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Assessment of Hearing Standard Threshold Shift based on Audiometric Findings in Steel Company Workers

MS Attarchi[1], Z Sadeghi[1], F Dehghan[2], MM Sohrabi[1], S Mohammadi[1]*

[1]Department of Occupational Medicine, Occupational Medicine Research Center, Iran University of Medical Sciences, Tehran, [2]AJA University of Medical Sciences, Tehran, Iran

Abstract

Background: Exposure of workers to excessive noise and its complications including hearing loss as one of the most important health problems in industries. Standard Threshold Shift (STS) is considered as an indicator for monitoring of the effectiveness of hearing conservation program (HCP) implemented in the industries. This study was designed to determine the frequency of STS and hearing loss in steel industry workers.

Methods: 310 steel workers with sound level exposure to unauthorized noise (85 dBA or higher) that had at least 3 years work experience were enrolled. Required data were recorded in a questionnaire through direct interview. STS was investigated using baseline audiogram and audiometric evaluations.

Results: 22.3% of workers in 2008 and 41.3% of workers in 2009 had STS in both ears. There was a significant relationship between the sound exposure level and work experience with STS, while the relationship between age and STS was not significant.

Conclusion: High frequency of STS in workers indicates unsuccessful hearing conservation program in the factory and careful implementation and reassessment of HCP seem necessary.

Keywords: Noise; Hearing loss; Standard threshold shift

Introduction

Noise is considered as one of the most common pollutants in work environments and as one of the most important occupational hazards in the whole world.[1-3] About six hundred million workers around the world are exposed to occupational noises.[4] Of these, 35 million people in European Union and 30 million workers in USA have been exposed to unpermitted occupational noises.[5] Noise-induced hearing loss is considered as one of the most common occupational diseases.[6,7] 153,000 men and 26,000 women in UK suffer from severe hearing loss due to high noise exposure at work.[8] This disease is considered as one of the major reasons for occupational compensation worldwide and it is estimated that 6,745 people in 1999 and 2000 in America requested compensation from occupational hearing loss and about 39,907,386 USD have been imposed to the society.[9] Occupational hearing loss is an irreversible disease, so prevention of the disease is an important issue. Prevention of this disease even in early stages is important because the threshold of hearing loss which is caused by noise is first appeared in high frequencies (3000 to 6000 Hertz) and is expanded to speech frequencies (500-3000 Hertz) in later phases and leads to verbal communication disorders and ultimately functional loss is appeared. Therefore, there is a step during the establishment of the disease in which the workers despite of hearing loss in high frequencies have no disorders due to the defect in speech frequencies. Occupational Safety and Health Administration (OSHA) has mandated that the presence of occupational noise at or

***Correspondence:** Saber Mohammadi, MD, Department of Occupational Medicine, Occupational Medicine Research Center, Iran University of Medical Sciences, Tehran, Iran. Tel: +98-21-66551204, Fax: +98-21-66551204, e-mail: sabermohammadi@gmail.com
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above exposure of 85 dBA is the threshold that triggers the need to implement a hearing conservation program.[10] This program includes various parts such as noise monitoring, engineering control of noise, administrative controls, workers education, providing hearing protection equipment for workers and periodic audiometric assessments. Evaluation of the efficacy of the program is one of the most important parts of hearing conservation program. This assessment will notify the executors about the efficacy of the hearing conservation programs and identify the defects in any parts of the program in order to be resolved. The most important method for program evaluation is comparison of hearing threshold changes during the time using periodic audiometric evaluation. Standard Threshold Shift (STS) indicates obvious and important changes in hearing threshold over the years. Executors of hearing conservation programs should pay more attention to the workers who are affected by STS and implement training programs, clinical examination and the audiometric evaluations in shorter intervals and should perform hearing conservation programs more accurately.[11] De Barba *et al.*'s study in 2005 which was conducted on the petrochemical industry workers showed that 45.3% of workers had STS.[12] Davies *et al.*'s study in 2008 in Canada on 22,376 workers indicated that 30% of workers suffered from STS.[13] Also Niebuhr *et al.*'s study in military industries reported STS of 15%.[14] Steel industry is considered as a common industry in our country and noise is an inseparable part of the process and the workers in this industry are generally exposed to unauthorized noise (85 dBA or higher).[15] The aim of this study was to evaluate the STS in steel industry based on workers' audiometric finding changes in order to assess the effectiveness of hearing conservation program in this industry.

Materials and Methods

This study was performed in 2009 in one of the steel industries in Iran. All workers of any operating parts of this industry who had history of occupational exposure to unauthorized noise (85 dBA or higher) and at least 3 years work experience entered the study. Demographic, medical and occupational data were recorded in a questionnaire through direct interview or referring to the workers' medical records. The data in the questionnaire included age, work experience in the current job, history of noise exposure in the previous occupations, smoking habits and personal entertainment. The exclusion criteria were lack of required medical information including pre-employment audiometric examination results, history of ototoxic drugs consumption, history of diabetes mellitus, hyperlipidemia and thyroid dysfunction, history of ear surgery or severe or recurrent ear infection, unilateral hearing loss or conductive hearing loss, history of severe head trauma, history of exposure to excessive and unconventional noise in the previous job, history of non-occupational or recreational exposure to any high and unusual noise (such as the use of loud Walkman, served in artillery units). After considering the exclusion criteria, 310 subjects were investigated as the study population. All workers used personal protective equipments. To evaluate and determine the sound pressure level in different parts of the factory, occupational hygienist team of the factory performed the administrative processes by using a sound level meter (CEL-440 model). The mean recorded sound levels in different parts of the factory were 101.05 dBA (range: 85-121 dBA).

Audiometric examination (PTA type) was performed by an experienced audiometer at least 12 hours after noise avoidance using a standard audiometer device (model AD 229b, interacoustic Denmark Co. Ltd) in an acoustic room in different frequencies of 0.5, 1, 2, 3, 4, 6 and 8 Kilohertz through air-conduction and bone-conduction in both ears. After collecting information of baseline audiogram (person's audiogram at the beginning of hearing conservation program) and workers' audiogram in 2008 and 2009 and comparing them together, STS and hearing loss were calculated. According to OSHA, if there was a mean difference of 10 dB or more between the last audiogram and the baseline audiogram in the frequencies of 2, 3, and 4 kilohertz in each ear, the worker was considered to suffer from STS.[11] Hearing loss was assessed using the following criteria: Average hearing threshold at 3, 4, 6 and 8 KHz more than 25 db for the workers based on the results of three different years audiometry.[16] Appropriate, relevant ethical standards (based on declaration of Helsinki) were adhered in .this study.

The mean and standard deviation was determined for quantitative variables and T test was used to compare them. To compare qualitative variables, Chi-Square test was used. Also to modify confounding factors and in order to evaluate the relationship between the exposure to different intensity of noise with hearing loss and STS, logistic regression statistical

analysis was used. Confidence interval of 95% and significance level of less than 0.05 were considered in all tests. All analysis was performed using SPSS software (Version 15 Chicago, IL, USA).

Results

All 310 workers were male with an age range of 22-59 years (mean age=36. 32 years) and work experience range of 5-25 years (mean work experience=9. 51 years). The assessment of smoking habits among subjects showed that 229 workers (73.9%) were non-smokers and 82 individuals (26.1%) were smokers. Frequency of STS was 69 cases (22.3%) in 2008 and 128 cases (41.3%) in 2009. Frequency of STS in each ear in 2008 and 2009 were shown in Table 1.

Table1: Frequency of STS in 2008 and 2009

Years	Right ear No. (%)	Left ear No. (%)
2008	41 (13.2)	50 (16.1)
2009	72 (23.2)	86 (27.7)

The noise monitoring showed that 69 workers (22.3%) had noise exposure level between 85 and 90 dBA and 241 workers (77.7%) had noise exposure level more than 90 dBA. Frequency of STS in separate noise exposure levels in 2008 and 2009 were shown in Table 2. Frequency of STS was significantly higher in workers with noise exposure level higher than 90 dBA Compared with the workers with noise exposure level between 85 to 90 dBA in 2008 and 2009 (p<0.001).

Frequency of STS based on noise exposure level in each ear in 2008 and 2009 were shown in Table 3. Frequency of STS in each ear was significantly higher in workers with noise exposure level higher than 90 dBA compared with the workers with noise exposure level between 85 to 90 dBA in 2008 and 2009 (p<0.001).

T-test was used to compare the mean age and work experience between the subjects with STS (in the left or right ear) and the individuals without STS. The results of this analysis showed no significant differences in ages between these two groups (p>0.05), but the work experience in people with STS (in the left or right ear) was significantly higher than those without STS (p<0.05). Based on audiometric assessment at the beginning of employment, the number of people who had hearing loss in 2008 and 2009 was 6 (1.9%), 31 (10%) and 45 (14.5%) respectively. The results of logistic regression statistical analysis showed that there was a significant relationship between work experience and intensity of noise exposure level with STS in 2009 and also with hearing loss in 2009 (p<0.05), but the relationship between age and cigarette smoking with STS and hearing loss was not significant (p>0.05) (Table 4 and 5).

Table 2: Comparison of the frequency of STS in separated noise exposure levels in 2008 and 2009.

Noise level (dBA)	STS in 2008 No. (%)	STS in 2009 No. (%)
85-90	6 (8.7%)	15 (21.7%)
Higher than 90	63 (26.1%)	118 (48.9%)
P-value	0/001*	0/001*
Odds Ratio (95% CI)	3.71 (1.53 – 9.007)	5.66 (2.75 – 11.585)

*Frequency of STS were significantly different (Chi-Square test, p<0.05)

Table 3: Comparison the frequency of Standard Threshold Shift in separated sound exposure level in each ear in 2008 and 2009.

Sound level (db)	2008		2009	
	Left ear No. (%)	Right ear No. (%)	Left ear No. (%)	Right ear No. (%)
85-90	3 (4.3)	4 (5.8)	3 (4.3)	8 (11.6)
Above 90	47 (19.5)	37 (15.3)	83 (34.4)	64 (26.5)
P-value	0.001*	0.043*	0.001*	0.009*
Odds Ratio (95% CI)	5.33 (1.60-17.69)	2.94 (1.01-8.58)	11.55 (3.52-37.78)	2.75 (1.25-6.07)

*Frequency of STS were significantly different (Chi-Square test, p<0.05)

Table 4: The relationship between age, experience and sound exposure level with STS based on regression statistical analysis.

Variable[(1)]	SE	*P*-value	OR	%95 CI
Age (year)	0.021	0.065**	1.015	0.974-1.057
Smoking (yes)	0.285	0.115**	1.567	0.896-2.470
Work Experience (year)	0.035	0.045*	1.073	1.002-1.150
Sound intensity (dBA)	0.376	0.001*	5.817	2.786-12.147

[(1)]Binary logistic regression analysis, *Statistically significant different (p<0.05), **Statistically non-significant difference (p>0.05)

Table 5: The relationship between age, experience and sound exposure level with hearing loss in high frequencies based on regression statistical analysis.

Variable[(1)]	SE	*P*-value	OR	%95 CI
Age (year)	0.027	0.621**	1.014	0.961-1.070
Smoking (yes)	0.363	0.208**	1.579	0.776-3.216
Work Experience (year)	0.042	0.017*	1.106	1.018-1.201
Sound intensity (dBA)	0.748	0.007*	7.533	1.740-32.606

[(1)]Binary logistic regression analysis, *Statistically significant different (*p*<0.05), **Statistically non-significant difference (*p*>0.05)

Discussion

Noise-induced hearing loss is one of the most common hearing problems in adults and includes about 30% of the causes of hearing loss in this group and also it is one of the most important occupational diseases that compromises a large number of workers' medical complaints. It causes large compensation charges in addition to physical and mental disabilities for the affected person and imposes large economical loads on the society.[17]

The findings from the effects of noise on the auditory system were in good agreement with other researches and clearly showed that hearing loss affects high frequencies (6-4 Kilohertz) more than other frequencies.[18,19]

Based on findings of this study, 22.3% of workers in 2008 and 41.3% of workers in 2009 who were exposed to unauthorized noises suffered from STS despite the use of personal protection equipment which corroborated the fact that the protective device has not been used properly by workers or the type or style of use has not been correct and in other words, the hearing conservation programs have been unsuccessful in the industry according to NIOSH, the effectiveness of hearing conservation programs would be acceptable if the maximum frequency of workers with STS is 5%.[20]

Based on OSHA rules, in workers with STS, hearing protective device should be provided for the worker and methods of proper use and maintenance should be taught and if the worker has already used the protective device, the type of the equipment should be evaluated and the affected worker should also be retrained.[21] The results of this research revealed no relationship between cigarette smoking and hearing loss while many studies have reported positive effects. For example Mizoue *et al.*'s study in 2003 showed that smoking increased hearing loss in both people with unauthorized noise exposure and people with permissible exposure.[1,4,22] The results showed that there was a correlation between noise exposure level and occurrence of STS and also hearing loss which has been reported in other studies.[12,23] We also found a significant relationship between work experience and STS, which corresponds to the results of other studies as well.[24-26] A survey conducted in 2008 and 2009 demonstrated higher frequencies of STS and hearing loss in the left than the right ear and these findings were compatible with other studies that may be due to more sensitivity of left ear or exposure of workers to the noise source at the left side.[27-30] Also in this study, the frequency of STS and hearing loss in high frequencies increased in year 2009 compared with year 2008 suggesting to lack of strict evaluation of the effectiveness of hearing conservation programs in the industry.

In our country, most studies have investigated the effects of noise on auditory system and there are little studies focusing on the efficacy of hearing conservation

programs in industries. In this research, we studied the effectiveness of hearing conservation programs following an exposure to unauthorized noise based on STS occurrence in workers. However there were some limitations in this study, such as inappropriate assessment of the type of ear protection devices and also duration of use and method of application of ear protection devices by the workers. This study showed that running of the hearing conservation program just based on personal protective devices use and ignoring other parts of the program such as engineering and administrative controls and workers' education that can cause STS in many subjects. It is recommended to perform hearing conservation programs exactly according to OSHA guidelines and if not achieved, the workers should have at least an active participation in the hearing conservation program and for proper implementation of this program, the workers should be trained about the importance of proper use of ear protection devices.

Conflict of interest: None declared.

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