups and Group II will be less affected by noise pollution than Group I (since, they were residing outside stone mine area). The study was restricted to single ethnic group (i.e. Santal) in order to avoid possible ethnic/genetic effect (if any) in respect of variables under study.

Santals are the third largest marginal (scheduled tribe) community and distributed in most of the districts of West Bengal (46). They were classified as ‘Pre-Dravidian’ tribe. Their language, Santal belongs to the Mundari branch of Austro-Asiatic language family (47) and now they have their own script i.e. ‘Oj-Chiki’.

Data on hearing thresholds
Cross-sectional data on audiometric measurements on both left and right ears were collected from 189 (Male=88, Female=101) adult Santal individuals by using ARPHI (500 MK I) audiometer (India). Audiometric measurements indicate hearing thresholds in different sound levels of individual/population. An audiometer is an electronic device that produces pure tones, the intensity of which can be increased or decreased in 5-dB steps. Air conduction thresholds were measured for different tone levels (e.g.500, 1000, 2000 and 4000 Hertz or 0.5, 1.0, 2.0 and 4.0 KHz). The method used for data collection was based on the American Speech Hearing Association (ASHA) guidelines for manual pure tone audiometry. Audiometric tests were performed in a comparatively soundless room in the field area. However, it was ideal to perform audiometric test in a sound proof room. Though, such facilities were not available in field situation. Besides, data on age, duration of work in the stone mine (quarry/crusher) area were also collected using standard questionnaire/schedule.

Data on noise pollution
The measurements of the sound level were carried out in 12 different locations (i.e. different areas [settlement area and working area] distant from source of noise) by using HTC SL-1352 sound level meter (India). All the measurements were carried out during working time/ days under ideal meteorological condition during the month of February to March. The instrument was mounted at a height of 1 meter above the ground with a vertical angle of 45° and the microphone was pointed at the source of noise. The instrument was set at the A-weighting network which is the most common frequency weighting in current use in environmental and industrial studies. This A-weighting network is also conform approximates to the response of the human ear. The instrument was set on automatic mode to run continuously for sixty minutes in each location. Finally, the average noise level at each location was used for further analysis.

Data classification
Study groups were classified as (1) Group I (individuals working and residing inside stone mine area) and (2) Group II (individuals working in the stone mine area but residing outside the stone mine area). Age of the participants were classified into three age groups (1) ‘<30’, (2) ‘30-40’ and (3) ‘>40+’ (following the distribution of data). Work duration classification was done on the basis of years spent in stone quarrying or crushing work. Following are the work duration groups (1) ‘short’ and (2) ‘long’ by using median value (i.e. 7.0 years for males and 3.0 years for females). Hearing impairment assessed following WHO classification (48). The threshold level was calculated using the following formula.

\[
\text{Threshold level (dBA)} = \left[ \text{individual audiometric value in (0.5+1.0+2.0+4.0) KHz} \right] \div 4
\]

<table>
<thead>
<tr>
<th>Hearing impairment status</th>
<th>Threshold level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>≤25</td>
</tr>
<tr>
<td>Impaired</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>26-40</td>
</tr>
<tr>
<td>Moderate</td>
<td>41-60</td>
</tr>
<tr>
<td>Severe</td>
<td>61-80</td>
</tr>
<tr>
<td>Profound</td>
<td>≥81</td>
</tr>
</tbody>
</table>

Ethical considerations
The research was conducted after prior approval from the Ethical Committee for the Protection of Research Risks to Humans, Indian Statistical Institute.

Statistical analysis
No statistical sampling attempted for the selection of study participants. Individuals who have been persuaded to participate and voluntarily agreed with written consent have been included in the present study without any bias. Descriptive statistics and cross-tabulation were computed for each variable. ‘t’ test and one-way ANOVA were performed to find out the mean differences between/among groups. To find out the concomitants of hearing threshold, multivariate logistic regression analysis performed, considering hearing threshold group (i.e ‘normal’ and ‘impaired’ hearing) as dependent variable while study groups, age group and work duration in mining work as independent variables. All the statistical analyses have been done using SPSS software 16.0 (49).

Results
Table 1 shows descriptive statistics of audiometric measurements across study groups in either sex. Mean values of all sound frequency levels (e.g. 0.5, 1.0, 2.0 and 4.0 KHz) were higher in Group I than Group II for both ears in either sex. All the mean differences were statistically significant between study groups (except 4.0 KHz for females in right ear and 4 KHz for both sexes in both ears).
Table 1: Descriptive statistics of audiometric measurements across study groups in either sex

<table>
<thead>
<tr>
<th>Ear</th>
<th>Sex</th>
<th>Study groups</th>
<th>I (kHz)</th>
<th>II (kHz)</th>
<th>t(df=86)</th>
<th>p</th>
<th>I (kHz)</th>
<th>II (kHz)</th>
<th>t(df=99)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Right</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male (n= 88)</td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td>0.004</td>
<td>0.014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>42.02</td>
<td>34.78</td>
<td>2.733</td>
<td></td>
<td></td>
<td></td>
<td>52.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>13.84</td>
<td>0.95</td>
<td></td>
<td></td>
<td></td>
<td>17.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female (n= 101)</td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td>0.004</td>
<td>0.014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>41.07</td>
<td>34.29</td>
<td>2.676</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td>52.49</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td>0.004</td>
<td>0.014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>38.55</td>
<td>28.80</td>
<td>3.731</td>
<td>&lt;0.001</td>
<td>0.010</td>
<td></td>
<td>39.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>10.21</td>
<td>1.04</td>
<td></td>
<td>0.019</td>
<td></td>
<td>12.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male (n= 88)</td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td>0.031</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>31.67</td>
<td>26.96</td>
<td>4.614</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td>34.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>10.74</td>
<td>9.34</td>
<td></td>
<td>0.001</td>
<td></td>
<td>10.98</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female (n= 101)</td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td>0.031</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35.60</td>
<td>28.15</td>
<td>4.260</td>
<td>&lt;0.001</td>
<td>0.021</td>
<td></td>
<td>31.25</td>
<td>0.073</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Left</td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td>0.031</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>41.07</td>
<td>34.18</td>
<td>3.731</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td>34.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>14.69</td>
<td>11.42</td>
<td></td>
<td>0.001</td>
<td></td>
<td>16.22</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 2 shows descriptive statistics of audiometric measurements across age groups in either sex. Mean values of most of sound frequency levels (e.g. 0.5, 1.0, 2.0 and 4.0 KHz) were highest in 40+ years age group followed by 30-40 and <30 years age group for both ears in either sex. Most of the mean differences were statistically significant between/ among study groups (except 0.5 KHz for males in both ears; 1.0 KHz for males in right ear; 0.5 KHz for females in left ear and 1.0 KHz for females in both ears).

Table 3 shows descriptive statistics of audiometric measurements across work duration groups in either sex. Mean values of all sound frequency levels (e.g. 0.5, 1.0, 2.0 and 4.0 KHz) were higher in long work duration group for both ears in either sex. All the mean differences were statistically significant between work duration groups for males only (except 1.0 KHz right ear). However, such statistically significant mean differences were not found in females.
Table 4 shows descriptive statistics of hearing impairment with respect to concomitants of hearing threshold in either sex. In males, the frequency of hearing impairment (in both ears) was higher in Group I (around 90%) than Group II (around 70%). Considering age groups, hearing impairment (in both ears) was highest in 40+ years age group (around 90%) followed by 30-40 (around 75%) and <30 years (around 72%) age group. Among work duration groups, hearing impairment (in both ears) was higher in long (around 88%) than short (around 70%) work duration group. Statistically significant association found between hearing impairment (in both ears) and study groups; hearing impairment (in right ear) and work duration groups.

Table 5: Descriptive statistics of noise level (dBA) at different locations of the study area

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Location</th>
<th>Approximate distance (m) from noise source</th>
<th>Noise level Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Settlements outside stone mine and crusher area (i.e. Group II)</td>
<td>2400 ± 47.32 ± 4.23</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Settlements inside stone mine and crusher area (i.e. Group I)</td>
<td>1500 ± 44.60 ± 5.50</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Settlements inside stone mine and cruiser area (i.e. Group I)</td>
<td>600 ± 46.05 ± 5.23</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Settlements outside stone mine and crusher area (i.e. Group II)</td>
<td>90 ± 59.60 ± 0.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Settlements outside stone mine and crusher area (i.e. Group II)</td>
<td>90 ± 61.50 ± 4.80</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Settlements outside stone mine and cruiser area (i.e. Group I)</td>
<td>60 ± 54.74 ± 1.40</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Settlements outside stone mine and cruiser area (i.e. Group I)</td>
<td>40 ± 63.76 ± 1.50</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Settlements outside stone mine and cruiser area (i.e. Group I)</td>
<td>40 ± 63.76 ± 2.61</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Settlements outside stone mine and cruiser area (i.e. Group I)</td>
<td>40 ± 56.80 ± 0.31</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Settlements outside stone mine and cruiser area (i.e. Group I)</td>
<td>30 ± 62.11 ± 1.90</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Inside stone mine and cruiser area (during work)</td>
<td>5 ± 78.25 ± 1.18</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Inside stone mine and cruiser area (during work)</td>
<td>1 ± 70.42 ± 1.19</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 shows the result of noise level (dBA) at different location of the study area. The measurements were divided into three categories as settlements outside stone mine and crusher area (i.e. Group II), settlements within stone mine and crusher area (i.e. Group I), and inside stone mine and crusher (during work). The noise level in the settlements outside the stone mine and crusher area (Group II) was between 44.60 to 47.30 dBA, which was below permissible limit (55dBA). The noise level in the settlements within stone mine and crusher area (Group I) was between 54.74 to 63.76 dBA, which was above permissible limit (55dBA). During work the noise level in stone mine and crusher area was between 78.25 to 90.42 dBA, which was also above permissible limit (75dBA).
Noise standard (CPCB, 2000) in the industrial area is 75 dBA and residential area is 55 dBA (daytime). Table 6 shows results of multivariate logistic regression analysis for hearing impairment (for both ears) in respect of concomitants like study group, age group and work duration group in either sex. Hearing impairment (i.e. ‘normal’ and ‘impaired’) was considered as dependent variable and concomitants (like study group, age group and work duration group) were considered as independent variables. In step-wise method, the last model was considered for highest R² (Negeleke’s R²) value. In males, hearing impairment (in both ears) was associated with study group. Individuals of Group I was more likely to develop hearing impairment (in both ears) than individuals of Group II. In females, hearing impairment (in both ears) was again associated with study group. Females of Group I was more likely to develop hearing impairment (in both ears) than females of Group II. However, age group and work duration group did not yield any result.

Discussion

The aim of the study was to understand the hearing threshold, level of noise pollution in the stone mine area and finally to find out the relationship of different concomitants on hearing threshold of Santal stone mine workers of Birbhum district, West Bengal. The individuals of the present study were from same ethnic origin, share more or less similar socio-economic condition and same ecological setup. The protocols for data collection were similar for all the individuals and the data were collected with a single set of instruments. The audiometric measurements were higher in Group I than Group II irrespective of sex and hearing impairment was more prevalent in Group I than Group II. This finding reflects that noise exposure to Group I had both occupational (working in mines and environmental (residing in mining area) origin, while, in Group II the noise exposure was exclusively due to occupation. Around 90% of workers of Group I had hearing impairment, this finding corroborates with other contemporary Indian studies conducted among mine workers (34), agricultural workers (36), industrial workers (50) and textile workers (38). Similar findings were reported from miners of Africa (28,51), construction workers of Iran (52) and factory workers of Saudi Arabia (12). Contrast to the present findings, Lie and colleagues reported hearing threshold level was more or less similar among railway drivers and conductor group with their non-exposed control group in Norway (53). They explained that similarities in such hearing threshold associated with the use of protective devices at workplace. However, in the present case most of the workers were unaware of sources hazards in the workplace, use of protective devices was negligible at workplace and mine authorities never provide any protective device to the workers. In fact, these protective devices (i.e. earplugs) were unavailable to most of the workers in the unorganized sectors of India as pointed out by Bhumika and colleagues (50).

The mean value of hearing threshold increases (hearing loss) with progression of age irrespective of sex. Therefore, hearing impairment was more prevalent among 40+ years age group workers than the younger workers. The most obvious explanation is due to cumulative exposure to noise at workplace. This finding corroborates with the study of Bhattacharya and colleagues (54), Engdahl and Tambö (55) and Solanki and colleagues (38). Etem et al. mentioned that hearing impairment was more prominent after 45 years of age among workers (56). However, Kim et al. (57) and Kerrett et al. (34) found that hearing impairment started among workers after 50 years of age. Galow and Gloring pointed out that the process of aging associated with slow but progressive degeneration of neuro-sensory cells of the inner ear that results in changes in hearing threshold (58).

The mean value of hearing threshold increases (hearing loss) with duration of work in the stone mines, however, significant result was found only in case of male workers. This finding corroborates with the study of Yıldırım et al. (59), who pointed out that hearing loss begins to the workers within first eight years of noise exposure. However, Kerrett and colleagues noted that hearing loss begins after 35 years of work experience in the chromite mines (34). Present findings also indicate that hearing impairment was more prevalent in males than females which corroborates with the study of Engdahl and Tambö (55), who found that the effect of occupation on women’s hearing were small compared to men in Norway. WHO reported that male workers are generally more exposed to excessive noise than female workers at same workplace due to their nature of work (60). In the present study, male workers were mostly assigned to blasting, crushing and hammering work where more noise were supposed to generate. On the other, female workers were mostly assigned as carrier of stone slabs and chips where the level of noise was relatively low. Moreover, the median value of work duration in stone mining work was higher in males (i.e. 7 years) than females (i.e. 3 years) which indicate male workers have prolonged noise exposure than female workers.

In India, an exposure of noise level of more than 75dBA for 8 hours per day for consecutive instances generally damage the hearing threshold of the worker (61). In the present case, stone mine workers were exposed to the noise level between 78.3 to 90.42 dBA at their workplace for more than 8 hours a day. This finding corroborates with studies conducted in stone mining and crushing units of Karnataka (41), Uttar Pradesh (42) and Rajasthan (44), where the level of noise pollution was above 90 dBA. Similar findings were also reported by Sinha et al. (62) as well as Saha and Padhy (63) from other parts of the country. All of these findings corroborate with the statement that noise producing processes or equipment do not have adequate noise control precautions in the Indian mines (33). Present finding also indicate that the workers residing inside the stone mine areas (i.e. in Group I) were exposed to the noise level between 54.74 to 63.76 dBA which was again above noise pollution standard (i.e. 55 dBA) (61). The high level of noise pollution in Group I associated with stone mining and crushing activity. Most of the crushers were set in proximity to the settlements of Group I. Similar findings were also reported by Naik et al. (41) and Green and colleagues (64). They added that heavy vehicular movements in settlements near stone mining area have a massive toll of noise pollution.

Result of multivariate analysis depicted that the most important concomitant of hearing thresholds was study group (i.e. work and residence) in both males and females. Hearing impairment (in both ears) was more common in Group I than Group II. This finding corroborates with the study of Rubak et al. (65), who found that the noise exposed workers had two times more risk of hearing impairment than non-exposed workers of Danish workforce, while, exposure duration of above 20 years had three times more risk of hearing impairment than their lower work duration counterparts. Ahmed et al. (12) and Bhumika et al. (50) also found that exposed workers had more risk of hearing impairment than their non-exposed counterparts in industrial sectors of Saudi Arabia and India respectively.

Conclusion

Present study indicates that hearing threshold was higher in Group I than Group II; in aged workers than young workers and working for longer periods than working for short periods in stone mines. The level of noise pollution inside the stone mine area was above the recommended standard. The most important concomitant of hearing threshold was residing at and working in stone mine. However, the result of present study is not conclusive enough for generalization due to small sample size, cross-sectional nature of the data and the study was done on a particular ethnic group. Moreover, some confounding
factors of hearing were not included in the present analysis (like smoking, infection, medication, etc.) which may have some obvious effects. The data on noise pollution were recorded only during working hours (i.e. daytime), however, diurnal variation in noise pollution, work-zone wise variation on noise pollution may provide more insight into the problem. Future studies should incorporate all these aspects to get better understanding of the issue.

**Take home message**

1. The level of noise pollution inside the stone mine area was above the recommended limit.
2. Hearing threshold more affected by working and residing in stone mine areas than only working in stone mine areas.
3. Hearing threshold also affected by the age of the workers.
4. There was none or very few health and safety measures at workplace in the stone mines of the study areas.

**Acknowledgement**

Authors are grateful to the study participants for their unhesitating involvement in the data collection. Financial and logistic supports were provided by the Indian Statistical Institute, Kolkata to conduct the fieldwork with ease.

**References**