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The Relationship between Occupational Noise Exposure and Noise Induced Hearing Loss (NIHL) in Small-Scale Industries: A Case Study in the City of Damavand, Iran

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Abstract

Background: Exposure to the excessive levels of occupational noise is one of the principal harmful agents affecting the workers' health. This study aimed to investigate the relationship between the occupational noise exposure and the hearing loss caused by working in small-scale service industries in the city of Damavand, close to the metropolitan capital city of Tehran, Iran.
Methods: This descriptive cross-sectional study investigated the occupational noise levels within the 90 small-scale industries (mainly service industries and workshops) working under the supervision of Damavand healthcare network governed by the Iranian ministry of health and medical education. A sound level meter (Bruel and Kjær 2250) was employed to determine the noise exposure levels based on the dB A, and according to the standard ISO 9612: 2009. The audiometric exam tests were performed by an audiometer (model MEVOX SA-900). The obtained data were then analysed by SPSS 16, using linear regression and t-test.
Results: The highest measured 8-hour equivalent continuous sound pressure levels (Leqs) were associated with auto body mechanics (89.2 dB A), foundry and casting workers (88.8 dB A), aluminium products fabrication workers (86.32 dB A), blacksmiths and forging (85.8 dB A) carpenters (84.93 dB A), and cabinet manufacturers, respectively (84 dB A). Results from the hearing threshold shifts of the workers from the studied occupational groups revealed that the highest work-related hearing loss associated with the right ear occurred among the auto body mechanics, aluminium products fabrication workers and carpenters. However, the most significant work-related hearing loss associated with the left ear was noticed among carpenters, aluminium products fabrication workers, and auto body mechanics, respectively. Pearson correlation coefficient was tested between Leqs, work experience and hearing loss, and the results implied that the progress of workers' hearing loss was correlated with the increase in work history and experience.
Conclusions: The 8-hour Leqs and work experience were, respectively, the most important factors affecting the rate of hearing loss among the participants of this study.

Keywords: Noise-Induced Hearing Loss, Sound Pressure Level, Small-Scale Industries

1. Background

Nowadays, particularly in the developing countries, small and medium-sized industries are attempting to lower their costs and enhance their profits mainly through increasing their production (1). Therefore, it is evident that more workers are being exposed to occupational harmful agents at their workplace. It is estimated that over 1,000 million people are employed in small- scale industries worldwide (2), many of whom come from developing countries where the state of occupational health and safety in small and medium- scale manufacturing industries is really poor or not at the top of the health issues or policies (3, 4).

Similar to the other developing countries, Iranian small-scale businesses and the informal sectors constitute the largest economic sectors, and represent the leading employment creation source in the country. According to the statistics from the Iranian Healthcare Network System, the small scale workshops (with less than 20 workers) constitute about 96% of the whole industrial workshops in the country, signifying the fact that more than 47% of the whole Iranian labour force are working in these small units.

While Iranian large scale industries have been running systematic occupational health and safety (OHS) management programs, and are usually observed and inspected by the inspectors from the Iranian ministry of health and medical education and ministry of labour, cooperatives and Social welfare, it seems that even the basic OHS concerns associated with the small scale industries have often been ignored. The overabundance of these small units along with their sparsity and unwillingness of the employers and employees to implement or follow OHS programs have led to the situation in which the risks of exposure to the occupational harmful agents constantly remain high.

Among physical harmful agents present at the workplaces, exposure to the high levels of occupational noise is one of the harmful factors affecting the health of a large number of workers in many working environments. The development of industries and the introduction of new technologies and machinery to the workplaces have increased the frequency and duration of noise exposure in industrial settings (1). Being permanent, irreversible and developing, occupational noise-induced hearing loss (ONIHL) is a significant health problem and a prevalent global occupational health hazard with considerable social, economic, and physiological impacts, including impaired hearing, poor communication, and disturbed well-being. Based on the world health organization (WHO), occupational noise accounts for 16% of the disabling hearing loss in adults (more than four million DALYs), with the disease burden estimates ranging from 7% in developed countries to 21% in underdeveloped and developing nations (5). Dobie (6) stated that almost 10% of the burden of hearing loss in the United States was attributed to occupational noise. In many Asian countries, NIHL is the most prevalent occupational disease, and the highest occurrence of hearing loss resulting from noise exposure in the world is attributable to Asian countries. Due to the large number of affected workers and the fact that in many Asian countries access to health services and preventive programmes are limited, NIHL is a serious health issue. Lack of awareness about NIHL among employers, employees, and healthcare professionals is one of the main barriers for the prevention of NIHL in Asia (7).

It is estimated that almost 2 million workers in Iran are exposed to noise levels exceeding 85 dBA TWA, which has been determined as harmful by the Iranian Ministry of Health and Medical Education (8).

Despite the fact that the previous studies have almost extensively explored the effects of occupational noise on human health, due to unidentified reasons, small scale businesses, industries and workshops have not been significantly the subject of such studies. However, several researches, particularly in developing countries have turned their attention to this issue.

Singh et al. revealed that the type of job was significantly associated with the development of NIHL among Indian iron and steel small and medium enterprises in a way that the occurrence of NIHL was significantly high among the workers of forging section compared to the workers from the other sections of that industry (9). Singh et al. also stated that the proportion of small and medium- scale industry workers exposed to the exceeding level of heat stress and noise exposure is excessively high, and compared to workers of other sections, the workers of forging and grinding sections faced the higher risk of developing NIHL at higher frequencies (3). In another study conducted among five small- scale hand tool-forging units in Northern India, it was established that workers of such units were exposed to the maximum noise levels, because their working schedule usually exceeded eight hours a day and five days a week (10).

Boateng and Amedofu came up with a strong correlation between the noise exposure levels, duration of exposure and development of ONIHL among workers of corn mills and saw mills in Ghana (11).

Results from the study conducted by Mbuligwe revealed that small-scale industries in Dar es Salaam city of Tanzania present a serious source of environmental noise pollution in their neighborhoods, posing even non-occupational groups of people to the risks associated with exposure to higher levels of noise (12).

The study conducted in the Ghanaian small-scale enterprises demonstrated that market mill workers were exposed to the noise levels ranging from 85.9 to 110.8 dBA, which far exceeded the permissible levels of 85 dBA. The authors of this study also concluded that the level of noise in this unregulated industry was likely to have contributed to a prevalence of significant sensorineural hearing impairment, and possible NIHL among mill workers (4).

Ahmadi et al. found that the auto body mechanics in the city of Qazvin in Iran are exposed to the excessive levels of occupational noise, contributing to the mean ONIHL of more than 22.1 dB (13).

Robinson et al. in a study on woodworkers in Nepal found that the workers were exposed to noise levels ranging from 71.2 to 93.9 dBA, and reported that 31% of the carpenters and 44% of the sawyers met criteria for NIHL, with 7 and 17% meeting world health organization (WHO) criteria for hearing impairment (HI), respectively (14).

Gabe in his survey of occupational health and safety in small-scale clothing enterprises in Botswana found that many workers in this sector were exposed to the excessive levels of occupationally generated noise (15).

There is strong research evidence that exposure to high levels of occupational noise is the main contributor to developing ONIHL (16-26).

This study aimed to investigate the relationship between the level of exposure to occupational noise in different small-scale service industries and the permanent noise-induced hearing loss in terms of age and years of work experience of the workers of medium and small-scale industries in the city of Damavand in Iran.

2. Methods

This cross-sectional study was conducted in two phases: Environmental noise monitoring, and audiometric tests. The participants were randomly selected from 90 small- scale industries and workshops under the supervision of Damavand health service network.

2.1. Phase 1

In the first phase of the study, managers and employees were provided with the necessary explanations about their participation and the objectives of the study. Then the required information in terms of workplace environment and employees were obtained, and the noise level measurement was conducted in three steps as follows:

2.1.1. Calculating Workers' Exposure

According to the standard ISO 9612: 2009, sound pressure levels (SPLs) were measured and recorded close to the employees' hearing zone in dBA on the spots where they stopped or passed. Having determined the level of background noise and the number of hours of exposure, the 8-hour equivalent continuous sound pressure levels (Leqs) were calculated. In addition, the maximum SPL and Leq and sound frequency analysis were, respectively, measured and recorded at the nearest point to the workstations.

The measurements were performed in two cases: When the workers were performing certain tasks and the devices and machines were on, and when all the devices and machines were turned off. The obtained results from the measurement in the latter case were considered as the background noise.

For the first case, duration of each task, along with the noise exposure throughout such time duration were determined.

For the second case, by considering the background noise as uniform, only short-term measurements were used, and the results were extended to the time when the devices and machines were turned off, and the workers were only exposed to the background noise. Such findings along with Equation 1 eventually determined the workers 8-hour equivalent level of exposure.

$$L_{eq}\left(dB\right) = 10LoG\left[\frac{1}{8}\sum\nolimits_{1}^{n} t_i 10^{\frac{SPL}{10}}\right] \quad (1)$$

2.1.2. The Background Noise

To determine the level of background noise, the principal sources of generating noise in the workplaces (mainly machinery and instruments) were turned off, and the level of background noise in the workplace was measured and recorded.

2.1.3. Determining the Noise Level at the Workplace

To determine the noise level of the workplace, each workplace was firstly divided into the regions with identical dimensions and the measurements were performed in the center of each region. Moreover, Leq s was measured and recorded at the center of the workplace. Then, by considering the workers' exposure to equivalent sound pressure levels of noise generating machinery, the number of hours of exposure and the level of background noise, we calculated the 8-hour Leq fine.

Noise levels were determined throughout all workstations, using a sound level meter (Bruel and Kjær type 2250 that conforms to IEC-6172-2 and ANSI-S type1). A handy, portable sound calibrator (Bruel and Kjae r type 4231) was used for calibration of the sound level meter.

To investigate the possible effects of variables such as SPL (combined 8-hour Leq) and work experience and age on the level of participants' NIHL, the obtained results were then analysed by SPSS 16 Software, using the multiple linear regression, with the significance level of less than 0.05 ($P < 0.05$).

2.2. Phase 2

The audiometric exam tests were conducted in a standard acoustic booth by an audiometer device (model MEVOX SA-900). The tests were designed in a way that firstly in each workplace one participants was randomly selected and after they completed a form (in the morning, before the beginning of the daily work), the test was performed. The tests were conducted by an experienced audiologist fulfilling ISO 8253-1:2010 criteria.

Pure-tone air conduction audiometric test was conducted to determine the hearing thresholds in the frequencies of 0.5, 1, 2, 3, 4, 6 and 8 kHz for both ears of each participant, respectively. Then, for better comparison and having a single-digit index, each ear hearing loss, which is defined as an average hearing threshold at frequencies of 0.5, 2 and 4, was calculated.

To determine the effects of age-related hearing loss (presbycusis), first such effect was eliminated and then the obtained results were deducted from the hearing thresholds at different frequencies, and the noise-induced hearing loss (NIHL) was calculated.

3. Results

In this study, 90 employees (on average one employee from each workplace) from small- scale industries (industries with less than 20 workers) were audiometrically examined. The majority of the employees had secondary education (n = 32, 35.6%), whereas only a minority of the employed workers did not have university degrees (5 participants, 5.6%).

Of the surveyed employees, 81.1% were married and only 18.9% were single. Most of the participants were from the workplaces with less than five (78.9%) employed individuals, and the lowest number of our participants came from the workshops with 16 to 20 employees (1.1%). The workplaces with two employed individuals were the most frequent (n = 31, 34.4%).

The largest number of surveyed workplaces were located next to the main streets (n = 44, 48.9%), and the lowest were in the industrial town (n = 3, 3.3%).

Tables 1 and 2 demonstrate the data associated with the measured noise levels within the workshops along with the information about the participants' age and work experience, according to their type of jobs.

Table 1. Distribution of the Studied Workshops and the Work Groups

The Type of Industry	The Type of Workshop	No. (%)
Metal Industries	Forging	11 (12.3)
	Aluminium products manufacturing	4 (4.4)
Mineral Industries	Masonry stone cutting and stone selling	7 (7.7)
	Stone crushing	8 (8.8)
Casting and foundry Industries	Casting	9 (10)
	Casting with sandblasting	6 (6.7)
Wood working Industry	Carpentry	9 (10)
	Cabinet manufacturing	6 (6.7)
Automobile service or repair workshops	Mechanics	6 (6.7)
	Auto body mechanics	6 (6.7)
	Automobile oil exchange	3 (3.4)
Other industries	Other industries	15 (16.6)
Total		90 (100)

According to Table 3, the mechanics had the highest mean age and the foundry and casting workers had the lowest mean age.

In terms of work experience, car mechanics and auto body mechanics were found to be the most experienced workers, while among all the studied work groups foundry and casting workers were the least experienced (Figure 1).

Table 2. The Average Age and Years of Work in Different Occupations[a]

The Type of Industry	Age, y	Work Experience, y
Forging	39.09 ± 13.3	17.8 ± 11.8
Aluminium products manufacturing	46.6 ± 7.3	23 ± 7.3
Carpentry	43.06 ± 11.01	20 ± 10.5
Cabinet manufacturing	2.33 ± 8.6	10.8 ± 4.61
Mechanics	47.5 ± 14.3	27.5 ± 14.1
Auto body mechanics	41.16 ± 10.8	23.5 ± 13
Automobile oil exchange	42 ± 4.2	19 ± 5.65
Stone crushing	37.2 ± 15.1	20.8 ± 12.1
Masonry stone cutting and stone selling	37.5 ± 13.1	13.5 ± 11.4
Casting	35.3 ± 7.9	9.3 ± 4.2
Casting without sandblast	28.2 ± 6.04	3 ± 1.9
Other industries	39.06 ± 11.9	16.4 ± 11.3

[a]Values are expressed as mean ± SD.

Table 3. Exposure Levels (Aggregation of Levels) in Different Studied Occupations (dB A)[a]

The Type of Industry	Exposure Levels
Forging	97.17 ± 6.69
Aluminium products manufacturing	99.73 ± 4.5
Carpentry	97.2 ± 4.3
Cabinet manufacturing	95.1 ± 3.81
Mechanics	91.6 ± 5.96
Auto body mechanics	100.8 ± 4.17
Automobile oil exchange	86.8 ± 3.01
Stone crushing	96.9 ± 5.37
Masonry stone cutting and stone selling	89.9 ± 5.4
Casting	97 ± 4.08
Casting without sandblast	86 ± 4.26
Other industries	92.9 ± 6.3

[a]Values are expressed as mean ± SD.

According to Table 4, the highest level of measured background noise was attributed to the forging and blacksmith workshops, while the lowest background noise belonged to car service workshops (mostly engine oil exchange).

As many of the studied workshops were located along the main streets and the roads, they were constantly exposed to the noise from the vehicle traffic and transportation that increased their exposure to the uncontrolled

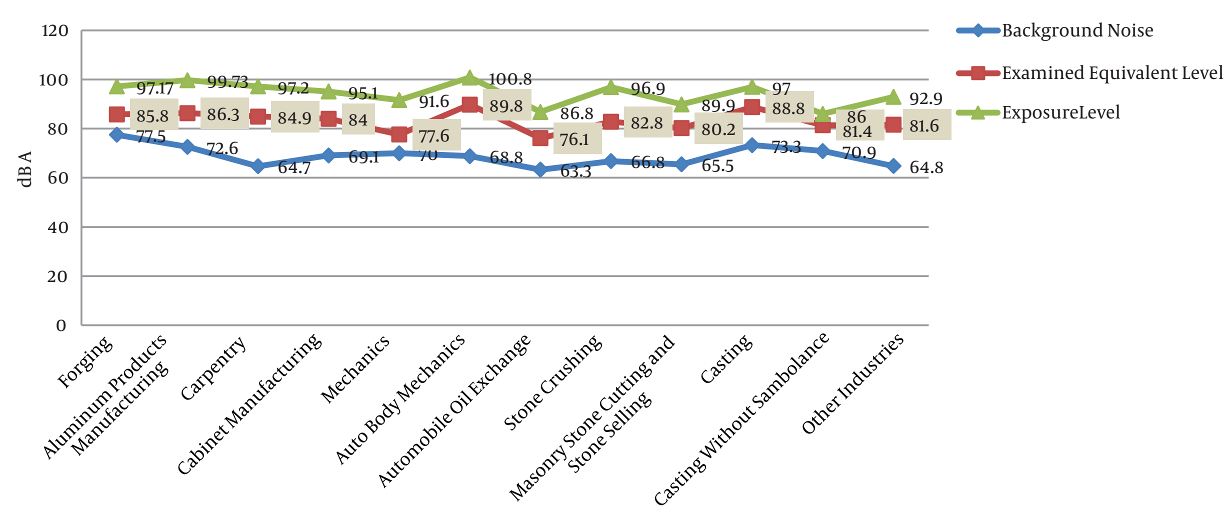

Figure 1. Linear Graph Showing the Average Background and Combined Noise in Different Occupations, Equivalent Level and Exposure Level (dB A)

Table 4. The Hearing Loss (after Deducting the Effect of Age) in Different Occupations (dB A)[a]

Type of Industry	Right Ear	Left Ear
Forging	18.5 ± 8.3	18.5 ± 9.3
Aluminium products manufacturing	22.2 ± 14.3	23.5 ± 10.1
Carpentry	19.2 ± 15.7	24.5 ± 17.8
Cabinet manufacturing	12 ± 9.5	15 ± 7.05
Mechanics	9.3 ± 7.5	10.3 ± 1.03
Auto body mechanics	36.5 ± 19.3	22.8 ± 18.1
Automobile oil exchange	9.8 ± 3.4	8.5 ± 3.3
Stone crushing	13.6 ± 8.01	19.7 ± 12.8
Masonry stone cutting and stone selling	9.5 ± 7.6	9.6 ± 6.8
Casting	13.8 ± 4.5	19.2 ± 14.1
Casting without sandblast	12.5 ± 4.2	14.5 ± 3
Other industries	11.8 ± 10.9	11.1 ± 8.1

[a]Values are expressed as mean ± SD.

level of background noise in such workshops (Figure 2). Moreover, the highest and lowest exposure levels occurred among auto body mechanics and car service workshops, respectively.

As demonstrated in Table 5, the mean of the maximum level of exposure (based on the work experience) was related to the auto body mechanics, while its minimum levels occurred among the workers of foundry and casting without sandblast and car service workshops.

$$Exposure \quad Level = Leq + 10\log(T) \tag{2}$$

T, work experience (years).

Based on the data, the greatest and the lowest hearing loss related to the right ear were seen among mechanics and auto body mechanics, respectively.

Considering the hearing loss in the left ear, the maximum and minimum hearing loss was related to carpenters and car service workshops, respectively.

To evaluate the effect of variables such as noise intensity and work experience on development of NIHL, regression analysis was performed.

Based on the results of the analysis, a significant relationship was found between the noise intensity, work experience and developing NIHL ($P < 0.05$) (Equations 3 - 5)

$$NIHL_R = -92.7 + 1.138 \times Leq + 0.520 \times we \tag{3}$$

$$NIHL_l = -92.7 + 1.196 \times Leq + 0.306 \times we \tag{4}$$

$$NIHL_t = -75.8 + 0.995 \times Leq + 0.470 \times we \tag{5}$$

Leq, 8-hours in a work shift; we, work experience in terms of years.

The variable coefficients SPL and work experience were found to be significant in these equations.

4. Discussion

Similar to several other countries such as Australia, France, Germany and Japan, enforcing legislation to control the noise exposure in the workplace in Iran is based on worker's time weighted average noise level of 85 dBA (27).

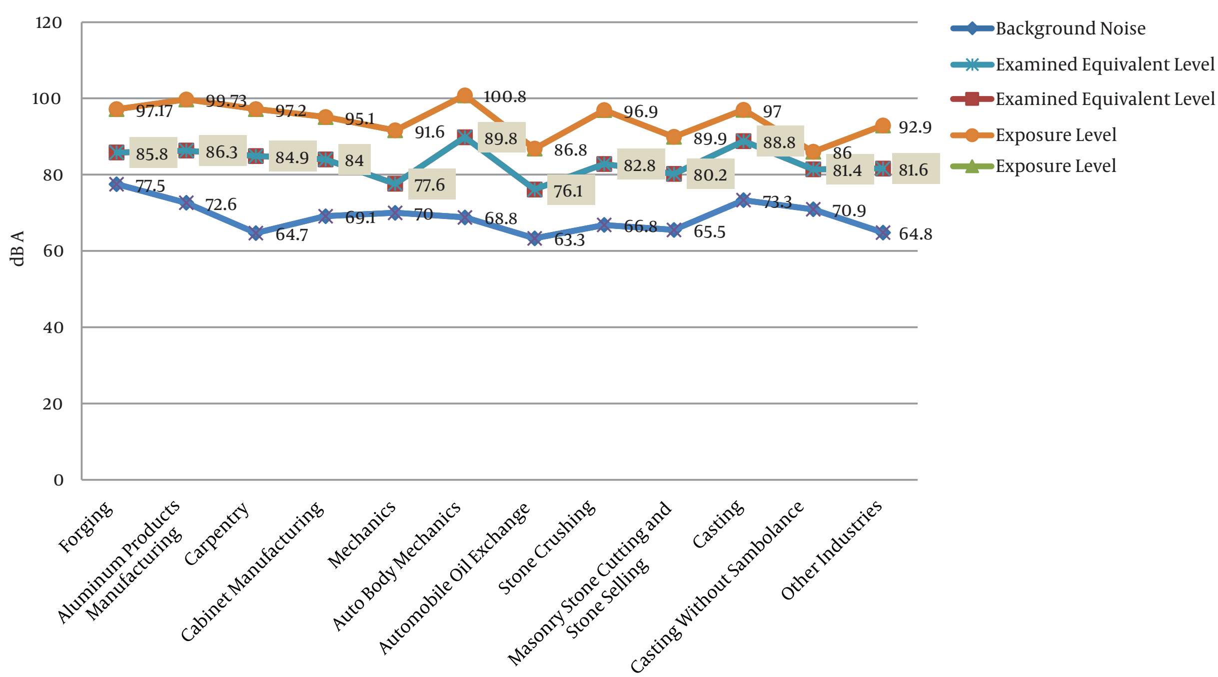

Figure 2. The Linear Graph Shows Different Levels of Hearing Loss in Different Occupations

Table 5. The Relationship between the Level of Hearing Loss, 8-Hour Leq and Work Experience

		NIHL R	NIHL L	NIHL T
leq	Pearson Correlation	495/0	491/0	508/0
	P Value (2-tailed)	0.001	0.001	0.001
Work experience	Pearson Correlation	412/0	281/0	370/0
	P Value (2-tailed)	0.001	0.001	0.001

In this study, it was found that in terms of level of exposure to noise at the workplace, mechanics and car service station workers (in the car service industry group), stoneworkers, stone sellers and crushers (in the mineral industry group), and workers of casting without sandblasting (in the foundry and casting industry) deemed to be safe. Nonetheless, if the value of 82 dBA is considered as the threshold for control measures, then it may be concluded that the wood industry occupations, such as carpentry and manufacturing cabinet and stone selling and crushing are within the margin of control measures, and working overtime and beyond normal working hours prolong the exposure level even more.

The results revealed that for the metal industry (including aluminium products fabrication, blacksmith and forging and foundry and casting) and car service industry (including auto body mechanics), the obtained 8-hour Leq exceeds 85 dBA, which highlights the need for taking engineering and administrative control measures.

Comparison of the results from different evaluated occupational groups revealed that the greatest levels of 8-hour Leq were related to auto body mechanics jobs (89.2 dBA), foundry and casting (88.8 dBA), aluminium products manufacturing (86.32 dBA), blacksmiths and forging (85.8 dBA), carpentry and woodworking (84.93 dBA) and cabinet manufacturing (84 dBA), respectively. The lowest level of 8-hour Leq was found among workers of car service workshops.

The results from the study conducted by Roohi, who examined four groups of occupations of doors and windows manufacturers, carpentry, car service workshops and metalworking in 56 small workshops, showed that 8-hour Leq of carpenters and doors and windows manufacturers were 86 dBA and 86.6 dBA, respectively. He also found that the exposures of the workers from the car service workshops and metalworking were less than the standard limit (28).

The former finding of this study is in line with the findings of our study as the 8-hour Leq of the iron and aluminium doors and windows manufacturers was 85.8 ± 3.2 dBA and 86.32 ± 3.49 dBA, indicating a non-permissible exposure.

In another study conducted in Tanzania to assess the exposure of workers in small- scale industries, it was found that the level of noise exposure was more than 90 dBA in metal and wood industry, but in occupations related to auto industry (mechanics and service workshops), the 8-hour Leq was less than the permissible level (12).

Comparison of the results showed that a significant reduction in exposures was found among the workers of the studied woodworking workshops, which might be due to the few studied workshops and the lack of employer cooperation in conducting the measurements. Nonetheless, implementation and planning of control measures for such workshops is essential considering the following facts: The 8-hour Leq measured in the carpentry and woodworking (84.93, 2.36 dBA), cabinet manufacturing workshops (84, 2.17 dBA), maximum and minimum measured SPL values (82 to 90 dBA), 82 dBA as the threshold for starting control measures, and excessive exposures of a number of workers in the studied workplaces.

The results of the exposure levels of auto body mechanics in this study were consistent with those from the study by Ahmadi et al. The obtained equivalent levels in both studies were more than the proposed standard values. However, due to the higher mean age and work experience of the participants as well as other factors, the level of workers' hearing loss in our study was higher than the study by Ahmadi et al. (13).

Most workers of small workshops, including auto body mechanics start their work from an early age. Therefore, when they are middle-aged, they usually have many years of work experience, signifying a prolonged and excessive exposure to high levels of noise, causing irreparable damages to their hearing.

Results from the evaluation of the workers' hearing loss among different occupational groups revealed that in the right ear, the greatest hearing loss was related to auto body mechanics, aluminium products manufacturers and carpenters. At the same time, the highest hearing threshold shifts of the left ear occurred among carpenters, aluminium products manufacturers, and auto body mechanics, respectively. Apart from auto body mechanics, in all occupational groups, the values of hearing in the left ear exceeded the right ear, reflecting that the left ear is more susceptible to exposure to excessive noise developing hearing impairment. This is almost consistent with several previous studies as well (9, 25, 29, 30).

According to the results on the relationship between the level of hearing loss, 8-hour Leq and participants' age and work experience in different work groups, it was evident that all the studied occupational groups (with exception of car service workshops and casting without sand-blasting), hearing loss had a significant relationship with 8-hour Leq ($P < 0.05$).

According to the results of the studied occupational groups, a significant relationship was found between the level of NIHL and work experience in woodworking and stone cutting and crushing industries. Similar results have been obtained in other studies as well (31, 32).

No statistically significant relationship was found between the participants' smoking habit and development of NIHL as well as educational level and development of NIHL, which was in agreement with the results of the study conducted by Singh (9, 31).

4.1. Conclusions

The findings of this study and similar other studies revealed that 8-hour Leq and work experience were, respectively, the major and the most important contributing factors for developing NIHL among the workers of small- scale industries. In addition, the results of the Pearson correlation coefficient between the 8-hour Leq and work experience and NIHL revealed that the progress of NIHL could be expected with the increase in the work experience.

Considering the existence of the large number of these industries and the large sizeable proportion of the workers they employ and lack of adherence to rules and regulations at workplaces, noise control measures, such as proper implementation of hearing conservation programs (HPCs), should be utilized to control the levels of exposure and minimize the risk of developing NIHL among workers.

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