2008-5435/14/63-172-178
INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE

IJOH 8: 172-178, 2016

ORIGINAL ARTICLE

The Time of Hearing Loss Onset among Workers in the Copper by-Industry and its Effective Factors

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Received April 20, 2016; Revised May 29, 2016; Accepted July 22, 2016

This paper is available on-line at *http://ijoh.tums.ac.ir*

ABSTRACT

Extended exposure to noise can cause permanent hearing damage. This study aimed to determine the incidence time of hearing loss and its effective factors in workers exposed to noise. This retrospective cohort study, was conducted on a total of 273 workers in various sectors of Kerman Copper by-industries Co. Their hearing status and the incidence of hearing loss (hearing threshold higher than 25 dB) were measured at regular intervals through audiographs. Survival analysis was done using the Kaplan-Meier method and Cox Regression analysis through STATA 12. The time range (from the onset of the risk to the incidence of hearing loss) was between 8 to 14 years. Systolic blood pressure alone and in interaction with years of employment was significantly related to the incidence of hearing loss at all frequencies. Initial hearing threshold and age at employment also had a significant impact on the onset time of hearing loss. The interaction between age at employment×initial hearing threshold; and years of employment×age at employment; in both low and high frequencies had a significant impact on the incidence time of hearing loss. Despite the availability of protective equipment in this industry, hearing loss occurred in at least half of the workers after about 10 years. High systolic blood pressure, age at employment, and initial hearing thresholds probably play a role in the incidence time of hearing loss.

KEYWORDS: *Occupational hearing loss, Survival analysis, Cox regression, Longitudinal study*

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INTRODUCTION

Noise and noise-induced hearing loss are huge industrial health problems all over the world. [1]. Exposure to noise at work is associated with many adverse effects including hearing loss, tinnitus, acute hypertension, sleep disorders, and reduction in performance. The most important side effect of exposure to noise is serious damage to the inner ear's auditory mechanisms that leads to hearing loss [2]. Long-term exposure to noise often damages the inner ear, and especially the hairy cells in the Corti organ, and eventually causes noise-induced hearing loss (NIHL). This disorder is sensorineural and bilateral which first damages that part of the cochlear which is sensitive to about 4000 Hz (3000 to 5000 Hz) and gradually damages hearing on adjacent frequencies, up to to 8000 Hz [3].

Although noise-induced hearing loss (NIHL) is potentially preventable, it is now regarded as one of the major public health problems and is one of the 10 leading causes of work-related diseases [4]. For instance, noise-induced hearing loss (NIHL) has been reported as one of the most common occupational diseases in the Netherlands [5]. Noise pollution is not limited to countries with advanced technology. In developing countries, noise pollution can be even more severe; and temporary or permanent hearing loss are more prevalent [6].

Estimates show, that about six hundred million workers are exposed to occupational noise in the world [7], and based on the available data, it appears that about 2 million workers are exposed to excessive noise in Iran [8]. Exposure to noise above 85 dBA is reportedly linked to various types of hearing loss [9]. Therefore periodic audiometric tests are very important for people who work at intensities greater than 85 dBA; because by screening, hearing disorder are identified in early stages; and affected workers can be taken away from the noisy environment [10].

One of the oldest, simplest and yet most reliable audiology tests is pure tone audiometry or PTA. Audiometry can qualitatively and quantitatively measure hearing loss and each person's hearing threshold at certain frequencies can be obtained. The main purpose of audiometry and audiogram records is to determine the severity and type of hearing loss in individuals. In order to determine the amount of hearing loss, the World Health Organization (WHO) considers the average hearing threshold at 500, 1000, 2000, and 4000 Hz [11].

The objective of this study was to determine the time of hearing loss onset among workers in the Copper by-Industry and the factors effective on this process. The results of this study may help postpone the negative effects of industrial noise on workers' hearing.

MATERIALS AND METHODS

This retrospective cohort study was conducted in 2013 on workers of the Shahid Bahonar Copper by-industries of Kerman. Eight hundred workers exposed to noise higher than 85 decibels were selected.

According to the classification of the National Standard Institute and The American Academy of Otorhinolaryngology, hearing loss between 25 to 40 dB is slight, between 40 to 55 is mild, 55-70 is moderate, 70-90 is severe and more than 90 is profound or permanent deafness [12].

In this study, the incidence of a hearing threshold higher than 25 dB at any frequency was considered as the incidence of hearing loss or occurrence of the event under study. Time to event for each worker was defined as the length of time elapsed since employment until the incidence of hearing loss.

Workers with under 10 years of work experience were excluded, because in order to confidently relate hearing loss to chronic noise exposure, it is preferred to include individuals who have been exposued to noise for at least 10 years [13]. Also workers who had been exposed to noise in their previous jobs or at their second job; as well as the workers who had hearing problems at the time they were employed were excluded from the study. Workers who had a long-term history of ototoxic drug use, had acute hearing injuries, or tympanic membrane rupture, were excluded from the study as well.

After reviewing the records and observing the exclusion criteria, a total of 273 workers were eligible to participate in this study.

Information such as systolic and diastolic blood pressure, years of employment, age, smoking, height, weight, and threshold at different frequencies were taken from the workers health records and the researchers of this study were not involved in data collection.

Blood pressure data was also analysed in this study, because there are studies that think high blood pressure may be related to hearing loss [14-15].

Statistical analysis was performed at different frequencies, as well as low frequencies (HTL-L), which was the average hearing threshold at frequencies of 500, 1000 and 2000 Hz; and high frequencies(HTL-H), which was the average of hearing threshold at frequencies of 4000 and 8000 Hz. Data analysis was done using Kaplan-Meier curves and Cox regression through STATA 12.

Published online: September 25, 2016

RESULTS

Among a total of 273 workers, 108 (39.5%) workers were smokers and 245 (90%) had normal blood pressure (equal to or less than 140/90 mm Hg) and 90% of the subjects were under 43 years of age. The descriptive statistics of other variables can be seen in Table 1. Statistical calculations showed that there was no significant difference between the left and right ear hearing loss. Therefore, the average hearing loss in both ears was used for each individual.

Table 2. Descriptive statistics of the workers surveyed

Variables	Mean ± Standard deviation
Years of employment (years)	14.50±2.27
Initial audiometry (years) Age of	24.97±3.22
Age of last audiometry (years)	37.28±5.49
Initial Systolic blood pressure (mmHg)	110.80 ± 0.68
last Systolic blood pressure (mmHg)	130.50 ± 1.12
Initial Diastolic blood pressure (mmHg)	7.68 ± 0.51
last Diastolic blood pressure (mmHg)	80.96 ± 0.71
Systolic blood pressure (mmHg)	125.60±0.93
Diastolic blood pressure (mmHg)	70.66±0.59
Initial BMI (kg/m^2)	23.09 ± 3.56
Last BMI (kg/m^2)	26.31 ± 3.41
Mean BMI (kg/m^2)	24.99±3.72
Initial hearing threshold at 250 Hz (dB)	12.05±4.15
Initial hearing threshold at 500 Hz (dB)	11.60±3.99
Initial hearing threshold at 1000 Hz (dB)	10.79±3.85
Initial hearing threshold at 2000 Hz (dB)	10.59±3.97
Initial hearing threshold at 4000 Hz (dB)	12.25±4.71
Initial hearing threshold at 8000 Hz (dB)	12.90±4.58

Fig.1 shows the hazard rate of hearing loss in workers in terms of working years at 4000 Hz. The Hazard Rate increases as the years go by. Because of the similarity of the figures in other frequencies, they were not included in this text. In Fig.2, the horizontal line is the years of employment and the vertical line is the percent of hearing loss in the population. As it can be seen, the percent of people with hearing loss is decreasing and by the 20th year it is close to 0%.

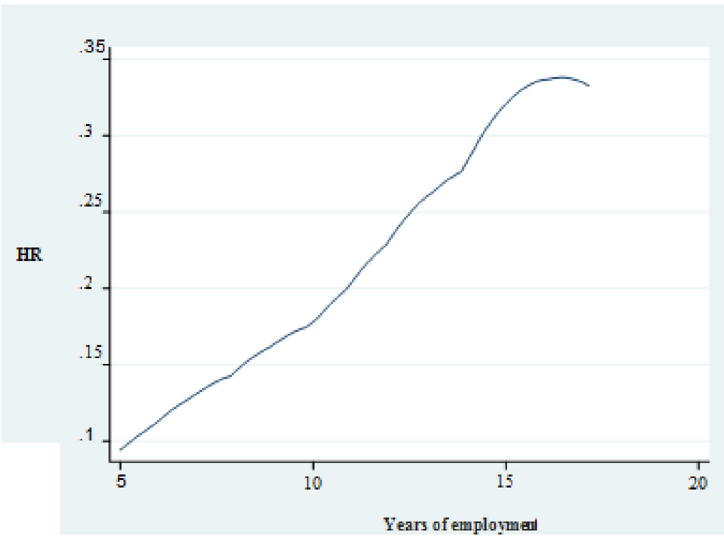

Fig.1. The hazard rate of hearing loss at 4000 Hz

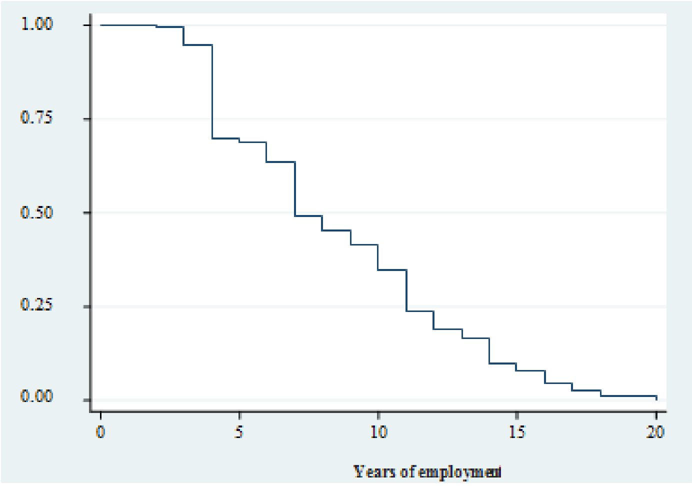

Fig.2. The Kaplan-Meier survival diagram at 4000 Hz

Table 2. The incidence of hearing loss in different frequencies

Frequency (Hz)	Incidence Rate (number of cases in each person-year)	Person – Years at risk	Survival time in years		
			25%	50%	75%
250	0.050	3492	11	14	17
500	0.065	2682	4	12	18
1000	0.053	2884	4	14	19
2000	0.075	2672	4	11	16
4000	0.092	2819	7	11	14
8000	0.110	2279	4	8	4
Low frequencies	0.038	3674	12	16	12
High frequencies	0.089	2901	7	11	7

Table 2 shows the incidence of hearing loss in person-years. The median time of onset of hearing loss was between 8 and 14 years in different frequencies. The incidence of hearing loss in one year at 8000 Hz was 0.11 and in 4000 Hz was 0.092. The incidence of hearing loss at low and high frequencies was 0.038 and 0.089, respectively. The results of Cox univariate and multivariate regression are shown in Tables 3 and 4. Multivariate regression analysis showed that in all frequencies, the interaction of hearing threshold×years of employment, as well as initial hearing threshold×age at employment and the interaction of years of employment×systolic blood pressure had a significant effect on the incidence time of hearing loss.

Systolic blood pressure was significant on the incidence time of hearing loss at different frequencies, but other variables alone had no significant effect on the incidence of hearing loss.

Also, only at 500 Hz, the effect of average body mass and the interaction of age at employment×average BMI was significant in the onset time of hearing loss.

Tables 3. Results of Univariate Cox Regression for the factors related to time of hearing loss in workers

Variable	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz	Low frequencies	High frequencies
Initial hearing threshold (dB)	0.580 (1.009)	0.160 (0.970)	0.700 (1.010)	0.490 (0.980)	0.740 (1.004)	0.840 (1.001)	0.650 (0.990)	0.800 (1.001)
Age at employment (years)	0.085 (1.030)	0.110 (1.030)	0.500 (1.010)	0.250 (1.020)	0.930 (1.001)	0.650 (0.990)	0.420 (1.020)	0.110 (1.030)
Smoking	0.040 (0.730)	0.0160 (0.690)	0.280 (0.830)	0.540 (0.910)	0.310 (0.870)	0.670 (0.950)	0.050 (0.720)	0.640 (0.940)
Systolic blood pressure (mmHg)	0.450 (0.940)	0.680 (0.970)	0.550 (0.950)	0.870 (0.980)	1.000 (1.001)	0.270 (0.930)	0.760 (0.970)	0.730 (1.040)
Diastolic blood pressure (mmHg)	0.860 (1.020)	0.440 (1.100)	0.160 (1.190)	0.110 (1.190)	0.810 (1.020)	0.440 (0.920)	0.083 (1.270)	0.800 (1.001)
Mean BMI (kg/m^2)	0.170 (1.020)	0.025 (1.040)	0.040 (1.030)	0.063 (1.020)	0.870 (0.990)	0.940 (0.990)	0.088 (1.030)	0.050 (1.030)

Published online: September 25, 2016

Initial hearing threshold × Years of employment	0.000 (0.990)	0.000 (0.990)	0.001 (0.990)	0.001 (0.990)	0.003 (0.990)	0.007 (0.990)	0.0001 (0.990)	0.0001 (0.990)
Years of employment × Age at employment	0.000 (0.990)	0.000 (0.990)	0.000 (0.990)	0.000 (0.990)	0.000 (0.990)	0.000 (0.990)	0.000 (0.990)	0.000 (0.970)
Years of employment × Mean BMI	0.0001 (0.980)	0.0001 (0.990)	0.0001 (0.990)	0.0001 (0.990)	0.0001 (0.980)	0.0001 (0.990)	0.000 (0.970)	0.000 (0.980)
Years of employment × Smoking	0.0001 (0.930)	0.0001 (0.940)	0.0001 (0.930)	0.0001 (0.940)	0.0001 (0.960)	0.0001 (0.960)	0.0001 (0.940)	0.000 (0.900)
Years of employment × Systolic blood pressure	0.0001 (0.970)	0.0001 (0.970)	0.0001 (0.970)	0.0001 (0.970)	0.0001 (0.990)	0.0001 (0.990)	0.0001 (0.970)	0.000 (0.940)
Years of employment × Diastolic blood pressure	0.0001 (0.950)	0.0001 (0.940)	0.0001 (0.960)	0.0001 (0.960)	0.0001 (0.980)	0.0001 (0.980)	0.0001 (0.960)	0.000 (0.940)
Age at employment × Smoking	0.182 (0.990)	0.106 (0.990)	0.460 (0.990)	0.850 (0.990)	0.330 (0.990)	0.560 (0.990)	0.0160 (0.990)	0.820 (1.001)
Age at employment × Systolic blood pressure	0.280 (1.001)	0.190 (1.001)	0.880 (1.001)	0.380 (1.001)	0.940 (1.001)	0.370 (0.990)	0.580 (1.001)	0.080 (1.001)
Age at employment × Diastolic blood pressure	0.130 (1.003)	0.064 (1.004)	0.230 (1.002)	0.080 (1.003)	0.840 (1.000)	0.470 (0.990)	0.120 (1.001)	0.160 (1.002)
Age at employment × Mean BMI	0.050 (1.000)	0.005 (1.001)	0.080 (1.001)	0.048 (1.007)	0.960 (0.990)	0.770 (0.990)	0.088 (1.000)	0.013 (1.003)
Age at employment × Initial hearing threshold	0.000 (0.990)	0.000 (0.980)	0.000 (0.980)	0.000 (0.980)	0.000 (0.990)	0.000 (0.980)	0.000 (0.980)	0.000 (0.980)

Table 4. Results of Multivariate Cox Regression for the factors related to time of hearing loss in workers

Variables	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**8000 Hz**	**Low frequencies**	**High frequencies**
Initial hearing threshold(dB)	0.540 (0.950)	0.180 (1.110)	0.700 (1.020)	0.240 (1.09)	0.090 (1.080)	0.280 (1.050)	0.000 (1.550)	0.000 (1.860)
Age at employment(years)	0.990 (0.990)	0.027 (1.300)	0.400 (1.020)	0.890 (1.002)	0.710 (0.990)	0.530 (0.980)	0.000 (1.180)	0.001 (1.200)
Systolic blood pressure(mmHg)	0.000 (2.300)	0.000 (1.730)	0.000 (1.740)	0.000 (1.610)	0.031 (1.180)	0.060 (1.160)	-	-
Initial hearing threshold × years of employment	0.000 (1.030)	0.000 (1.020)	0.001 (1.010)	0.006 (1.010)	0.028 (1.007)	0.060 (1.020)	-	-
age at employment × Initial hearing threshold	0.000 (0.960)	0.000 (0.96۰)	0.000 (0.97۰)	0.000 (0.970)	0.000 (0.970)	0.000 (0.960)	0.000 (0.980)	0.000 (0.980)
years of employment × Systolic blood pressure	0.000 (0.930)	0.000 (0.950)	0.000 (0.950)	0.000 (0.960)	0.000 (0.980)	0.000 (0.970)	-	-
Age at employment × Mean BMI	-	0.039 (1.310)	-	-	-	-	-	-
Mean BMI	-	0.035 (0.990)	-	-	-	-	-	-
Age at employment × years of employment	-	-	-	-	-	-	0.000 (0.980)	0.000 (0.940)

DISCUSSION

This study was a longitudinal study conducted to investigate the effects of noise on time of hearing loss based on the audiometries of workers exposed to noise in their work environment with at least 10 years work experience. This study took a different approach from previous studies [3, 6, 8]. The main objective of this study was to determine the incidence time of hearing loss in a group of workers exposed to industrial noise.

This cohort was conducted on workers of the Shahid Bahonar Copper by-industries of Kerman who were exposed to noise above 85 dB in their workplace for 8 hours a day. In this study, possibly because workers were constantly moving and their workplace was a closed building, symmetrical bilateral hearing loss with no significant difference had occurred.

Hearing loss as a permanent change in the hearing threshold is the result of extended exposure to noise above the permissible threshold, and happens initially at 4000 Hz and if the exposure is not stopped, hearing loss will also happen in other frequencies. Noise-induced hearing loss in both ears are usually bilateral and symmetric; however, it can be more severe in one ear due to working conditions [16].

In a study on workers exposed to noise in an agro-industrial factory, researchers reported that the average time from exposure to event (hearing loss) was 22 years [1]. In this study, at 4000 Hz, the median time to event was 11 years.

In a study based on data from two centers;

i.e. Occupational Surveillance Scheme for Audiological Physicians (OSSA) and Occupational Physician Reporting Activity (OPRA) from 1997 to 2000 in the United Kingdom, the annual incidence of hearing loss was respectively as 1.94 and 1.23, per 100,000 workers in the average of 4000, 1000 and 2000 Hz [17]. This present study showed low and high frequency hearing loss respectively as 0.0126 and 0.04 in 100,000 person years.

A study by Lookzadeh et al in tile industry workers showed that after 10 years of exposure to noise, work-related hearing loss increases significantly [18]. Our study also showed that at all frequencies within 8-12 years after exposure, 50% of the people will suffer from hearing loss.

A study by Schink et al about hearing loss in musicians in comparison to unexposed people, found that the crude incidence rate of hearing loss among professional musicians was 1.27 and the adjusted hazard rate was 1.45. Also, the adjusted hazard rate for occupational hearing loss was 3.61 and the incidence of occupational hearing loss among the exposed was 112 per 100,000 person–years. Their study also showed the significant effect of age at employment on occupational hearing loss [19]. In our study, the effect of age at employment on hearing loss was significant at low and high frequencies.

In the study done by Farhadian et al, in order to assess the risk factors of hearing loss in workers of a metal industry, smoking was reported to be related to hearing loss [20]. However, our study showed no effect of smoking on the incidence time of hearing loss.

In other studies, Cox regression models showed that factors such as alcohol consumption and exposure to metal fluids are related to the onset of hearing loss [21]. However, in another study, consumption of alcohol was reported as a protective factor for hearing loss [22]. Data for alcohol consumption was not available in this study, however as Iran is a religious Muslim country, with alcohol trade and consumption being illegal; we think very few workers consumed alcohol.

Another study showed a significant relationship between hearing loss and blood lead levels, and also urinary cadmium levels [23]. These factors although important were not examined in this study and can be considered as a limitation of this study.

We did not find any more studies about the factors affecting the incidence time of occupational hearing loss to compare with.

CONCLUSION

The results of the current study showed that high systolic blood pressure may accelerate the time of hearing loss. Age at employment and initial hearing threshold alone and in combination with each other or with years of employment are effective on the time of development of hearing loss. Accordingly, authorities should better consider these factors in occupational health care programs.

ACKNOWLEDGEMENT

The authors declare that there is no conflict of interests.

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