ORIGINAL ARTICLE

Combined Effect of Noise Exposure and Smoking on Hearing Thresholds in Workers in a Petrochemical Plant

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ABSTRACT

Background: Cigarette smoking and high levels of industrial noise exposure are known as health risk factors especially affecting hearing status, which need paying more attention to coincidence of these factors in order to conserve industrial workers' hearing health.
Aim: To determine combined effect of noise exposure and smoking on hearing thresholds in workers.
Methodology: 503 male workers with age, job experience and sound level exposure ranges 28-29 y, 3-31 y and 73-90 dB-A, respectively, enrolled in this investigation. Personal noise dosimeters were used to monitoring noise exposure. Health status and smoking data were collected by questionnaire.
Results: Results of Chi-square test showed that the odds ratio (OR) for hearing loss in smokers with noise exposure was 2.06 (95% CI=1.35-2.73) in comparison with nonsmokers without noise exposure (group1). Also, OR for nonsmokers with noise exposure was 1.37 (95% CI= 1.15-1.93) in comparison with group1. The OR obtained from logistic regression analysis indicated similar results in our study (OR=2.04, 95% CI=1.33-2.67). In addition, calculated synergy index was equal to 2.4.
Conclusion: The present study results revealed a synergic effect between tobacco smoke and industrial noise exposure on hearing loss.
Keywords: Hearing loss, noise, smoking

INTRODUCTION

Noise as a physical factor in the workplaces have a wide range of effects on human health including noise induced hearing loss (NIHL), tinnitus, changes on patterns of secretion of endocrine hormones, elevated blood pressure, stress, annoyance and decrease performance etc[1,2,3,4]. Long-term noise exposure often causes irreversible damage in inner ear which is generally known as NIHL. NIHL has second rank in hearing loss after presbycusis and is originated from noise exposure at work[5,6]. It is estimated that about 28% of workers are exposed to high levels of noise in ranges from85 to 90 dB in the European Union[7]. National institute for occupational safety and health (NIOSH) has reported that about 5.7 million workers in industrial plants are exposed to unsafe noise levels[8]. Before end stage of NIHL which is irreversible damage and permanent, it can be prevented by proper intervention and establishing a good hearing conservation program[9, 10]. Pure tune audiometric test (PTA) is a method for screening hearing status that can be performed for monitoring hearing condition in industrial workers[11]. Cigarette smoking is regarded as a harmful behavior that it is very common in the world. It is estimated that 1300 million people in the world smoke and about 80 % of them live in developing countries[12]. Some adverse health effects of cigarette smoking include atherosclerosis, cardiovascular diseases and malignancies[13-15]. Moreover, many studies showed a relation between smoking and developing hearing loss[16-18]. A study showed direct association between the number of cigarette packs smoked in year and hearing loss in the smokers[19].In contrast, some other studies stated no relation between smoking and hearing loss[20-22]. According to the above mentioned controversy results, additional research is needed to clear the smoking effect on development of NIHL in smokers. The aim of this study is to determine combined effect of noise exposure and smoking on hearing thresholds in workers in a petrochemical plant.

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MATERIALS AND METHODS

This cross-sectional study was conducted from May 2016 to May 2017 and assessed the combined effect of industrial noise exposure and cigarette smoking on hearing threshold levels of industrial workers with noise exposure above 85 dB-A. Male workers, who worked in different parts of a complex petrochemical plant, participated in this study. From total of 1460 employers, 503 workers participated in the study and were divided in 4subgroups as follows:

1. 120 Smokers with noise exposure.
2. 130 smokers without noise exposure.
3. 120 non-smokers with noise exposure.
4. 133 non-smokers without noise exposure.

All workers were interviewed and were required to complete a physical examination and health related information questionnaire. The purpose of the study was introduced to the workers by an occupational physician. The study protocol was approved by the Ethics Committee, and all workers enrolled voluntarily in this study. Female employers were not included in the study because they were not exposed to high levels of noise. The exclusion criteria in the study were included as: 1- History of head injury or otologic surgery. 2- History of ototoxic drug use. 3- History of diabetes mellitus, hyper and hypo thyroid. 4- Workers who had pure tone audiometry (PTA) showing unilateral hearing loss or conductive hearing loss. 5-

Workers with a history of any exposure to loud and unconventional noise in their previous job or a second job.

Noise exposure measurement: For accurate monitoring and measurement of noise exposure levels in each work satiation, personal dosimeters (CASELLA CEL 360, UK) were used. The equivalent continuous A-weighted sound level was calculated by below equation[23].

$L_{Aeq\text{-}8h} = 10 \log10 ((Dose/100) (8/T)) + 85$ dB-A(1)

Where, Dose: noise exposure dose, in percentage acquired in T hours, L_{Aeq} : A-weighted, sound pressure level over T hours, T : the running time, in hours, of the measurement. In order to gain accurate values, calibration was carried out with calibrator (CEL-4726) before and after each run of experiments. Dosimeters were installed at the waist of worker and the microphone in the back of his collar.

Audiometry test: PTA was carried out according to ISO 8253 standards in an isolated acoustic room with a calibrated PTA (Model CA 86, Pajvak Ava Company, Iran) by an audiologist. Hearing thresholds were measured at frequencies of 0.5, 1, 2, 3, 4, 6 and 8 kHz in each ear and at the beginning of work day after 1.5 day rest time.

Smoking status survey: Health and lifestyle questionnaire were obtained and filled by interview. Data acquisition on smoking habit included smoking status (non‐smokers and smokers) and daily number of cigarettes smoked.

Statistical analysis: For data analysis, descriptive statistical parameters was used including min, max, mean and standard deviation and the relationship between variables was tested by Chi-square and Kruskal-Wallistests and etc. Two tailed P-values were used, and P-value ≤ 0.05 was established as the level of significance.

RESULTS

Average and standard deviation of collected data are presented in table 1. Comparison between two groups (with noise exposure (n=240) and without noise exposure (n=263) regardless their smoking status)in case of age and job experience factors, showed no significant difference. However, noise exposure levels ($L_{Aeq\text{-}8h}$) had significant difference (P<0.030).Results of Chi-square test are presented in table 2. It should be mentioned that group 1 (nonsmokers without noise exposure) is considered as the reference group in comparisons. Comparing between groups showed that groups 3 and 4 were different from the reference group, in case of hearing loss. For moderating interfering factors, logistic regression was used. Results revealed that noise exposure and smoking after moderating interfering factors still had a determining role in hearing loss (table 3).Likewise for determining the combined effect of noise exposure and cigarette smoking on hearing loss, Rothman et al.(24) method for calculating synergy index, was used (S= 2.4 > 1),according to results if S > 1, the effect is a synergic one, thus our result showed a synergic relation between smoking and noise exposure on hearing level. Figure 1 shows the average of hearing threshold levels in workers which are divided in four groups. In the smoker workers with noise exposure, hearing threshold was significantly higher (5.8, 7.1 and 15.4 in right ear, 3.1, 4.3 and 15.5 in left ear)at 4000 Hz rather than other groups (P=0.023). No statistically significant difference was observed between smokers without noise exposure and non-smokers with noise exposure in all frequencies. Results of statistical analysis of hearing loss and number of cigarettes daily smoked by workers in two groups (smokers without or with noise exposure) are presented in table 4.According to the results of Mann-Whitney test, the workers whether with or without noise exposure, while smoking 10 up to 20 cigarette in a day, had significant difference in hearing loss. It means that noise exposed workers with cigarette smoking had higher hearing loss. Similar condition was obtained for the other group (20 up to 30 cigarettes per day).However, no significant relationship was observed for works with 1-10 cigarettes per day. According to the results in table 4, based on the post-test Kruskal-Wallis, mean value of hearing loss had significant difference for two years in 3 groups of workers with different cigarette daily smoked and without noise exposure (p-value<0.05). Also, the same results were observed in smoker workers with noise exposure (p-value<0.05).

Table 1: descriptive statistics and comparison of data between groups

Variable	Smoking and noise exposure status	mean ± SD	t	df*	P_{value}**
Age (year)	Smokers with noise exposure (n=120)	38.4±7.8	1.23	501	0.101
	Non-smokers with noise exposure (n=120	37.3±10.5			
	Smokers without noise exposure (n=130)	37.9±8.9			
	Non-smokers without noise exposure (n=133)	38.2±9.9			
Job experience (year)	Smokers with noise exposure (n=120)	19.6±11.2	1.04	501	0.545
	Non-smokers with noise exposure (n=120	19.9±10.3			
	Smokers without noise exposure (n=130)	19.6±10.7			
	Non-smokers without noise exposure (n=133)	20.4±11.5			
$L_{Aeq\text{-}8h}$ (dB-A) [min, max]	Smokers with noise exposure (n=120)	88.8±4.5 [85.4, 91.3]	-0.514	501	0.030
	Non-smokers with noise exposure (n=120	87.9±3.8 [84.8, 89.6]			
	Smokers without noise exposure (n=130)	75±2.1 [72.6, 78.3]			
	Non-smokers without noise exposure (n=133)	75±2.1 [72.6, 78.3]			

*Degree of freedom, **Significant differences (P<0.05)

=Table 2: Comparison of hearing loss between four groups by Chi-Square test

Variable [a]	OR[b]	95% CI[c]	P value[*]
Group 1	1	--	--
Group 2	1.10	-0.33-3.68	0.297
Group 3	1.34	1.15-1.93	0.006
Group 4	2.06	1.35-2.73	0.001
Age	2.26	-1.70- 3.01	0.064
Job experience	1.99	-1.33-2.89	0.320

a:group1: Non-smokers without noise exposure, as reference group. group2: Smokers without noise exposure. group3: Non-smokers with noise exposure. group4: Smokers with noise exposure. b: Odd Ratio. c: Confidence Interval. *Significant differences (P<0.05)

Table 3: Relationship between hearing loss and age, job experience, noise exposure and cigarette smoking by logistic regression

Variable [a]	β	SE[b]	OR[c]	95% CI[d]	P value
Group 1	-1.44	0.15	1	--	0.82
Group 2	0.44	0.21	1.29	0.89-1.85	0.04
Group 3	0.57	0.22	1.31	1.14-1.91	0.01
Group 4	0.71	0.19	2.04	1.33-2.67	0.001
Age	0.18	0.21	--	--	0.21
Job experience	-0.14	0.16	--	--	0.33

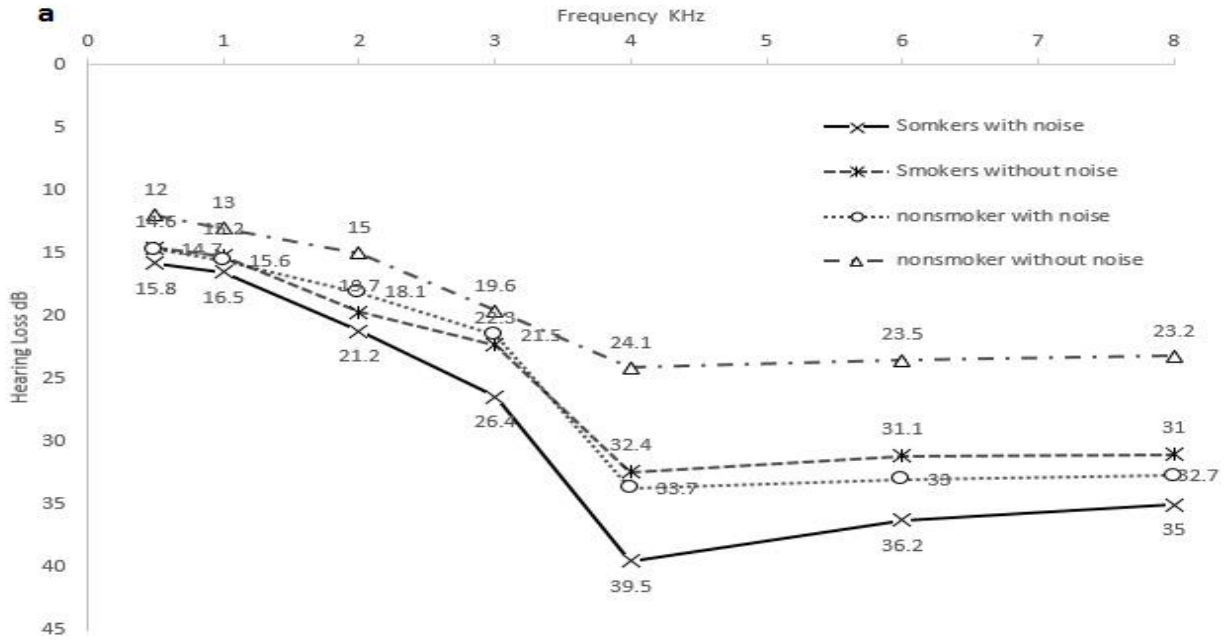
a:group1: Non-smokers without noise exposure. group2: Smokers without noise exposure. group3: Non-smokers with noise exposure. group4: Smokers with noise exposure. b: Standard Error. c: Odd Ratio. d: Confidence Interval. *Significant differences (P<0.05)

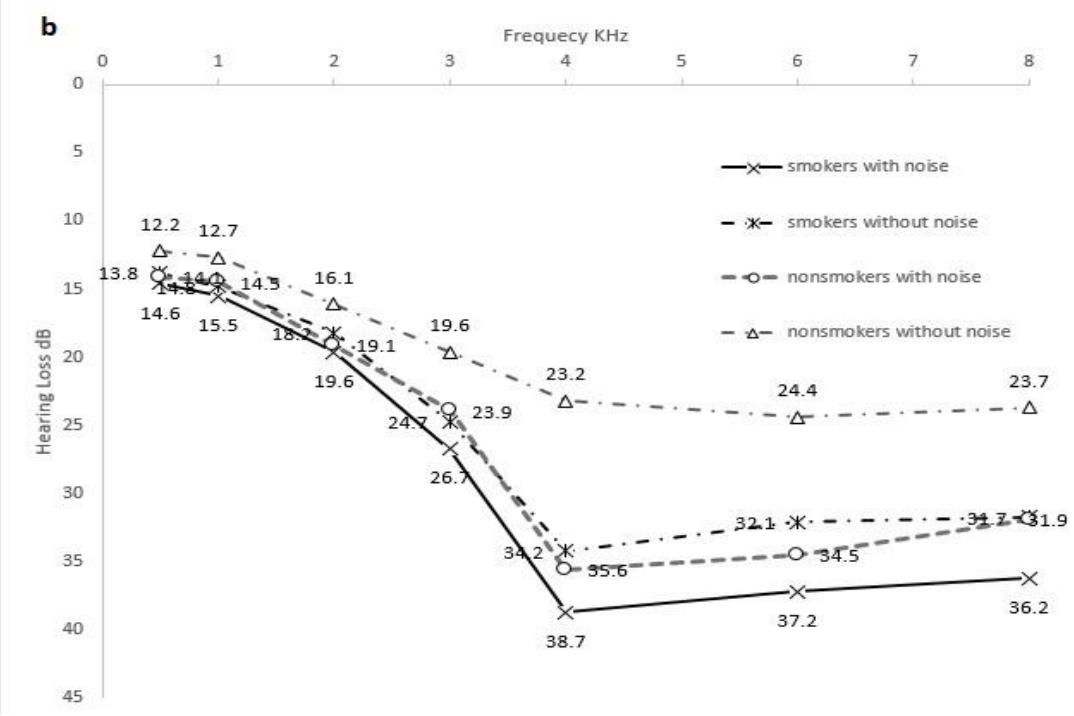
Table 4: comparison between average of hearing loss and number of cigarettes daily smoked in two smokers groups

Hearing Loss / number of cigarettes smoked per day		Without noise exposure			With noise exposure			P-value [*]
		N	HL/right ear dB	HL/left ear dB	N	HL/right ear dB	HL/left ear dB	
1 to 10	mean±SD	89	16±5.8	14.9±5	86	17.5±3.8	16.2±5.7	0.09
10 to 20	mean±SD	39	17.5±4.8	16.8±4.1	29	23.2±12.7	22.9±7.5	0.001
20 to 30	mean±SD	2	19.7±0.1	19.2±0.2	5	29.5±13.8	28.2±12.4	0.05
P-value [**]			0.02	0.002		0.005	0.009	

*Mann-Whitney test, P<0.05. **Kruskal-Wallis test, P<0.05

Figure 1: Comparison of the binaural hearing loss median between four groups (a) right ear (b) left ear





DISCUSSION

Direct effect of noise exposure on auditory system includes destruction of hair cells on the cochlea by mechanical, vascular and metabolic function. Also smoking affects hearing status by mechanisms that include vasoconstriction, hypoxia and nicotinetoxicity [25-27], some of these mechanisms have common effects between noise and smoking on hearing. The study results showed that smoking and high levels of industrial noise exposure could have an adverse effect on workers hearing threshold levels. Thus, coincidence of smoking and noise exposure should be considered as a critical condition in workplaces. The results showed that the average hearing loss at4000 Hzin right and leaf ears in smokers with noise exposure group was significantly higher than nonsmokers with noise exposure group, 39.5, 38.7, 33.7 and 35.6 dB, respectively. Also the mean hearing loss in smokers without noise exposure (32.4, 34.2 dB) was higher than nonsmokers without noise exposure (24.1, 23.2 dB).These results concur with other studies which have demonstrated the relationship between smoking and noise induced hearing loss by focus on smoking that can increase the chance of hearing damage[25, 28-31]. Results of Chi-square test showed that the odds ratio (OR) for hearing loss in smokers with noise exposure (group4) was 2.06 (95% CI=1.35-2.73) in comparison with group1 (nonsmokers without noise exposure).In addition, OR for group 3 was 1.37 (95% CI= 1.15-1.93) in comparison with group1.The OR obtained from logistic regression analysis indicated similar results in our study (OR=2.04, 95% CI=1.33-2.67). Also OR for groups 2 and 3 were 1.29 and 1.31, respectively. These results are consistent with some other studies with OR =1.48‑2.20[29, 32, 33].Also, some studies have reported higher OR value[31, 34].One of possible reasons for these different results is variation of sample size and number of participants groups. According to our results, hearing loss in the worse ear at 4 kHz was 39.5 dB. This finding is similar to other studies[35, 36]. The results of the study showed a synergy effect between cigarette smoking and industrial noise exposure. Several studies reported similar conclusion[31, 33, 34]. (In addition, many studies stated different result (additive effect between smoking and noise exposure)[20,32,37].The study finding declares that hearing loss is higher among participants with more consumption of cigarette per day in the same groups. In addition, risk of hearing loss among workers with industrial noise exposure and more cigarette smoking per day were higher than workers without noise exposure and same smoking per day. Thus, our study showed the combined effect of cigarette smoking and industrial noise exposure resulting in higher hearing loss. Many studies reported similar results [29, 33, 39].Also some studies revealed a dose-response relationship between the number of cigarette smoking and hearing loss[25, 27, 34].In present study, noise-dosimeter was used to measure personal workers' noise exposure in workplaces. Although, other similar studies generally used sound level meter to measure environmental noise[22, 29, 33, 34, 40].Except two study which used noise dosimeter[25, 30].Also, this study design was so that the participants were divided into four subgroups. But previous studies were performed with two groups instead of four. Limitation of the study can be regarded as the need for larger study population (male and female) and longer duration of follow up. Combined effects of two or more factors such as age, gender, race, smoking, job experience and noise exposure in increasing hearing threshold levels were survived in previous studies[29, 30, 41-43]. According to some studies common pathogenic mechanisms related to smoking and long-time noise exposure included cochlear hypoxia,

capillary vasoconstriction, and increased blood viscosity[22, 44-46]. Also, tobacco smoke releases some chemical agents such as toluene, styrene, xylene, carbon monoxide and etc. these independent material had a synergistic effects in combination with noise exposure on hearing loss[42].The present study results revealed a synergic effect between tobacco smoke and industrial noise exposure on hearing loss.

CONCLUSION

From the outcome of this investigation, it is possible to conclude that the descending amount of hearing loss among study groups is as follows first, smoker workers with noise exposure second, nonsmokers with noise exposure third, smokers without noise exposure and at last, nonsmokers without noise exposure. Regarding these findings, training workers (without or with industrial noise exposure) to reduce and quit habit of smoking for conservation of hearing, is very important. In addition, hearing monitoring program should be done for smoker workers in industrial plants with more cautions.

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