DOI: 10.2478/10004-1254-61-2010-2013

Scientific Paper

COMBINED EFFECTS OF OTOTOXIC SOLVENTS AND NOISE ON HEARING IN AUTOMOBILE PLANT WORKERS IN IRAN

Saber MOHAMMADI, Yasser LABBAFINEJAD, and Mirsaeed ATTARCHI

Department and Occupational Medicine Research Center of Iran University of Medical Sciences, Tehran, Iran

Received in December 2009
Accepted in June 2010

Exposure of workers to mixtures of organic solvents and to occupational noise is frequent in a number of industries. Recent studies suggest that exposure to both can cause a more severe hearing loss than exposure to noise alone. Our cross-sectional study included 411 workers of a large automobile plant divided in three groups. The first group included assembly workers exposed to noise alone; the second included workers in a new paint shop, who were exposed to a mixture of organic solvents at a permissible level; and the third group included paint shop workers exposed to both noise and higher than permissible levels of organic solvents in an old paint shop. These groups were compared in terms of low-frequency hearing loss (model 1; average hearing threshold >25 dB at 0.5 kHz, 1 kHz, and 2 kHz) and high-frequency hearing loss (model 2; average hearing threshold >25 dB at 3 kHz, 4 kHz, 6 kHz, and 8 kHz). High-frequency hearing loss was more common in workers exposed to a combination of noise and mixed organic solvents even at permissible levels than in workers exposed to noise alone even after correction for confounding variables. This study shows that combined exposure to mixed organic solvents and occupational noise can exacerbate hearing loss in workers. Therefore, an appropriate hearing protection programme is recommended, that would include short-interval audiometric examinations and efficient hearing protectors.

KEY WORDS: *assembly line, hearing loss, occupational exposure, paint shop*

Hearing loss is a common occupational disorder in various industries (1). In England, 153,000 men and 26,000 women suffer from severe hearing loss due to occupational noise (2, 3). The most important cause of hearing loss is exposure to noise above 85 dB in a working environment (4). This kind of exposure and therefore hearing loss are frequent in construction, mining, agriculture, transportation, and military industry workers (5).

A few studies have suggested that there is an association between hearing loss and chronic occupational exposure to neurotoxic chemicals, organic solvents in particular (6, 7). Organic solvents are widely used in the production of shoes, furniture, dyes, adhesives, plastic, rubber, and in electronic and printing industries (8). Chemical industry is the third largest industry in Europe, employing about 1.7 million workers (9). The National Institute of Occupational Safety and Health (NIOSH) estimated that 9.8 million US workers were exposed to organic solvents in the first half of the 1970s. In the 1980s, about 400,000 or 15 % of Danish workers were exposed to organic solvents on a daily basis (8).

Chronic occupational exposure to organic solvents and noise can impair hearing (10, 11). There are a number of theories about the effects of solvents on hearing. Exposure to solvents can damage sensory cells and nerve endings in the cochlea and auditory pathways in the brain, and retrocochlear damage is also possible (12, 13). Makitie et al. (14) reported that concomitant exposure to noise and styrene can damage pillar cells. However, Deiters' cells seem to be the most vulnerable target of organic solvents (15, 16). Animal studies have shown that noise and organic solvents have a synergistic effect on sensorineural hearing loss (14, 17). This has been confirmed by study in humans (18). Only a few studies have been conducted in humans and their data seem controversial. In a study by Barregard et al. (19) on shipyard painters who were exposed to noise and organic solvents, occupational hearing loss was more severe than expected from exposure to noise alone. In a study by Bergstorm et al. (20) in a paper mill factory, workers exposed to solvents in the chemical department had the most severe hearing loss even though this department was exposed to less noise than other parts of the factory. Morioka et al. (21) pointed to combined effects of organic solvents and noise on hearing thresholds, even when exposures are within limits. Another study by Sliwinska-Kowalska et al. (22) has shown that combined exposure to styrene and noise contribute to hearing loss more than exposure to noise alone. However, several studies have not established a relation between styrene exposure and hearing loss (23-25).

Workers in various industries are repeatedly exposed to both noise and organic solvents (21) and this combined exposure deserves a more detailed investigation. The aim of our study was to evaluate the effect of occupational exposure to noise and mixed organic solvents on hearing loss in car manufacture workers.

SUBJECTS AND METHODS

Study design and subjects

This is a cross-sectional study conducted in a major automobile plant outside Tehran in 2008. Initially, all workers of the assembly and paint shops (an old and a new) who worked there for more than 6 months were included in the study. All participants were interviewed for demographic data, medical history, and occupational background. Questions included the age, previous exposure to noise and organic solvents, duration of current exposure, history of ototoxic drug use and of recurrent or chronic ear infection, smoking, alcohol consumption, history of systemic diseases such as diabetes mellitus or thyroid dysfunction, history of surgery or severe head trauma, second job or previous employment, and individual habits and hobbies. Exclusion criteria were: history of ototoxic drug use, diabetes mellitus, hyperlipidemia, thyroid dysfunction, history of ear surgery or severe and recurrent infection, unilateral or conductive hearing loss, previous exposure to organic solvents or loud noise in previous or second job, history of non-occupational or recreational exposure to organic solvents or loud and unusual noise (like occasional alcohol use, listening to loud music, military service in artillery or front line of war). In this plant, 176 subjects worked in an old paint shop, 117 in a new paint shop, and 184 in the assembly shop for than 6 months. After screening for exclusion criteria, 164 workers from the old paint shop, 104 from the new paint shop, and 173 from the assembly entered the study. All participants were men and worked eight hours a day. All workers participated voluntarily in this study and signed informed consent form. This study was approved by the Ethics Committee of Iran University of Medical Sciences.

Evaluation of exposure to noise and organic solvents

Sound pressure and organic solvents in the working environment were measured by a team of in-house occupational hygienists. Sound pressure in the two paint shops and the assembly shop was measured using a CEL-440 sound level meter (CASELLA, USA).

Organic solvents used in the old paint shop included benzene, toluene, xylene, and tetrachloroethylene. Solvents used in the new paint shop include benzene, toluene, xylene, and acetone. Considering that the these solvents have similar and sometimes even synergistic effects on the same organ system, the equation below was used to set the permitted limit for the mixture of organic solvents (26). In addition, this limit is based on the American Conference of Governmental Industrial Hygienists Threshold Limit Values (ACGIH-TLV), which are the standard annual limits for chemical substances and physical agents.

$$E_m = C_1/L_1 + C_2/L_2 + \dots + C_n/L_n$$

Where E_m is the equivalent exposure for the mixture of organic solvents, C_n is the mean concentration of organic solvent in ambient air, and L_n is the exposure limit for the organic solvent (26). E_m higher than 1 indicates that the organic solvent mixture concentration in the working environment is above the threshold. In the assembly shop organic solvent concentrations were zero or negligible.

We compared three groups of workers in this study; the first were workers exposed to noise alone (assembly workers), the second were the new paint shop workers exposed to both noise and mixed organic solvents at concentrations lower than the permitted (E_m<1), and the third group were old paint shop workers exposed to noise and mixed organic solvents at concentrations higher than the permitted limit (E_m>1). We did not detect any neurotoxic agent in the working environment other than organic solvents or their concentrations were negligible. Ambient air concentrations of organic solvents was measured at the breathing level using the National Institute for Occupational Safety and Health method (27). Air samples were collected on charcoal tubes with constant flow (100 mL min^{-1}) pumps (SKC 226-01, SKC Gulf Coast Inc., USA) at 7 positions at the old paint shop, 9 at the new paint shop, and 9 at the assembly shop. Air was monitored continuously for 8 working hours. Samples were analysed and average concentrations determined using using a HP 5890 gas chromatograph (Hewlett-Packard, Avondale, PA, USA).

Hearing loss measurement

Audiometry was taken with a standard audiometer (AD 229b, Interacoustics, Denmark) in an acoustic room by a skilled audiometrist after at least 14 hours of non-exposure to noise at the workplace. Pure tone audiometry was performed at 0.5 kHz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, and 8 kHz by both air and bone conduction. Results were recorded in a predesigned form. Since exposure to excess noise at first causes hearing loss at high frequencies (3 kHz to 6 kHz) and then extends to lower frequencies (0.5 kHz to 2 kHz), we evaluated hearing loss at low (model 1) and high (model 2) frequencies using the following criteria (5): average hearing threshold above 25 dB at 0.5 kHz, 1 kHz, and 2 kHz (model 1); and average hearing threshold above 25 dB at 3 kHz, 4 kHz, 6 kHz, and 8 kHz (model 2).

Statistical analysis

ANOVA and *t*-test were used to compare these variables among the groups. Chi-square and Fisher's exact test were used to compare the qualitative variables. Logistic regression analysis was used to eliminate the confounding variables and test the correlation between exposure to noise and organic solvents and hearing loss. P values less than 0.05 were considered statistically significant. The results of statistical analysis are expressed as odds ratio (OR) with 95 % confidence intervals (95 % CI). All the mentioned calculations were performed using SPSS v.15 software.

RESULTS

The results are presented as mean ± standard deviation (SD) and range of quantitative variables. The average age of all workers was 33.07 years (range: 20 to 58 years). Average work experience of all workers was 8.06 years (range: 0.5 to 30 years). One hundred and eight workers were smokers (24.5 %). Table 1 show that the groups did not significantly differ in age, work experience, and smoking.

Average sound level was 84 dBA (range: 79 dBA to 86 dBA) in the assembly shop, 83.5 dBA (range: 77 dBA to 86.5 dBA) in the new paint shop, and 85 dBA (range: 75 dBA to 88 dBA) in the old paint shop.

Table 1 *Comparison between worker groups according to age, work experience, and smoking*

Variables	F	Assembly workers (N=173) Mean±SD	New paint shop workers (N=104) Mean±SD	Old paint shop workers (N=164) Mean±SD	*P-value
Age / years	2.46	33.36±6.95	31.87±5.49	33.53±6.22	0.086
Work experience / years	2.33	8.49±4.93	7.37±3.35	8.05±3.65	0.098
Smoking / pack per year	2.39	1.67±3.65	0.82±1.62	1.49 ±3.40	0.092

* *ANOVA*

Table 2 shows the concentrations of organic solvents in the paint shops. In the old paint shop, the equivalent exposure (E_m) was 2.52, which is above the limit, and in the new shop it was 0.496, which is within the limit.

Table 3 compares hearing loss between the groups according to the type of hearing loss. Low-frequency hearing loss (model 1) was the most common in old paint shop workers and the least common in assembly workers; however, this difference was not significant. Similar findings were obtained for high-frequency hearing loss (model 2), but this time the difference was statistically significant ($P<0.001$).

Based on model 2, average hearing threshold in assembly workers was (24.08±11.89) dB. Average hearing threshold in workers of the new and old paint shop were (25.71±7.01) dB and (32.77±16.04) dB, respectively.

To eliminate confounding variables and more precisely evaluate the relationship between hearing loss and exposure to mixed organic solvents, we employed log regression (see Table 4). Even after elimination of confounding variables such as age, work experience, and smoking, concurrent exposure to noise and mixed organic solvents in concentrations above or below the permitted caused a more severe hearing loss (model 2) than noise alone ($P<0.05$). We also observed a correlation between hearing loss (model 2) and age or work experience. We did not observe any significant correlation between smoking and hearing loss (model 2).

DISCUSSION

Exposure to noise above the permissible level of 85 dBA (4) is the main cause of hearing loss among workers. However, hearing loss can be exacerbated by exposure to chemical solvents even when noise levels are within this limit (28). Our results have shown that concomitant occupational exposure to noise and mixed organic solvents increases the rate of hearing loss compared to noise alone. As our study groups did not differ in age, work experience, or smoking, their hearing loss can largely be attributed to concomitant exposure to noise and mixed organic solvents. Model 1 (low-frequency) hearing loss was more common in the old paint shop workers (who were exposed to excessive concentrations of mixed organic solvents and noise) than in the new paint shop workers (who

Table 2 *Mean levels of organic solvents measured at the study sites*

Study site	Concentration / mg m^{-3}					E_m
	Benzene	Toluene	Xylene	Acetone	Tetrachloroethylene	
Old paint shop	0.003	19	137	101	-	2.52
New paint shop	2.012	31	388	-	41	0.446
ACGIH-TLV*	1.627	191	441	1206	173	

**American Conference of Governmental Industrial Hygienists Threshold Limit Values*
E_m - the equivalent exposure for the mixture of organic solvents

Table 3 *Low-frequency and high-frequency hearing loss by study groups*

Hearing loss	Assembly workers (N=173) n (%)	New paint shop workers (N=104) n (%)	Old paint shop workers (N=164) n (%)	P-value
Model 1 (low-frequency)	2 (1.56)	2 (1.96)	7 (4.26)	>0.05
Model 2 (high-frequency)	60 (34.68)	47 (45.19)	113 (69.90)	<0.05

Table 4 *Correlation between high-frequency hearing loss and variables of exposure to mixed organic solvents, age, work experience, and smoking by logistic regression analysis*

Variable	β	SE	Adjusted OR	95 % CI	P-value
Exposure to solvent group (E_m)					
Assembly workers (E_m = 0)	-	-	1	-	-
New paint shop workers (E_m = 0.446)	0.59	0.26	1.81	1.08-3.03	<0.05
Old paint shop workers (E_m = 2.52)	1.14	0.23	4.13	2.59-6.58	<0.001
Age / years	0.33	0.16	1.36	1.06-2.03	<0.05
Work experience / years	0.54	0.26	1.45	1.12-2.47	<0.05
Smoking / yes	0.56	0.24	1.02	0.89-1.86	>0.05

SE - standard error; OR - odds ratio; CI - confidence interval

were exposed to permissible concentrations of mixed organic solvents and noise) or assembly workers (who were exposed to noise alone) but these differences were not significant. Chang et al. (29) showed that combined exposure to noise and toluene or carbon disulphide had greater impact on hearing loss at speech frequencies than noise alone. Toluene and noise-exposed workers had poorer thresholds than did noise-only-exposed workers at 1 kHz frequencies, but not necessarily at high frequencies.

In our study, model 2 (high-frequency) hearing loss was significantly more common in the old paint shop workers than in the new paint shop workers or assembly workers, which is in line with other studies (7, 30). Sliwinska-Kowalska et al. (30) found that the odds ratio (OR) for hearing loss increased to approximately 3 in the noise-only group and to almost 5 in the noise and solvent group. These results suggest an additive adverse effect. Rabinowitz et al. (1) concluded that solvent exposure was significantly associated with high-frequency hearing loss. Even though exposures were low and the time of observation was quite short, workers developed additional hearing impairment at high frequencies (1).

Kim et al. (5) studied workers in the aviation industry and found an association between hearing loss and mixed organic solvents even within recommended exposure limits of solvents. In contrast, Jacobsen et al. (31) reported that combined exposure to noise and solvents did not seem to have a greater impact on hearing loss than exposure to noise alone. Sliwinska-Kowalska et al. (32) showed that workers exposed to mixed organic solvents at moderate concentrations had an increased risk of hearing loss, but found no correlation between hearing loss and the concentrations of organic solvent. The discrepancy between studies may be accounted for by the type and concentration of the solvent or mixture under study. Regression analysis in our study showed a correlation between age and hearing loss, which is in accordance with similar studies (5, 10). After eliminating confounding factors like age, work experience, and smoking, we observed a significant correlation between combined exposure to noise and excessive concentrations of mixed organic solvents and high-frequency hearing loss, which is supported by earlier studies (10, 33). Moreover, we observed a correlation between hearing loss and exposure to mixed organic solvents at concentrations below the threshold, which is in line with other studies (11). Some studies suggested a synergistic effect of noise and solvents on hearing (17, 18). Our study confirmed the increased effect of combined exposure in respect to noise alone.

The limit of our study is that, being cross-sectional, it can not establish causal relations. This can be addressed in a prospective study. In addition, we were not able to estimate the cumulative dose of exposure because we did not have information on previous exposure levels.

In our study, benzene was the major component of the organic solvent mixture. Some animal studies have shown that benzene adversely affects hearing (34, 35). This has also been confirmed in humans (36). Cappaert et al. (37) compared the effects of ethyl benzene on the hearing system in guinea pigs and rats. Rats showed deteriorated auditory thresholds in the mid-frequency range. In contrast, guinea pigs showed no threshold shifts after exposure to much higher ethyl benzene levels.

In a study by Morata et al. (38), concomitant exposure to noise and organic solvents mixture in which benzene was the major component significantly affected hearing thresholds among refinery workers.

CONCLUSION

Our results indicate that, in addition to occupational noise, attention should be paid to identifying and monitoring ototoxic agents. Moreover, implementation of an accurate and comprehensive hearing protection programme, that would include short-interval audiometric examinations and use of more effective hearing protectors to reduce noise to acceptable levels (<85 dBA) is a must for industries whose workers are exposed to a combination of mixed organic solvents and noise.

REFERENCES

1. Rabinowitz P, Galusha D, Slade M, Dixon-Ernst C, O'Neill A, Fiellin M, Cullen M. Organic solvent exposure and hearing loss in a cohort of aluminium workers. Occup Environ Med 2007;65:230-5.
2. Palmer K, Griffin M. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. Occup Environ Med 2002;59:634-9.
3. Palmer K, Griffin M. Cigarette smoking, occupational exposure to noise and self reported hearing difficulties. Occup Environ Med 2004;61:340-4.
4. Mizoue T, Miyamoto T. Combined effect of smoking and occupational exposure to noise on hearing loss in steel factory workers. Occup Environ Med 2003;60:56-9.
5. Kim J, Park H, Ha E, Jung T, Paik N, Yang S. Combined effects of noise and mixed solvents exposure on the hearing function among workers in the aviation industry. Ind Health 2005;43:567-73.
6. Morata T. Chemical exposure as a risk factor for hearing loss. J Occup Environ Med 2003;45:676-82.
7. Morata T, Dunn D, Kretschmer L, Lemasters G, Keith R. Effects of occupational exposure to organic solvents and noise on hearing. Scand J Work Environ Health 1993;19:245-54.
8. Rosenstock L, Cullen MR, Brodkin CR, Redlich CA, editors. Textbook of Clinical Occupational and Environmental Medicine. 2nd ed. Philadelphia: Elsevier Saunders; 2004.
9. Sliwinska-Kowalska M. Exposure to organic solvent mixture and hearing loss: literature overview. Int J Occup Med Environ Health 2007;20:309-14.
10. Schaper M, Seeber A, Vanthrlel C. The effects of toluene plus noise on hearing threshold: an evaluation based on repeated measurements in the German printing industry. Int J Occup Med Environ Health 2008;21:191-200.
11. Morata T, Johnson A, Nylen P, Svensson E, Cheng J, Krieg E, Lindblad A, Ernstgard L, Franks J. Audiometric findings in workers exposed to low levels of styrene and noise. J Occup Environ Med 2002;44:806-14.
12. Fechter L, Liu Y, Herr D, Crofton K. Trichloroethylene ototoxicity: evidence for a cochlear origin. Toxicol Sci 1998;42:28-35.
13. Prasher D, Al-Hajjaj H, Aylott S, Aksentijevic A. Effect of exposure to a mixture of solvents and noise on hearing and balance in aircraft maintenance workers. Noise Health 2005;7:31-9.
14. Makitie A, Pirvola U, Pyykko I, Sakakibara H, Riihimaki V, Ylikoski J. The ototoxic interaction of styrene and noise. Hear Res 2003;179:9-20.
15. Chen GD, Chi LH, Kostyniak P, Henderson D. Styrene induced alterations in biomarkers of exposure and effects in the cochlea: mechanisms of hearing loss. Toxicol Sci 2007;98:167-77.
16. Chen GD, Tanaka C, Henderson D. Relationship between outer hair cell loss and hearing loss in rats exposed to styrene. Hear Res 2008;243:28-34.
17. Lataye R, Campo P, Loquet G. Combined effects of noise and styrene exposure on hearing function in the rat. Hear Res 2000;139:86-96.
18. Morata T, Dunn D, Sieber W. Occupational exposure to noise and ototoxic organic solvents. Arch Environ Health 1994;49:359-65.
19. Barregard L, Axelsson A. Is there an ototraumatic interaction between noise and solvents. Scan Audiol 1984;13:151-5.
20. Bergstrom B, Nystrom B. Development of hearing loss during long-term exposure to occupational noise. A 20-year follow-up study. Scan Audiol 1986;15:227-34.
21. Morioka I, Miyai N, Yamamoto H, Miyashita K. Evaluation of combined effect of organic solvents and noise by the upper limit of hearing. Ind Health 2000;38:252-7.
22. Sliwinska-Kowalska M, Zamyslowska-Szmytke E, Szymczak W, Kotylo P, Fiszer M, Wesolowski W, Pawlaczyk-Luszczynska M. Ototoxic effects of occupational exposure to styrene and co-exposure to styrene and noise. J Occup Environ Med 2003;45:15-24.
23. Calabrese G, Martini A, Sessa G, Cellini M, Bartolucci G, Marcuzzo G, De Rosa E. Otoneurological study in workers exposed to styrene in the fiberglass industry. Int Arch Occup Environ Health 1996;68:219-23.
24. Moller C, Odkvist L, Larsby B, Tham R, Ledin T, Bergholtz L. Otoneurological findings in workers exposed to styrene. Scand J Work Environ Health1990;16:189-94.
25. Sass-Kortsak A, Corey P, Robertson J. An investigation of the association between exposure to styrene and hearing loss. Ann Epidemiol 1995;5:15-24.
26. Rom WN. Occupational and Environmental Medicine. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2007.
27. National Institute for Occupational Safety and Health (NIOSH). NIOSH Manual of Analytical Methods. 4th ed. DHEW publication. NO 94-113. Cincinnati (OH): NIOSH; 1994.
28. Morata T, Fiorini A, Fischer F, Colacioppo S, Wallingford K, Krieg E, Dunn D, Gozzoli L, Padrgo M, Cesar C. Toluene-induced hearing loss among rotogravure printing workers. Scand J Work Environ Health 1997;23:289-98.
29. Chang SJ, Shih TS, Chou TC, Chen CJ, Chang HY, Sung FC. Hearing loss in workers exposed to carbon disulfide and noise. Environ Health Perspect 2003;111:1620-4.
30. Sliwinska-Kowalska M, Zamyslowska-Szmytke E, Szymczak W, Kotylo P, Fiszer M, Wesolowski W, Pawlaczyk-Luszczynska M, Bak M, Gajda-Szadkowska A. Effects of coexposure to noise and mixture of organic solvents on hearing in dockyard workers. J Occup Environ Med 2004;46:30-8.
31. Jacobsen P, Hein H, Suadicani P, Parving A, Gyntelberg F. Mixed solvents exposure and hearing impairment: an

epidemiological study of 3284 men. The Copenhagen male study. Occup Med 1993;43:180-4.
32. Sliwinska-Kowalska M, Zamyslowaska-Szmytke E, Szymczak W, Kotylo P, Fiszer M, Dudarewicz A, Wesolowski W, Pawlaczyk-Luszczynska M, Stolarek R. Hearing loss among workers exposed to moderate concentrations of solvents. Scand J Work Environ Health 2001;27:335-42.
33. Schäper M, Demes P, Zupanic M, Blaszkewicz M, Seeber A. Occupational toluene exposure and auditory function: results from a follow-up study. Ann Occup Hyg 2003;47:493-502.
34. Cappaert N, Klis S, Baretta A, Muijser H, Smoorenburg G. Ethyl benzene-induced ototoxicity in rats: a dose-dependent mid-frequency hearing Loss. J Assoc Res Otolaryngol 2000;1:292-9.
35. Gagnaire F, Langlais C. Relative ototoxicity of 21 aromatic solvents. Arch Toxicol 2005;79:346-54.
36. Pollastrini L, Abramo A, Cristalli G, Baretti F, Greco A. [Early signs of occupational ototoxicity caused by inhalation of benzene derivative industrial solvents, in Italian]. Acta Otorhinolaryngol Ital 1994;14:503-12.
37. Cappaert NL, Klis SF, Muijser H, Kulig BM, Ravensberg LC, Smoorenburg GF. Differential susceptibility of rats and guinea pigs to the ototoxic effects of ethyl benzene. Nerotoxicol Teratol 2002;24:503-10.
38. Morata TC, Engel T, Durao A, Costa TRS, Krieg EF, Dunn DE, Lozano M. Hearing loss from combined exposures among petroleum refinery workers. Scand Audiol 1997;26:141-9.

Sažetak

KOMBINIRANO DJELOVANJE OTOTOKSIČNIH OTAPALA I BUKE NA SLUH RADNIKA U TVORNICI AUTOMOBILA U IRANU

Profesionalna izloženost radnika mješavinama organskih otapala i buci česta je u mnogim industrijskim granama. Nedavna su istraživanja pokazala da izloženost i jednom i drugomu može dovesti do većih oštećenja sluha negoli samo izloženost buci. Ovo je presječno ispitivanje obuhvatilo 411 radnika velike tvornice automobila u Iranu, koji su podijeljeni u tri skupine. Prva je skupina obuhvatila radnike na sklapanju dijelova izložene samo buci, druga radnike u novoj autolakirnici, koji su uz buku bili izloženi mješavini organskih otapala u dopuštenim razinama, a treća je skupina obuhvatila radnike u staroj autolakirnici, koji su uz buku bili izloženi prekomjernim razinama mješavine organskih otapala. Te smo skupine usporedili s obzirom na gubitak sluha za niže frekvencije (0,5 kHz, 1 kHz i 2 kHz; prosječni prag >25 dB) odnosno više frekvencije (3 kHz, 4 kHz, 6 kHz i 8 kHz; prosječni prag >25 dB). Gubitak sluha za više frekvencije bio je učestaliji u radnika izloženih kombinaciji buke i mješavini organskih otapala nego u radnika izloženih samo buci, čak i kada su razine otapala bile unutar dopuštene granice te kad su se uklonile ometajuće varijable. Ovo je ispitivanje potvrdilo da istodobna profesionalna izloženost mješavini organskih otapala i buci može pogoršati gubitak sluha. Stoga je nužno osmisliti odgovarajući program zaštite sluha koji bi obuhvatio učestalo testiranje sluha i djelotvornu zaštitnu opremu.

KLJUČNE RIJEČI: *autolakirnica, gubitak sluha, profesionalna izloženost, sklapanje dijelova*

CORRESPONDING AUTHOR:

Mirsaeed Attarchi
Occupational Medicine Department
Faculty of Medicine - Iran University of Medical Sciences
P.O. BOX 14155-5983, Tehran, Iran
E-mail: *drmsattarchi@gmail.com*