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The Effect of Active and Passive Smoking on Hearing Loss in Noise-Exposed Metal Workers

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Abstract
Background: Many people are exposed to cigarette smoke actively or passively. We aimed to determine the effect of active and passive smoking on hearing thresholds and hearing loss noise-exposed workers.
Methods: This cross-sectional study was conducted on 929 metal workers. We divided the workers into 3 groups according to smoking status—current smokers, nonsmokers, and passive smokers. Audiometric testing was recorded for both ears. Hearing loss was defined by 3 models. The SPSS software Version 24 was used to analyze the collected data. We used an independent t test, chi-square, Fisher exact, and analysis of variance tests and logistic regression, and the significance level was set at P <0.05 to interpret the relationships between variables.
Results: The hearing threshold levels at 4000 Hz, high frequencies, and low frequencies were significantly higher in smokers than nonsmokers ($P < 0.05$). Also, and hearing loss at the 4000 Hz ($P = 0.002$; odds ratio [OR] = 1.96; 95% CI = 1.27-3.03) and high frequencies ($P = 0.001$; OR = 2.15; 95% CI = 1.36-3.4) had a significant correlation with smoking. Hearing loss was significantly correlated with passive smoking at 4000 Hz ($P < 0.001$; OR = 5.87; 95% CI = 3.29-10.47), high frequencies ($P < 0.001$; OR = 7.16; 95% CI = 3.97-12.89) and low frequencies ($P = 0.021$; OR = 4.16; 95% CI = 1.12-15.43).
Conclusion: The findings show that active and passive smokers who work in noisy environments are at higher risk for noise-induced hearing loss. Therefore, smoking cessation in smoker workers and reduction of environmental exposure to cigarette smoke is necessary to reduce the exacerbation of hearing loss. Moreover, more attention should be paid to passive smokers and they should be given priority in the same programs.

Keywords: Passive smoker, Noise, Hearing loss

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Introduction
Noise is considered one of the most influential physical risk factors in workplaces around the world. As estimated, 30 million workers in the United States and 600 million workers worldwide are being noise-exposed (1).
According to a survey conducted in some European countries, about 28% of the workers are being employed in environments with a sound level more than 85 dB (2). Long-term noise exposure in workplaces can cause sleep disorders, increased blood pressure, decreased performance, stress, tinnitus, and hearing loss (3-7). Noise-

↑What is "already known" in this topic:
Many recent studies have shown the adverse effects of simultaneous exposure to cigarette smoke and noise on hearing loss; however, there are a few studies about the effect of concurrent exposure to noise and passive smoking on workers' hearing.

→What this article adds:
Our study findings show that active and passive smokers who work in noisy environments are at higher risk for noise-induced hearing loss. Therefore, smoking cessation in smoker workers and reduction of environmental exposure to cigarette smoke is necessary to reduce the exacerbation of hearing loss. Moreover, more attention should be paid to passive smoker workers.

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induced hearing loss (NIHL), which is usually symmetrical and sensorineural, is an irreversible and permanent damage induced by the hair cells of the Corti organ in the inner ear because of prolonged sound exposure (5, 7, 8). Despite engineering control programs and the use of hearing protection devices, NIHL is increasing (9-11), as 23 million persons in the United States suffer from hearing impairment (12). In addition to noise exposure in the workplace, there are other risk factors (eg, aging, race, gender, exposure to ototoxic factors, and smoking) that affect hearing loss (13, 14).

Smoking is a common habit all around the world. Besides increasing the probability of noise-exposed damage smoking, directly increases the level of carboxy hemoglobin, reduces cochlear blood flow, and enhances damage to the hair cells so that its side effects are almost the same as noise on the auditory system (15-17). The findings of the studies in this field, however, are not clear and accurate. In some studies, a positive relationship is documented between these 2 factors (17, 18). In a study performed by Ferrite in Brazil, it was found that smoking has a synergistic impact on NIHL in the work place (19). In a majority of these studies, smokers are at a higher risk of hearing loss than nonsmokers (20-22). In addition to the positive findings regarding the cumulative effect of smoking and noise in the workplace, several studies have shown that there is no clear correlation between these 2, and some recent studies have claimed that smoking does not cause hearing loss by itself (20, 23, 24). Moreover, in most studies conducted in this field, less attention has been paid to smoking with more details, including years of smoking and passive smoking (11).

Since the hearing health status of workers in different industries has a significant impact on the provision of services to them, identifying the relationship between or the impact of smoking on NIHL would play an important role in accommodating the work environment for smokers. As smoking is a changeable habit in one's lifestyle, this study aimed to investigate the role of active or passive smoking (being exposed to smoke) on hearing loss in noise-exposed metalworkers.

Methods

This cross-sectional study was conducted on all metal workers employed in the metal industry in Kerman province in 2017. The inclusion criteria for the metalworkers were a work experience longer than 6 months and exposure to noise of more than 85 dB for 8 hours. In addition to the workers' annual checkups, a checklist was used to collect some demographic information, including age, gender, marital status, work experience, previous job title, length of being exposed to noise in the current job, and education level. This checklist also contained information about smoking, the number of cigarettes per day, years of consumption, and the indirect consumption of cigarette smoke (passive smokers). The checklist was completed by a medical physician and through interviews with the workers. Among the participants in the study, workers with a history of ear infections in childhood, hereditary hearing impairment, history of trauma and ear surgeries, a history of diabetes and hyperlipidemia, thyroid diseases, consumption of ototoxic drugs, single-sided hearing loss, exposure to solvents and ototoxic metals, recurrent ear infections, a history of acoustic trauma, and a history of exposure to noise in the second job were excluded.

Based on information collected on the consumption of cigarettes, the metalworkers in this industry were divided into 2 groups smokers—current smokers and nonsmokers. Among the smokers, the average daily consumption of cigarettes and years of consumption were determined. Nonsmokers were classified into nonpassive and passive smokers' groups in terms of being or not being exposed to cigarette smoke. In this study, passive smokers were considered to be individuals who did not smoke but were exposed to cigarette smoke (25).

To assess the level of noise exposure, a sound assessment method using a sound level meter (440) was adopted by a professional health team located in the HSE unit of the plant. The results of these assessments showed that the average noise level in all working units was 89 ± 3.40 dB—with a minimum level of 85 dB and a maximum level of 92 ± 4.2 dB.

Data on the workers' hearing thresholds after a minimum of 14 hours working at the plant was collected by an experienced audiometric expert using a standard audiometric meter (AD 229d Model) in an acoustic room. The average hearing threshold was recorded for both ears at the frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. This study compared hearing loss among by 3 models in smokers, nonsmokers, and passive smokers. The hearing threshold at a frequency of 4000 Hz in both ears was greater than 25 dB, defined as Noise-induced hearing loss (NIHL). According to some studies on hearing loss, 2 other models were also defined.

In the first model, the average hearing threshold greater than 25 dB at frequencies of 500, 1000, and 2000 Hz was considered as hearing loss at low frequencies. In the second model, the average hearing threshold greater than 25 dB at frequencies of 3000, 4000, and 6000, and 8000 Hz was considered as hearing loss at high frequencies (26, 27).

After collecting the required data, the SPSS software Version 24 (IBM) was used to analyze the collected data. The qualitative variables were described using the frequency and percentage and the quantitative variables were also described using the mean and standard deviation. In this study, independent t, chi-square, Fisher exact, and analysis of variance tests were used to compare the variables. In this study, the variable NIHL and relevant variables were introduced into the logistic regression model to determine the factors affecting noise induced hearing loss. In this study, the significance level was set at $P < 0.05$ to interpret the relationships between variables.

Results

According to the inclusion criteria, 1030 metalworkers were included in the study, of whom 101 workers not meeting the inclusion criteria were excluded due to the following reasons: suffering from ear infections in childhood (n = 8 [0.77%]), hereditary hearing impairment (n =

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2 [0.19%]), history of ear trauma (n =7 [0.67%]), ear surgery (n =4 [0.38%]), metabolic diseases (n = 6 [0.67%]), taking autotoxin drugs (n = 4 [0.38%]), exposure to solvents and metals (n = 31 [3%]), history of chronic diseases, and especially recurrent ear infections (n = 7 [0.67%]), abnormal examination of the ears (n = 9 [0.87%]), a history of acoustic trauma (n = 3 [0.29%]) and single-sided hearing loss (n = 20 [1.94%]). Hence, the final analysis of this study was performed on a total of 929 workers.

In this study, 117 (12.27%) of workers were smoker and average smoking rate per year among the smokers was 3.2 ± 0.54 pack year. A total of 52 workers (5.5%) were also considered as passive smokers.

The mean age and work experience of the participants were 34.6 ± 4.6 years and 9.2 ± 4.5 years, respectively. In this study, no significant difference was observed between the mean age of smokers (35.48 ± 7.69 years) and nonsmokers (34.48 ± 6.29 years) (*P* = 0.182) and the mean work experience among smokers was significantly higher than nonsmokers (6.10 ± 3.16 vs 5.29 ± 2.95; *P* = 0.006). In this study, educational level in 551 of participations (59.3%) was high diploma. Also, 876 participants (94.6%) were married and only few participants (2.2%) had a second job.

The average hearing thresholds at the low frequencies for smokers' right and left ears were 11.98 ± 5.02 Hz and 12.69 ± 8.2 Hz, respectively. The average hearing thresholds at the low frequencies for nonsmokers' right and left ears were 10.83 ± 4.7 Hz and 10.72 ± 4.5 Hz, respectively. The average hearing thresholds in the high frequencies for smokers' right and left ears were 19.18 ±11.1 and 16.96 ± 8.4, respectively. The average hearing thresholds at the high frequencies for nonsmokers' right and left ears were 16.10 ± 8.4 and 14.92 ± 7.7, respectively. The average hearing thresholds at 4000 Hz for smokers' right and left ears were 21.7 ± 14.4 and 18.93 ± 10.4, respectively. The average hearing thresholds at 4000 Hz for nonsmokers' right and left ears were 18.5 ± 10.5 and 16.72 ± 9.6, respectively. As a result, at 4000 Hz, high and low frequencies, the hearing threshold level was significantly higher in smokers than nonsmokers (*P* < 0.05) (Table 1).

In this study, hearing loss at 4000 Hz (*P* = 0.002; odds ratio [OR] = 1.96; 95% CI = 1.27–3.03) and above 4000 Hz (*P* = 0.001; OR = 2.15, 95% CI = 1.36-3.4) had a significant correlation with smoking; however, such a correlation was not significant for low frequencies (*P* = 0.069) (Table 2).

In this study, smoking workers were divided into 2 groups according to the mean annual smoking rate (2.3 packet/year), and their average hearing thresholds were compared. The average hearing thresholds at low frequencies in the right and left ears of smokers with an annual cigarette consumption rate of more than 2.3 packet/year were 13.63 ± 7.3 and 13.28 ± 4.3, respectively. The average hearing thresholds at low frequencies in the right and left ears of smokers with an annual cigarette consumption rate of less than 2.3 packet/year were 12.32 ± 8.5 and 11.46 ± 5.1, respectively. The average hearing thresholds at high frequencies in the right and left ears of smokers with an annual cigarette consumption rate of more than 2.3 packet/year were 18.71 ± 7.47 and 20.98 ± 7.36, respectively. The average hearing thresholds at high frequencies in the right and left ears of smokers with an annual cigarette consumption rate of less than 2.3 pack-

Table 1. The average hearing thresholds (dB) at 4000 Hz, high and low frequencies in smoker and nonsmoker workers

frequencies	Right ear			Left ear		
	4000 (Mean ±SD)	High (Mean ±SD)	Low (Mean ±SD)	4000 (Mean ±SD)	High (Mean ±SD)	Low (Mean ±SD)
smokers	10.4±18.93	8.4±16.96	8.2±12.96	14.4±21.7	11.4±19.18	5.02±11.98
Non-smokers	9.60±16.72	7.7±16.92	4.5±10.72	10.5±18.50	8.4±16.10	4.7±10.83
P-value	0.021	0.009	0.000	0.004	0.000	0.025

Table 2. Prevalence hearing loss (number, %) at 4000 Hz, high and low frequencies in smoker and nonsmoker workers

Hearing loss	4000Htz		High frequencies		low frequencies	
	yes	No	yes	No	Yes	No
Smokers(n=117)	35*(29.9) **	82 (70. 1)	30 (25.6)	87 (74.4)	5 (4.3)	112 (95.7)
Nonsmokers(n=812)	145(17.85)	667 (82.15)	112 (13.8)	700 (86.2)	14 (1.7)	798 (98.3)
P-value	0.002		0.001		0.069	
Odds Ratio	1.96 (1.27-3.03)		2.15 (1.36-3.4)		2.54 (0.89-7.2)	

*: Prevalence hearing loss by number
**: Prevalence hearing loss by percent

Table 3. Prevalence hearing loss (number, %) at 4000 Hz, high and low frequencies in smokers

Hearing loss	4000Htz		High frequencies		Low frequencies	
	Yes	No	Yes	No	Yes	No
Annual cigarette consumption rate more than 2.3 PY(n-=33)	14* (42.4)**	19 (57.6)	12 (36.4)	21 (63.6)	2 (6.1)	31 (93.9)
Annual cigarette consumption rate less than 2.3 PY(n=84)	21 (25)	63 (75)	18 (21.4)	66 (78.6)	3 (3.6)	81 (96.4)
P-value	0.062		0.091		0.543	
Odds Ratio	2.21 (0.94-5.16)		2.09 (0.86-5.05)		1.74 (0.27-10.9)	

*: Prevalence hearing loss by number
**: Prevalence hearing loss by percent

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Table 4. Prevalence hearing loss (number, %) at 4000 Hz, high and low frequencies in passive and non-passive smoker workers

Hearing loss	4000Htz		High frequencies		low frequencies	
	Yes	No	Yes	No	Yes	No
Passive smokers(n=52)	27* (52)**	25 (48)	25 (48)	27 (52)	3 (5.8)	49 (2.94)
Non-passive smokers(n=760)	118 (15.5)	642 (84.5)	87 (4.11)	673 (88.6)	11 (4.1)	749 (6.98)
P-value	0.000		0.000		021.0	
Odds Ratio	5.87 (3.29-10.47)		7.16 (3.97-12.89)		4.16 (1.12-15.43)	

*: Prevalence hearing loss by number
**: Prevalence hearing loss by percent

Table 5. Relationship between some variables and prevalence NIHL by binary logistic regression

Variables	*P*-value	$Exp_{(\beta)}$	CI	
			Low	High
Age(year)	0.000	1.06	1.03	1.09
Work experience(year)	0.151	1.04	0.99	1.10
smoking	0.063	1.55	0.9	2.5
Passive smoking	0.000	5.37	2.76	9.14

et/year were 16.27 ± 8.8 and 18.48 ± 12.27, respectively. The average hearing thresholds at a frequency of 4000 Hz in the right and left ears of smokers with an annual cigarette consumption rate of more than 2.3 packet/year were 23.48±10.93 and 21.06 ± 10.44, respectively. The average hearing thresholds at 4000 Hz in the right and left ears of smokers with an annual cigarette consumption rate of less than 2.3 packet/year were 18.09 ± 10.3 and 21.01 ± 15.63, respectively. Based on the findings, the average hearing thresholds at 4000 Hz, high and low frequencies in both right and left ears were higher among smokers with an annual cigarette consumption rate of more than 2.3 packet/year than other workers with a lower cigarette consumption rate (*P*< 0.05). In this study, hearing loss was not significantly correlated with the cigarette consumption rate in smokers at 4000 Hz (*P* = 0.062), high frequencies (*P* = 0.091), and low frequencies (*P* = 0.543) (Table 3).

The average hearing thresholds at low frequencies in passive smokers' right and left ears were 13.42 ± 4.6 and 12.59 ± 5.9, respectively. The average hearing thresholds at low frequencies in nonpassive smokers' right and left ears were 10.77 ± 4.3 and 10.48 ± 5.06, respectively. The average hearing thresholds at high frequencies in passive smokers' right and left ears were 23.47 ± 3.1 and 20.91 ± 4.2, respectively. The average hearing thresholds at high frequencies in nonpassive smokers' right and left ears were 15.92 ± 8.1 and 14.71 ± 3.1, respectively. The average hearing thresholds at 4000 Hz in passive smokers' right and left ears were 27.57 ± 8.5 and 24.07 ± 4.6, respectively. The average hearing thresholds at 4000 Hz in nonpassive smokers' right and left ears were 18.20 ± 6.3 and 16.72 ± 9, respectively. Accordingly, the average hearing thresholds at 4000 Hz, high and low frequencies were significantly higher in passive smokers than nonpassive smokers (*P* < 0.05).

In this study, hearing loss was significantly correlated with passive smoking at the frequencies of 4000 Hz (*P* < 0.001; OR = 5.87; 95% CI = 3.29-10.47), high frequencies (*P* < 0.001; OR = 7.16; 95% CI = 3.97-12.89), and low frequencies (*P* = 0.021; OR = 4.16; 95% CI = 1.12-15.43) (Table 4).

In the regression analysis, after including the NIHL as a dependent variable, among variables such as age, work experience, cigarette consumption rate, and passive smoking added to the regression model, the variables age and passive smoking remained in the regression model and were considered as NIHL predictors among the metal workers (*P*< 0.05) (Table 5).

Discussion

In this study, 919 noise-exposed workers of metal industry were examined. The results of the present study showed that active smokers and even passive smokers have a clear and significant relationship with hearing loss at 4000 Hz and high frequencies. In general, according to various sources, such as the World Health Organization, smoking rates have been reported to be high throughout the world, especially in developing countries; however, the officially recorded rates are not consistent with the real rates. Hence, it can be asserted that all study participants conceal their lifetime smoking rates in order to keep their jobs and due to societal difficulties. This is why the prevalence of smoking has not been reported to be higher than 15% in none of the studies, even those in developing countries, in spite of frequent and enormous smoking side-effects observed in the society. In the present study, the annual cigarette consumption rate was reported to be 3.2 packet/year, which was lower than the rate reported by Silva in Malaysia (3.8 packet/year per year) (9).

In our study, the hearing loss at low frequencies (2000, 1000, and 500 Hz) was not statistically significant between smokers and nonsmokers. The results were also consistent with the findings of a study in a still plant in Japan, suggesting no significant difference in hearing loss at low frequencies between smokers and nonsmokers (11) but in a study by Palmer et al, hearing loss due to smoking in speech frequencies has also been seen (28). A study by Sung et al on 8543 workers, indicated that cigarettes consumption leads to hearing loss at low frequencies, which was influenced by the cigarettes consumption dose-response (29). It is believed that the inconsistencies between the findings of the present study and those in other similar studies are caused by the low sample size, the lack of control on the impact of some intervening factors, and most importantly dishonesty in revealing the actual cigarette consumption rates by workers.

According to this study, there was a significant difference in smokers and nonsmokers' hearing loss at high

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frequencies. The results of the study by Professor Mizoue, Nakanishi, Ferrite also confirm the results of our study (9, 11, 22).

The results of our study were consistent with the studies carried out at by a car factory in Iran. In this study, high-frequency hearing loss in smokers was much higher than nonsmokers (30).

In our study, the average hearing threshold and hearing loss at 4000 Hz was significantly higher in smokers than nonsmokers. The findings were in line with the studies carried out in the Japanese shipyard workers, and the rate of hearing loss in the frequency of 4KHZ and 2000-3000 in smokers was higher than nonsmokers (31). In most studies, hearing loss at 4000 Hz in smokers is significantly higher than nonsmokers (11, 32).

Accordingly, it might be claimed that the effect mechanism of smoking on the hearing loss is not clear. It is shown that smoking can damage the hair cells, increase the level of carboxy hemoglobin, or reduce the blood flow to the cochlear. In fact, smoking through vascular changes can lead to hypoxemia and hearing loss at high frequencies. In this case, the effect of noise on hearing loss is roughly the same as the effect of smoking on the Corti organ.

With regard to the findings of our study, hearing loss was more observed at high frequencies and at 4 KHZ among smokers than nonsmokers, and this correlation rises as pack-year rates rise, yet there is no apparent relationship between smoking amounts and observable hearing loss. In a study by Wang, hearing loss at frequencies of 2000, 1000, 2000, and 4000 was higher in smokers than nonsmokers, and there was a positive association between smoking and hearing loss (8). However, in the shipyard study, there was a positive correlation between the amount of smoking per year and hearing loss at low frequencies (31). The reason for the observed difference in some studies with our study seems to be due to differences in the NIHL definition criteria and inappropriate smoking intake by participants in various studies.

In our study, hearing loss at 4000 Hz, high frequency, and low frequency had a significant relationship with passive smoking. It could be said that those who were passive smokers were more at risk for hearing loss than others and even smokers. According to a study by Dawes et al, nonsmokers who are passively exposed to tobacco smoke had a 28% increased risk of developing hearing loss (25).

Contrary to the results obtained in our study, Chang et al found that current smoking had significantly increased hearing thresholds compared with passive smoking and nonsmoking participation, and passive smoking did not have an elevated prevalence of either speech-frequency bilateral hearing impairment or high frequency bilateral hearing impairment (26). Some studies have reported a relationship between hearing loss and passive smoking in children and adolescents (27, 33). Exposure to environmental tobacco in children is suggested to decrease response in transient evoked otoacoustic emissions and effects on outer hair cells (27). A few studies have been done on the relationship between passive smoking and hearing loss in adult workers.

However, these studies have shown that the effect of passive smoke on hearing loss is similar to that of hearing loss by noise (25, 34).

In our study, the association between hearing loss at all frequencies and passive smoking appears stronger than the association between hearing loss and smoking. The cause of the observed difference is probably due to the fact that some nonsmokers are exposed to cigarette smoke and the relationship between smoking and hearing loss is lower than the actual rate. Therefore, it is better to compare smokers with nonsmokers who are not exposed to cigarette smoke.

It is advised that employees in professions subjected to noise levels higher than 85 dB give up smoking and decrease their exposure to cigarette smoke, or that further engineering measures be implemented. Noise pollution prevention is carried out on these workers' hearing loss. Perhaps screening tests in shorter intervals and in the early years of employment can be helpful in preventing hearing loss.

The present study has some strengths and weaknesses. One of the strengths of the study is a relatively acceptable sample size and homogeneous work population. Furthermore, examining hearing loss in 3 different models and groups (active smoker, passive smokers and non-passive smokers) is also considered as another strength of this study. On the other hand, one of the weaknesses includes nonreported background of smoking by the participants, which might have an intervening effect on the findings. In this study, participants were not divided based on the severity of exposure to noise in the workplace. Therefore, it is advised that future studies investigate the impact of exposure duration on smoking and hearing loss over the course of a year.

Conclusion

The findings show that active and passive smokers who work in noisy environments are at greater risk for noise induced hearing loss than nonsmokers. Therefore, smoking cessation in smokers and reduction of environmental exposure to cigarette smoke is necessary to prevent the exacerbation of hearing loss caused by noise. In the use of hearing protection programs, more attention should be paid to passive smokers and they should be given a priority in the same programs. Since this study was cross-sectional, the future researchers are recommended to use prospective studies to investigate the relationship between hearing loss and smoking.

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Conflict of Interests

The authors declare that they have no competing interests.

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