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Occupational Noise Exposure and Hearing Impairment among Spinning Workers in Iran

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Abstract

Background: Hearing impairment (HI), resulting from noise exposure, can be incapacitating and irreversible.

Objectives: The present study aimed to determine the relationship between noise exposure and HI among workers and employees in a spinning industry.

Methods: This cross sectional study was conducted on 489 workers in a spinning industry in Iran during 2015. The census method was applied for the purpose of sampling. The hearing threshold of each ear was determined during work shifts, using Madsen audiometric device. HI was calculated, based on the guidelines by the American Medical Association (AMA). The effects of different variables on HI were assessed via regression analysis.

Results: The mean noise level at workplace was 88.87 $\pm$ 13.6 dB. The highest noise level in the sampled worksites was observed in the ring spinning section (94.1 $\pm$ 3.2 dB). Based on the results, maximum HI in both ears was 41%. The findings showed a significant relationship between HI and noise level, age, educational level, and work shift. Also, a linear equation was proposed in which each dB increase in noise level resulted in an approximately 0.5% decline in HI.

Conclusions: By introducing an equation, this study demonstrated that spinning workers, who are exposed to relatively high noise levels, are at risk of major HI. In addition, a number of potential contributing factors, including age, work experience, occupation, and work shift, were correlated with HI.

Keywords: Occupational Noise, Hearing Impairment, Hearing Impairment Predictors, Spinning Industry

1. Background

One of the most important sources of noise pollution is industrial noise. Meanwhile, 16% of incapacitating and irreversible cases of hearing loss in adults are caused by exposure to occupational noise worldwide (1, 2). The effects of noise exposure on the auditory system in working populations have been recognized in several countries (3-5). In general, prolonged exposure to excessive noise leads to adverse effects on one's performance. These effects are due to noise-related hearing damage and mental consequences, which reduce the efficiency of employee performance (1, 6-8).

Noise-induced hearing loss (NIHL) is one of the most common chronic hearing problems, which affects approximately 29 million Americans (9, 10). The pathophysiology of NIHL includes a combination of mechanical and metabolic factors. In fact, chronic exposure results in metabolic changes in cochlear hair cells and capillary vasoconstriction. Hearing loss, caused by exposure to high levels of occupational noise, depends on the duration of exposure, noise characteristics, and the individual's susceptibility (11-13). However, with respect to the reversibility of NIHL, the available data supporting the role of demographic factors are inconclusive (14).

NIHL is divided into 2 categories: temporary and permanent hearing loss (15). Permanent NIHL occurs by the degeneration of hair cells and is often irreversible (14, 16). In recent decades, a better understanding of NIHL has led to the adaption of noise exposure standards and a set of regulations in order to limit noise exposure in most countries. On the other hand, the increasing prevalence of NIHL in developing countries is due to the absence of pre-employment audiometric assessments and exposure background investigations (17).

The occupational safety and health administration (OSHA) estimated that more than 7.9 million workers in the U.S. are influenced by noise levels above 80 dB in their workplace. Also, the United States environmental protection agency (EPA) has estimated that more than 9 million U.S. workers in the industrial section are exposed to noise levels of 85 dB or above (18). Moreover, according to statistics reported by several organizations, more than 30 to 40 million Americans are regularly exposed to high levels of noise. Approximately 10 to 15 million people of all age groups have been reported to suffer from hearing problems in the U.S. (19, 20).

In Sweden, about 9% of the entire workforce is constantly exposed to harmful levels of noise. Hearing loss is quite costly for industries, and an indemnity of approximately 100 million dollars is annually paid in Sweden. It is claimed that an estimate of 14,000 Canadian dollars has been given to the Canadian compensation board for hearing impairment (HI) (17). Also, the reparation for hearing problems in the U.S. was estimated at around 200 million U.S. dollars in 1990 (21). In addition, in Greece, 10% of known illnesses and occupational diseases were caused by occupational exposure to noise (22).

In general, audiometric testing is used for the detection and diagnosis of HI (23, 24). Typically, the noise exposure limit is 85 dB in the workplace during an 8-hour work shift. Also, based on the increment in sound intensity, the exposure time should be reduced to half by implementing the rule of 3 dBA (25).

The industrial section in Iran is rapidly growing. Yazd is one of the major growing spinning districts in the country. Overall, workers in such industries (eg, textile and spinning) are concerned about the high noise levels during duty hours. However, few investigations have been carried out on HI in different industries, and little attention has been paid to predicting occupational noise exposure. With this background in mind, the purpose of the present study was to: (1) determine HI among spinning employees, (2) determine factors associated with HI, and (3) perform regression analyses in order to assess the effect of different variables on HI.

2. Methods

2.1. Subjects

This cross sectional study was conducted on workers in a spinning industry in Yazd, Iran during April-August 2015. The study population included all workers with at least 3 years of work experience, selected via census sampling (512 male employees). In order to check the exclusion criteria, a medical visit was arranged for all the participants. The exclusion criteria were as follows: (1) use of ototoxic medications; (2) cigarette smoking; (3) hypertension, hyperlipidemia, or diabetes; (4) exposure to non-occupational noise such as recreational music; and (5) eardrum perforation. Also, 12 workers with less than 3 years of work experience were excluded from the study. Finally, a total of 489 workers were included in the study. In case of impacted ear wax, re-examination was performed after ear washing. The employees worked 8 - 12 hours daily (5 - 6 days a week).

2.2. Procedure

A self-administrated questionnaire was designed to extract the demographic and occupational variables, including age, educational level, occupation, work shift, and work experience. The hearing threshold of each ear was determined with a calibrated Madsen audiometric device (model 100-2PS), using the ascending procedure at frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz while wearing a headphone with a red earbud in the right ear and a black earbud in the left ear (1, 14).

Audiometric assessments were conducted in the morning after the weekend (prior to the start of work shift); probable temporary threshold shift was excluded. On average, 20 to 30 minutes were required to perform the procedures for each worker; meanwhile, subjects did not wear any type of hearing protection prior to being tested. Clinical pure-tone audiometry was performed by 2 experienced audiologists, and the Pearson's correlation coefficient was calculated for the audiograms obtained by the audiologists at each frequency. The coefficients ranged between 0.8 and 0.95, indicating the sufficient agreement of audiograms obtained by the audiologists.

The sound pressure level was measured 3 times by a calibrated sound level meter (B8K 2232 model) during work-related activities (3 measurements per work area), and the mean of measurements was used for further analysis (20, 26). In addition to the hearing threshold, demographic data and some factors, such as age, work experience, occupation, work shift, and education, were gathered using a standard questionnaire, administered by a team of trained interviewers (14, 27). Work shift was defined as work longer than the ordinary hours (8 hours).

2.3. Calculation of Monaural and Binaural HI

One of the most reliable methods for the measurement of HI has been presented by the American medical association (AMA). According to this method, the hearing threshold was changed to HI percentage for monaural HI in the following steps:

1. First, the mean hearing threshold was calculated at 0.5, 1, 2, and 3 kHz for each ear.

2. Second, in each ear, the mean value was subtracted from 25 dB (the highest normal hearing threshold level) and then multiplied by 1.5%.

Also, to determine binaural HI in both ears, the lower percentage (dysfunction level of the better ear) was multiplied by 5, added to the value obtained for the other ear (worse ear's dysfunction level), and finally divided by 6 (28).

2.4. Statistical Analysis

All statistical analyses were performed with SPSS version 19 (SPSS Inc., Chicago, IL). Categorical variables were presented as frequency (percent). Normal distribution of numerical variables was assessed, using Kolmogorov-Smirnov test. To assess the relationship between noise and HI, the simple linear regression method was applied. Also, to find the role of age, work experience, and work shift, multiple linear regression model was applied. In addition, ANOVA test was used to examine the difference between ordinal variables (age, work experience, and occupation) and binaural HI. Tukey's post hoc test was used to determine the confidence intervals between variables and binaural HI. Also, paired-sample t test was used to detect the difference between HI in the left and right ears. P value less than 0.05 was considered statistically significant.

2.5. Ethical Considerations

The institution's ethics committee approved the present study (ethical approval code, MHRC 482) (2015). The participants were assured about their privacy. Also, the gathered data were analyzed as a whole rather than individually and remained confidential. All the participants were thoroughly informed about the aims of the study.

3. Results

The mean ($\pm$ SD) age and work experience of the subjects were 30.98 $\pm$ 5.3 and 5.79 $\pm$ 2.76 years, respectively. The study population consisted of 243 (49.69%) workers from the ring spinning section, 128 (26.17%) workers from the doubling section, and 118 (24.13%) workers from other sections (such as the laboratory staff and office workers) (Table 1). All workers at the factory were exposed to the mean ($\pm$ SD) noise level of 88.87 $\pm$ 6.13 dBA. Binaural HI was calculated at nearly 22.63% among the subjects. ANOVA test showed a significant association between binaural HI and occupation (P = 0.001) (Table 1).

HI in the left and right ears was reported to be 28.57% and 24.81%, respectively (Table 2). T-test results showed no significant difference in HI between the left and right ears. However, the ANOVA test results for binaural HI (in both ears) showed a significant difference among various age groups (P = 0.001). Also, occupation, educational level, workplace noise level, and work shift showed a significant relationship with binaural HI.

The post hoc test results demonstrated a significant difference in binaural HI among ring spinning workers and employees of other sections (P = 0.001). Also, there was a significant difference in binaural HI between the group with an educational level below high school diploma and the group including diploma holders and undergraduates.

The linear regression analysis of noise level and binaural HI presented the following formula:

Binaural HI = -28.385 + 0.537(X) (P < 0.0001)

Where X denotes a 1 dB increment in noise level. According to the extracted formula, with each dBA increase in the noise level, a 0.537% increment in binaural HI percentage was predictable.

Table 3 shows the results related to the prediction of binaural HI by the selected demographic predictors. Multiple regression analysis indicated that age, work experience, occupation, and work shift accounted for a significant amount of variation in total HI (P < 0.05). The regression analysis showed that age was the strongest predictor of binaural HI, and accordingly, approximately 30% of HI was predicted by the proposed model.

4. Discussion

The present results demonstrated that spinning workers, who are exposed to a relatively high noise level, have major HI. Also, each dB increase in noise level resulted in an approximately 0.5% deterioration in HI. In addition, in this survey, a number of potential contributing factors, including age and work shift, were correlated with binaural HI.

Based on the literature, the impact of noise on hearing health has not been assessed in linear regression models. According to the extracted equation in the current study, each dBA increase in noise level predicted a 0.537% increment in binaural HI percentage. In general, NIHL is a well recognized global concern (29). So far, several studies around the world have assessed the impact of industrial noise on hearing ability. In some of these studies, noise is likely to be more harmful in some work processes, especially cutting and punching activities. Textile industry, particularly weaving and spinning, clearly expose workers to a noisy workplace (30). In the present study, the spinning process caused a large amount of noise exposure for the employees. This finding highlights the necessity of engineering control as a major preventive priority in worksites.

The present study detected an increasing auditory deficit with advancing age, which is in line with a study by Hong et al. in Korea in 2001, who found a relationship between age and NIHL. These researchers indicated that hearing loss is more likely to be due to noise exposure rather than age 30. Also, the relationship between age and hearing loss, revealed in the current study, is in correspondence with the findings reported by Farrow and Ferrite (31, 32).

The adverse relationship between NIHL and work experience in this study can be considered an important fac-

Table 1. The Relationship Between Independent Variables and Binaural HI

Variables	No. (%)	Binaural HI	SD	P Value
Age group, y				0.001
22 - 29	138 (28.22)	15.56	8.87	
30 - 34	253 (51.74)	15.84	8.75	
> 35	98 (20.04)	25.35	10.59	
Educational level				0.042
Lower than high school diploma	128 (26.17)	19.78	11.12	
High school diploma	236 (48.27)	15.64	9.03	
Above diploma	125 (25.56)	7.58	4.87	
Work experience, y				0.025
1 - 4	116 (23.73)	16.49	9.726	
5 - 9	286 (58.48)	16.96	9.766	
> 9	87 (17.79)	18.87	12.55	
Occupation				0.001
Ring spinning worker	243 (49.69)	23.48	9.12	
Doubling worker	128 (26.17)	19.18	10.32	
Others	118 (24.13)	11.74	7.87	
Work shift				0.028
Morning	97 (19.83)	5.92	3.4	
Evening	68 (13.92)	10.31	3.9	
Rotating	234 (47.85)	18.75	10.13	
Morning and evening	90 (18.40)	13.72	6.98	

Table 2. Indices of Central Tendency and Dispersion of Age, Work Experience, Sound Intensity, and Binaural HI Among the Subjects

Variables	Number	Min	Max	Mean ± SD
Age, y	489	22	55	30.98 ± 5.3
Work experience, y	489	3	25	5.79 ± 2.76
Sound level at workplace, dBA	489	65	98	88.87 ± 13.6
HI in the left ear, %	489	1	38	28.57
HI in the right ear, %	489	1	36	24.81
Total HI	489	9	41	32.28

Abbreviations: Max, maximum; Min, minimum.

tor for hearing loss, as indicated by other investigators (33-36). Years of active work was considered as the basic measure for the chronic status of noise exposure. In this regard, calculation of daily hours of active work constitutes another measurement method, which is by itself more detailed (36). Since the auditory effect of noise is gradual, estimating the exposure time by only measuring the working hours is not adequate; therefore, use of a larger time frame, similar to the one applied in the present study, is often needed.

In the present study, we only used pure-tone auditory in our assessments. Overall, periodic evaluation of threshold levels using pure-tone auditory is the most important outcome measure in hearing health surveillance of exposed workers (37). Moreover, audiometric prediction of hearing loss is an important part of hearing conservation

Table 3. The Regression Analysis for Predicting Binaural HI Based on the Selected Demographic Predictors Among the Subjects[a]

Parameters	B	Std. Error	t	P Value
Age group, y				0.043
22 - 29	0.049	0.487	0.359	0.520
30 - 34	-0.311	0.398	-2.070	0.004
> 35		Reference Category		
Educational level				0.051
Below high school diploma	-0.280	0.486	-0.762	0.514
High school diploma	-0.693	0.433	-2.816	0.631
Above diploma		Reference Category		
Work experience, y				0.049
1 - 4	0.084	0.487	0.359	0.535
5 - 9	-0.211	0.398	-2.571	0.043
> 9		Reference Category		
Occupation				0.046
Ring spinning worker	0.128	0.959	2.985	0.031
Doubling worker	0.647	0.977	1.967	0.051
Others		Reference Category		
Work shift				0.048
Morning	0.024	0.059	0.802	0.652
Evening	-0.647	0.977	-1.002	0.508
Rotating	0.166	0.033	2.821	< 0.001
Morning and evening		Reference category		

[a] r^2 = 0.292, adjusted r^2 = 0.277, dependent variable: total HI.

programs (38).

NIHL is related to a combination of personal and environmental factors (39). Researchers often include some occupational and non-occupational risk factors, in addition to in-site noise to determine the distinct role of noise in hearing loss. In this manner, age, sex, work experience, and exposure to vibration have been evaluated (35, 40, 41). Moreover, non-occupational sources of sound, mainly personal music players and gunshots, are other important confounding variables (42). It should be noted that workers in low-exposure sites were considered as the control group in the present study. In fact, for reliable assessment of NIHL, it is critical to include a control group which has similar characteristics to the case groups (except for noise exposure) (35, 41).

The linear regression between occupational noise level and HI was the main subject of this survey. Although hearing loss due to occupational noise pollution is majorly specified at frequencies of 3000 to 6000 Hz, according to some guidelines such as OSHA, Standard Threshold Shift (STS) is based on changes in the threshold at frequencies of 2000, 3000, and 40000 Hz. We predicted that this new insight (effect of noise at low frequencies) could follow a logical pattern; however, more comprehensive studies are needed to confirm this statement.

Based on the regression analysis, binaural HI was associated with noise level, age, educational level, and occupation. Moreover, binaural HI was significantly associated with the noise pressure level. Although some studies have revealed that variables, such as non-occupational noise exposure, medical condition, and type of industry have no independent association with hearing loss (35), some have reported results in line with the present study (43, 44). In addition, smoking and alcohol use have been shown to affect hearing ability (12).

In every study on NIHL, a defined method has been selected for evaluating the hearing status of workers, including a threshold shift at a frequency of 4000 (with or without 3000 and 6000 Hz), mean thresholds of 3000, 4000, and 6000 Hz, mean thresholds of 500, 1000, and 2000 (or

3000 Hz), and also occurrence of notch. In the present study, we used the AMA method for binaural HI (28). Indeed, this estimation was based on a 25-dB low fence and a 92-dB high fence, which were finally measured at 0% to 100%. Also, word recognition tests are incorporated in binaural HI assessment for a better understanding of hearing performance. However, they slightly improve the objectiveness of binaural HI estimation, and therefore, they play an insignificant role in legal matters (45).

The present study had a number of strengths. First, we used binaural HI as a somewhat original tool to assess the hearing status of a working population. Second, as noted earlier, a linear regression model was designed as a computable scale for assessing noise-related health outcomes. Third, hearing loss among spinning workers has been less assessed by Iranian researchers, and the present study was among the first investigations. On the other hand, an important limitation of this study was that some dependent variables, such as smoking habit, were not evaluated. In this regard, in a number of studies, a communication performance scale, as a self-assessment tool, has been incorporated to calculate binaural HI.

4.1. Conclusions

In this study, we aimed to determine the hearing status of spinning workers in Iran by estimating HI using a novel model in a work setting. In this model, the relationship between HI, noise exposure, and some contributing factors was remarkable. Although it is difficult to generalize our findings to all noisy work stations in different settings, close attention should be paid to the hearing status of noise-exposed workers via impairment estimation systems in periodic health surveillance programs.

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Footnote

Conflicts of Interest: The authors declare no conflicts of interest in this study.

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