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Effect of Noise Exposure on Occupational Injuries: A Cross-sectional Study

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ABSTRACT

Background: Noise exposure is the most frequent occupational factor which may increase the risk of work-related injuries. The purpose of this study was to estimate the association between occupational injuries and noise exposure as well as hearing loss.

Methods: This study was conducted from April 2008 to March 2009 on 1062 workers in the Tabriz Tractor Manufacturing Plant. Sound pressure level (SPL) ≥ 85 dB in the workplace was considered as the independent variable (exposure) and physical occupational injuries as the dependent variable (outcome). Data were extracted from the workers' medical records using a checklist.

Results: Of 1062 volunteers, 392 (36.9%) were exposed (with $SPL \geq 85$ dB) and 670 (63.1%) were unexposed (with $SPL < 85$ dB). One hundred and seventy-six injuries occurred during the study period. Frequency of injuries was about 16 per 200,000 hours, severity of injuries was about 75 per 200,000 hours and incidence rate of injuries was 16%. The exposed group had 1.52 fold increased risk of injury compared to unexposed group ($P=0.012$). Compared to group with normal hearing status, the risk of occupational injuries increased 1.72 fold in group with partial hearing loss ($P=0.062$), 7.87 fold in group with mild hearing loss ($P=0.003$), and 4.58 in group with moderate hearing loss ($P=0.049$).

Conclusion: Occupational noise exposure and hearing impairment have adverse effect on work safety and can increase the probability of work-related injuries. This means reducing noise exposure can contribute to increase safety in workplaces where noise is a factor. Furthermore, using assistive listening devices may reduce risk of work injuries among hearing-impaired workers.

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Introduction

Noise exposure is one of the most common and important risk factors in workplaces¹. This common occupational risk factor threat millions of workers worldwide². Occupational injuries have an important role in loss of productivity and resources so that 90% of industrial recompenses pertain to occupational injuries³.

Noise exposure may lead to many complications; the most common is hearing loss^{4,5}. Continuous and prolonged exposure to sound pressure level (SPL) ≥ 85 dB can cause temporary or permanent hearing loss. This condition may lead to impairment of communication and hence lack of proper and effective understanding of warning signs^{3,6}. On the other hand, prolonged exposure to noise in the workplace can increase fatigue and hence decrease concentration, which may in turn increase human errors³. In addition, prolonged exposure to noise may lead to other complications such as cardiovascular, gastrointestinal and neurological disorders^{2,7}.

Inadequate attention to noise exposure and its role in causing work injuries have led to an underestimation of the importance of noise exposure and its potential effect on occupational injuries^{3,8,9}. A few studies which investigated the correlation between noise and work injuries have shown that harmful noise exposure in workplace may be considered as a potential risk factor for occupational injuries^{1,10}. In these studies, the effect of several variables on work injuries was investigated. However, noise exposure may lead to both hearing loss^{4,5} and work injuries^{1,10}. Hence, it is not clear how much of work related injuries is attributable to hearing loss and how much to the noise in workplace.

The purpose of this study was to estimate the increased risk of work related injuries attributable to occupational noise exposure and hearing loss simultaneously.

Methods

This cross-sectional study was conducted on workers of Tabriz Tractor Manufacturing Plant, the north west of Iran, in

2009. The eligible workers, who had at least four consecutive years of work experience and worked in the manufacturing department, were enrolled. Of 6000 workers in this plant, 2300 worked in the manufacturing department, 1062 of whom had at least four years of experience. The exposure of interest was harmful noise exposure in workplace. Thus, workers who exposed to SPL < 85 dB were considered as exposure negative and those who exposed to SPL ≥ 85 dB in the workplace was considered as exposure positive. Work-related injuries were considered as the outcome of interest. Work-related injury was defined as physical injury that occurs on the job and as a direct result of the duties assigned to the specific job position¹¹. The episodes of work related injuries were determined according to what was recorded in workers' medical record. All work-related physical injuries, ranging from mild to severe, occurred in the factory from April 2008 to March 2009 were evaluated.

In order to determine the level of noise exposure in different parts of the workplaces, the eight hours equivalent sound pressure (Leq) was estimated using noise map prepared by an occupational health services engineering company. Measurements were carried out at A-weighted network according to ISO 9612 standard method¹² using calibrated sound level meter type 2. Since noise was continuous in this industry, slow mode was used for sound measurements. The position of microphone was at the height of 1.50 m above the ground and near the hearing area of workers.

Exposure to equivalent SPL was calculated based on the time average sound pressure levels (SPL_{TWA}) and total exposure time using the following formula:

$$L_{eq} (dB) = 10 \log \left[\frac{1}{T} \sum_{i=1}^n t_i 10^{\frac{L_{P_i}}{10}} \right]$$

In this formula, Leq represents the equivalent level of exposure, t_i represents the duration of exposure in hour, T represents the reference time (usually eight hours), and LP_i represents the SPL of exposure (dB). Accordingly, the workers who had a SPL ≥ 85 dB were considered as exposed group and those who had a SPL < 85 dB were considered as unexposed group.

Permanent hearing loss in right and left ears was determined for each worker within 500, 1000, 2000, and 4000 Hz frequency using audiogram. Then, workers were divided into four different groups based on the overall amount of hearing

Table 1: Characteristics of the workers by level of sound pressure level (SPL) among unexposed group (with SPL < 85 dB) versus exposed group (with SPL ≥ 85 dB)

Characteristics	Unexposed group			Exposed group			P value	Total		
	Number	Mean	SD	Number	Mean	SD		Number	Mean	SD
Age (yr)	886	35.10	7.15	176	35.00	6.87	0.864	1062	35.08	7.10
Work experience (yr)	886	10.51	6.15	176	10.02	5.63	0.329	1062	10.42	6.06

Of 1062 volunteers, 392 (36.9%) subjects worked in noisy workplaces and thus were exposed to SPL ≥ 85 dB whereas 670 (63.1%) subjects worked in noiseless workplaces and hence were exposed to SPL < 85 dB. One hundred and seventy-six injuries with different severities occurred during the study period. A total of 841 days lost due to injuries. AFR was estimated about 16 per 200,000 hours, and ASR was estimated about 75 per 200,000 hours and AIR was estimated 16%.

The effect of sound pressure level on occurrence of occupational injuries is shown in Table 2. Accordingly, the OR

loss³: (a) normal hearing (zero to 15 dB), (b) partial hearing loss (15.1 to 30 dB), (c) mild hearing loss (30.1 to 40 dB), and (d) moderate hearing loss (40.1 to 50 dB). No one had severe hearing loss (>50 dB).

In addition, data on workers' age, years of work experience, and duration of daily work in noisy workplace were extracted from their medical record using a checklist of items. The number of occupational injuries, the number of working days lost due to injuries, and the reasons of injuries were extracted from the medical records too.

The accident (injury) frequency rate (AFR) was calculated using the following formula¹³:

$$AFR = \frac{\text{Number of accident} \times 200,000}{\text{Number of workers} \times 40 \times 50}$$

The accident (injury) severity rate (ASR) was calculated using the following formula¹³:

$$ASR = \frac{\text{Number of working days lost due to injuries} \times 200,000}{\text{Number of workers} \times 40 \times 50}$$

The accident (injury) incidence rate (AIR) was calculated using the following formula¹³:

$$AIR = \frac{\text{Number of accident}}{\text{Number of workers}} \times 100$$

The odds ratio (OR) estimate of occupational injury was investigated among workers who worked in noisy workplace (SPL ≥ 85 dB) over workers who worked in noiseless workplace (SPL < 85 dB) using logistic regression model. Both adjusted and unadjusted ORs were used to assess the confounding effects of the age and years of work experience on the association between noise and occupational injuries. All analyses were performed at 0.05 significance levels using the statistical software Stata 11 (StataCorp, College Station, TX, USA).

Results

All workers were men with mean age of 35.08 yr (SD=7.10) ranged from 24 to 63 years. The mean years of work experience of the workers was 10.42 (SD=6.06) ranged from 4 to 33 years. There was not statistically significant difference between the mean age (P=0.864) and the mean work experience (P=0.329) in exposed and unexposed groups (Table 1).

estimate of work injury was 1.53 in exposed group (with SPL ≥ 85 dB) compared to unexposed group (with SPL < 85 dB) (P=0.010). The OR estimate of work injury adjusted for age and years of work experience was 1.52 in exposed versus unexposed groups (P=0.012).

The association between the level of hearing loss and occurrence of occupational injuries adjusted for age and years of work experience is shown in Table 2. The OR estimate of risk of occupational injuries in group with partial hearing loss was 1.72 (P=0.062), in group with mild hearing loss was 7.87

($P=0.003$), and in group with moderate hearing loss was 4.58 ($P=0.049$) compared to group with normal hearing status. The

OR estimate of occupational injuries for each level of hearing loss compared to the previous level was 1.85 ($P=0.001$).

Table 2: The effect of sound pressure level and hearing loss on occupational injuries using logistic regression model

Variable	Injury		Unadjusted OR (95% CI)	P value	Adjusted OR (95% CI) ^a	P value
	Absent	Present				
Sound pressure level (dB)						
Unexposed group (≤ 85)	574	96	1.00		1.00	
Exposed group (> 85)	312	80	1.53 (1.11, 2.13)	0.010	1.52 (1.10, 2.11)	0.012
Hearing loss (dB)						
Normal (0.0-15.0)	777	144	1.00		1.00	
Partial hearing loss (15.1-30.0)	73	20	1.48 (0.87, 2.50)	0.145	1.72 (0.97, 3.05)	0.062
Mild hearing loss (30.1-40.0)	4	5	6.74 (1.79, 25.42)	0.005	7.87 (2.01, 30.82)	0.003
Moderate hearing loss (40.1-50.0)	4	3	4.04 (0.90, 18.27)	0.069	4.58 (1.00, 20.89)	0.049
Trend ^b	-	-	1.73 (1.25, 2.39)	0.001	1.85 (1.31, 2.62)	0.001

^a OR estimates of injury adjusted for age and work experience

^b OR estimates of injury for each level of hearing loss compared to the previous level

Discussion

The results of this study revealed that workers who exposed to $SPL \geq 85$ dB were at higher risk of occupational injuries compared to workers who exposed to $SPL < 85$ dB. The association shown here between noise exposure and occupational injuries has also been identified by other studies^{1,10,14,15}. This evidence indicates a consistency between different studies in different populations. Replication of findings is particularly important in epidemiology and is in favor of a causal relationship. If an association is observed, we would also expect it to be seen consistently in different population and in different settings¹⁶. However, it is important to note that risk of work-related injuries is not homogeneously distributed throughout different categories of workers having different jobs and tasks¹⁰. In other words, work content, which is a critical factor for occupational injuries, can increase the risk of occupational injuries besides noise per se, what was not evaluated in this study due to limitation of study design. Therefore, the relationship between noise and work injuries shown here may be biased with work content, although we conducted logistic regression analysis to control for other available confounding variables such as age and work experience.

Another important evidence of causal relationship is so-called biological plausibility. Biological plausibility refers to coherence with the current body of biologic knowledge. It appears quite plausible that exposure to noise acts as a causal factor for work injuries, because continuous and long-term exposure to high SPL may lead to excessive fatigue^{17,18} and hence decreased concentration^{19,20} which may increase the risk of work accidents³.

In addition, there was an association between the level of hearing loss and occurrence of occupational injuries. In other words, the risk of occupational injuries increased with the severity of hearing loss. The number of subjects with mild and moderate hearing loss was small in our study. Hence, the correlation seen between hearing loss and work injury might be effect by random error, although statistically significant but the confidence interval is wide. The correlation between hearing loss and occupational accidents has also been reported by other studies^{3,21}. Picard et al³ carried out a study on a sample of 52,982 male workers exposed to a minimum of 80 dB in workplace in Quebec between for the 1983-1998 periods. They con-

cluded that about 12.2% of accidents were attributable to a combination of noise exposure in the workplace and noise-induced hearing loss. Choi et al¹⁹ conducted a study on 150 farmers from 1999 to 2002. They revealed that exposure to noise in workplace elevated the risk of agricultural injuries in those farmers with hearing loss or hearing asymmetry. The use of occupational hearing protection was significantly associated with an increased risk of work-related injuries. The reason is that hearing loss interfere the person-to-person communications and may reduce the understanding warning signs and hence may increase the probability of work injuries³. This evidence suggests that noise may also increase the probability of occupational injuries indirectly through hearing loss.

In practice, exposure to noise in workplace is known to occur at different levels, depending on each worker's job and task. Since it was impossible to obtain a refined measurement of noise exposure for each worker, the noise exposure assessments were conducted as mean sound pressure levels over a general area in workplace rather than for each subject. Presumably even within that area, some workers might have higher exposure than others and workers might also move from one area to another. These issues might prone the results of the study to measurement bias. Furthermore, other factors associated with workplaces such as unfavorable light, heat stress, and safety of the machines, which may affect the probability of work accidents, were not evaluated in this study. This issue might have confounding effect on the association between SPL and occupational injuries.

Another limitation of this study was that the frequency of work injuries was determined based on the episodes of work injuries documented in the workers' medical recodes. However, there might be some work injuries, especially the mild ones, which might have occurred but were not recoded. This might prone the association of noise and work related injuries to underestimation. In addition to these limitations, all workers were men. Therefore, factors such as gender-specific hearing acuity and health care-seeking behavior might be different in men and women. For this reason, the results of this study cannot be generalized to female workers.

Despite its limitations, strengthen of the current study was that the correlation between noise exposure as well as hearing loss and work injuries was measured simultaneously using an

adjustment method. Hence, it helped to distinguish the proportion of work injuries attributable to noise in workplace adjusted for hearing loss and vice versa. Therefore, these results may be helpful for policymakers who plan preventive program to improve workplace safety and to reduce occupational injuries. However, more evidence based on long-term prospective cohort studies is needed to support the effect of noise exposure and occupational injuries.

Conclusion

Occupational noise exposure and hearing impairment have adverse effect on work safety and can increase the probability of work-related injuries. This means reducing occupational noise exposure can contribute to increase safety in workplaces where noise is a factor. Furthermore, using assistive listening devices may reduce risk of work injuries among hearing-impaired workers.

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Conflict of interest statement

The authors have no conflicts of interest to declare for this study.

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