DOI: 10.1590/2317-1782/20152014128

Original Article

Artigo Original

Training on hearing protector insertion improves noise attenuation

Atenuação do protetor auditivo após treinamento para colocação

Alessandra Giannella Samelli[1]
Clayton Henrique Rocha[1]
Patrícia Theodósio[1]
Renata Rodrigues Moreira[2]
Ivone Ferreira Neves-Lobo[1]

Keywords

Noise-induced Hearing Loss
Ear Protective Devices
Inservice Training
Occupational Health
Hearing

ABSTRACT

Purpose: To determine the efficacy of hearing protector insertion by comparing attenuation values measured by objective (MIRE) and subjective (REAT) methods in groups with and without training. **Methods:** The study included 80 male subjects assigned to experimental (with training) and control (without training) groups. The following procedures were performed: occupational history, objective and subjective assessment of hearing protectors. Only subjects in the experimental group received training and guidance on proper hearing protector insertion. **Results:** Attenuation values were significantly higher in the experimental group than in the control group at all frequencies (500, 1000, 2000, and 4000 Hz) investigated through the objective (MIRE) and subjective (REAT) methods. In addition, attenuation values in the control group were lower than those provided by the hearing protector manufacturer. **Conclusion:** Both objective and subjective attenuation tests demonstrated the efficacy of training on insertion of hearing protectors because the group that received training on proper hearing protection insertion exhibited higher attenuation values than the untrained group.

Descritores

Perda Auditiva Provocada por Ruído
Dispositivos de Proteção Auditiva
Capacitação em Serviço
Saúde Ocupacional
Audição

RESUMO

Objetivo: Determinar a eficácia da colocação do protetor auditivo comparando os valores de atenuação obtidos pelos métodos objetivo (MIRE) e subjetivo (REAT) em grupos com e sem treinamento. **Métodos:** Participaram do estudo 80 indivíduos do sexo masculino, separados em grupo pesquisa (com treinamento) e controle (sem treinamento). Os procedimentos realizados foram: anamnese e avaliações objetiva e subjetiva do protetor auditivo. Apenas os indivíduos do grupo pesquisa receberam treinamento e orientações para colocar corretamente o protetor auditivo. **Resultados:** Os valores de atenuação no grupo pesquisa foram maiores com diferenças estatisticamente significantes em relação ao grupo controle em todas as frequências (500, 1000, 2000 e 4000 Hz) investigadas por meio dos métodos objetivo (MIRE) e subjetivo (REAT). Além disso, os valores de atenuação no grupo controle foram menores do que as previstas pelo fabricante do protetor auditivo. **Conclusão:** Ambos os métodos de avaliação da atenuação (objetivo e subjetivo) demonstraram a eficácia da colocação do protetor auditivo. Entretanto, o grupo que recebeu treinamento para colocação adequada do protetor auditivo apresentou valores de atenuação maiores do que o grupo sem treinamento.

Correspondence address:
Professor Alessandra G. Samelli
School of Medicine
Universidade de São Paulo
Rua Cipotânea, 51, Cidade Universitária,
São Paulo (SP), Brazil, CEP: 05360-160.
E-mail: alesamelli@usp.br

Received: 08/12/2014

Accepted: 04/30/2015

CoDAS 2015;27(6):514-9

Study carried out at the Department of Physical Therapy, Speech-Language Pathology and Audiology, and Occupational Therapy, School of Medicine, Universidade de São Paulo – FMUSP – São Paulo (SP), Brazil.
(1) Department of Physical Therapy, Speech-Language Pathology and Audiology, and Occupational Therapy, School of Medicine, Universidade de São Paulo – FMUSP – São Paulo (SP), Brazil.
(2) University Hospital of Universidade de São Paulo – USP – São Paulo (SP), Brazil.
Conflict of interests: nothing to declare.

INTRODUCTION

Noise-induced hearing loss (NIHL) is a hearing disorder that results from exposure to high-intensity sound. Even though preventable, NIHL is an increasingly prevalent occupational health problem[1].

Noise reduction or elimination is the best strategy to eliminate or minimize the risk of hearing loss from exposure to high-intensity sound. However, the use of individual hearing protection has been the strategy used by most employers, as it is simpler and less costly in the short term[1,2].

Hearing protection devices (HPDs) are noise barriers which have to be used to protect the user's hearing; however, its effectiveness depends on a wide range of intrinsic characteristics and also physiological and anatomical individual features. The selection of a particular device type should consider the working environment of the user in addition to comfort and acceptance, cost and durability, communication problems during use, safety, and hygiene[3,4]. Moreover, the hearing protectors selection should consider mainly the attenuation provided by the device, which should be enough to protect user's hearing while preventing overprotection and negative effects such as communication isolation and increased risks caused by the inability to hear alert sounds[5,6].

In order to ensure the effectiveness of using a HPD, it is necessary to provide guidance and training for workers, regarding the suitable position, cleaning and exchange of HPD. These actions may be done through illustrative handouts and presentations. Also, it is important to consider the worker's function, encouraging them to use HPD in all situations and also provide regular warning concerning possible damages that may happen whether the HPD is not used properly[7].

Commonly the employee receives the HPD, however do not receive instructions about the proper use of it as well as regarding risks that my happen due to its misuse. In the absence of orientations, fails in checking the HPD may rise the number of NIHL cases[8].

The selection of HPDs is also based on Noise Reduction Ratings (NRRs) provided by manufacturers in accordance with environmental protection agency regulations[2,9]. In general, the sound attenuation provided by a HPD can be defined as the difference between sound pressure levels that reach the ear canal (near the eardrum) with and without the device[5].

NRRs are based on noise reduction obtained in laboratory conditions according to ANSI and/or ISO guidelines that check noise attenuation levels provided by hearing protectors. However, laboratory conditions differ considerably from typical occupational environments, which can lead to substantial differences in the attenuation provided by HPDs in real-world situations, resulting in significant health effects on workers exposed to noise. This problem can be solved by conducting individual fit testing of HPDs[2,10-12].

Methods that assess hearing protector insertion in real-world situations are essential to determine if the protection provided by the HPD is appropriate to a particular individual. Moreover, improving HPD insertion should help to increase hearing protection efficacy, as some studies have shown that the lack of training and education among workers exposed to occupational noise impairs the establishment of effective hearing conservation programs (HCPs) and contributes to high NIHL prevalence[3,4].

Two methods have been used to measure the attenuation of HPDs in real-world situations. Real-ear attenuation at threshold (REAT), a subjective method, performed in a soundproof booth or circumaural headphones, which measures thresholds in the sound field with and without the HPD; and *Microphone-in-real-ear* (MIRE), an objective method in which measurements are obtained using two microphones (one inside the ear canal and another for recording external sound field)[2,9,10,13-15].

The use of hearing protectors and training regarding the proper use of HPD are both in the laws, but, contrarily, assessment of the effectiveness of the training and the real efficacy of hearing protectors are not mentioned in the workers' health laws.

This study aimed to determine the efficacy of training on the insertion of hearing protectors, comparing attenuation values measured by objective (MIRE) and subjective (REAT) methods in groups with and without training. In addition, we compared the attenuation values found in this study to those provided by a hearing protector manufacturer.

Thus, the results of this study may provide future shifts in the current health and safety legislation and also stimulate the acquirement of proper instruments which will enable professionals to best check the efficacy of training HPDs placing, develop hearing conservation programs, and in the establishment of fast and objective measurements of HPD's attenuation in the workplace.

METHODS

This study was designed as cross sectional, and counted on 80 voluntary male participants aged between 18 and 53 years (mean age of 32 years) who were divided into two groups. The experimental group (EG) is composed of 40 workers from a public university (University of São Paulo), exposed to occupational noise who participated in a hearing conservation program that included guidance on proper hearing protector insertion. The control group (CG) consisted of 40 students and workers from a public university (University of São Paulo), with no occupational noise exposure and no training on hearing protector insertion. During a period of three months within the routine care of periodic audiometric tests, the subjects were invited to participate in the study, which characterizes it as a convenience sample.

All subjects were informed about the study and signed an informed consent form before participation in the study, which was approved by the Ethics Committee of the Institution, under protocol N°. 858/08.

The exclusion criteria in both groups was the occurrence of any changes to the external ear such as cerumen, abnormalities in the ear canal, and foreign bodies that could prevent the completion of tests or insertion of hearing protectors. Three subjects of EG were excluded from the initial sample because of excessive cerumen.

The following procedures performed in all individuals:

1. Otologic and occupational history.
2. Meatoscopy to examine the EAM and tympanic membrane using a *Heine Mini 3000* otoscope.

3. Microphone-in-real-ear (MIRE) objective test: using *Interacoustics MS40 Hearing Aid Analyzer* insertion gain analyzer (this equipment is commonly used to measure gain of hearing aids). The analyzer scans frequencies from 125 to 8000 Hz using a warble tone at an intensity range of 40–140 dB SPL (Sound Pressure Level). A 70 dB SPL input was used for data collection and frequencies from 500 to 6000 Hz were analyzed. The subjects were seated in a chair in the soundproof booth and instructed to remain during the entire procedure, at a distance of 40 cm from the loudspeaker positioned at 0º/0º azimuth. Two measurements were taken in the following order:
    a. REUR – Real Ear Unaided Response “as a function of frequency, at a specified measurement point in the ear canal, for a specified sound field, with the ear canal unoccluded” (16).
    b. REOR – Real Ear Occluded Response “as a function of frequency, at a specified measurement point in the ear canal, for a specified sound field, with the hearing aid (and its acoustic coupling) in place and turned off”[16]. In this study, it was placed the earplug instead the hearing aid.

To determine REOR, the HPD was placed by all individuals in the same ear as the probe microphone, in both groups, after REUR measurement. The silicone tube measured 58 mm, however only 28 mm were inserted into the ear canal of participants, value adopted by the geometric method[17,18]. This method guarantees that the probe will not be disrupted by the HPD. It is important to point out that before each trial the probe was measured to check its size. To assist proper placement of the probe in the ear canal, we used an otoscope and a flashlight to pre mold.

The probe was marked in red, which allowed standardizing the size to be inserted into the ear canal. In the study, the red mark was positioned towards the antitragus, in order to ensure that they were in the same deepness into the ear canal of all individuals.

The control group (CG) did not receive training on proper hearing protector insertion. These subjects fitted the protectors as they thought appropriate following the instructions provided on the hearing protector packaging, in accordance with ANSI 12.6-1997 (Method B – Subject fit)[19], which determines that fitting of the protectors is done by the subject, according to his interpretation of instructions for use provided by the manufacturer, and without external help. Conversely, individuals in the EG had received previous training and guidance on proper hearing protection insertion. The researcher showed the adequate procedure to place the HPD properly, which included performing its correct rolling movement and positioning using hands to improve the ear canal to open, the placement of the HPD and the perception of attenuation provided in the occluded ear when comparing it to the free ear. After the presentation, the participant was asked to put the HPD, supervised by the researcher.

4. Real-ear attenuation at threshold (REAT) subjective test: in this test, the probe microphone was removed and the HPD was kept in the same position as in the previous test. Subsequently, pure tone audiometry was conducted with and without the HPD using a GSI-61 audiometer with GSI speakers. The subjects were instructed to keep their head directed to the loudspeaker at 0º/0º azimuth and at a distance of 60 cm, and were instructed to signal whenever they heard a sound stimulus. Hearing thresholds were determined with (occluded ear) and without (unoccluded ear) hearing protectors at frequencies ranging from 500 to 6000 Hz using a warble tone. Additionally, narrow band noise masking was used in the non-tested ear (without hearing protector), using a TDH-39 headphone, at 40 dB SL to prevent it from responding to the signal presented to the test ear.

The objective and subjective tests were performed in one ear only, which was selected according to the best manual dexterity presented by the individual in inserting the HPD, once that several studies reported differences in attenuation between the ears due to the manual dexterity of the individual.

The hearing protectors used by all individuals were disposable earplugs from a well-known brand.

HPD attenuation measurements were calculated by the difference between REUR and REOR in the MIRE method, and between hearing thresholds values with and without the HPD in the REAT method.

All results (differences between values recorded for each method) were expressed as mean ± standard deviation. All analyses were performed using one-way analysis of variance (ANOVA) with significance level set at $p \leq 0.05$.

RESULTS

Results in Tables 1 and 2 show the values obtained by the experimental and control groups (respectively) when

Table 1. Values of real ear unaided response and real ear occluded response obtained by the Microphone-in-real-ear and Real-ear attenuation at threshold in the Experimental Groups at frequencies from 500 to 6000 Hz (n=40)

	MIRE (dB)	REAT (dB)
	Mean±SD	Mean±SD
REUR		
500 Hz	64±5.03	15.13±11.18
1000 Hz	66.2±4.95	13.75±11.08
2000 Hz	76.4±8.4	18.38±12.22
3000 Hz	79.4±8.09	21.13±13.56
4000 Hz	73.38±7.94	30.75±17.52
6000 Hz	67.18±8.13	28.75±17.39
REOR		
500 Hz	52±9.28	29.38±12.72
1000 Hz	52.9±8.15	31.13±13.61
2000 Hz	57.4±9.16	47.25±13.35
3000 Hz	56.53±8.2	56.88±13.95
4000 Hz	61.23±7.46	65.88±15.52
6000 Hz	61.13±7	60.88±14.45

Caption: MIRE = Microphone-in-real-ear; REAT = Real-ear attenuation at threshold; REUR = real ear unaided response; REOR = real ear occluded response; SD = standard deviation assessed by MIRE and REAT methods, with free ear (REUR) and occluded (REOR). It is important to point out that MIRE method assess the level of sound pressure in the ear canal with and without HPD, whereas REAT investigates the hearing threshold at the sound field of participants with and without HPD.

Sound attenuation was higher in the EG than in CG at all frequencies measured by the MIRE method; the difference in attenuation was statistically significant at 500–3000 Hz and 6000 Hz frequencies (Table 3).

Attenuation of the hearing protector was significantly higher in the EG at all frequencies measured by the REAT method (Table 4). In addition, REAT values in the CG were lower than the values provided by the hearing protector manufacturer (Table 5).

Table 2. Values of real ear unaided response and real ear occluded response obtained by the Microphone-in-real-ear and Real-ear attenuation at threshold in the Control Groups at frequencies from 500 to 6000 Hz (n=40)

	MIRE (dB)	REAT (dB)
	Mean±SD	Mean±SD
REUR		
500 Hz	69.5±2.99	15.75±8.44
1000 Hz	70.5±3.56	12.38±6.7
2000 Hz	80.35±5.26	13.38±6.54
3000 Hz	83.6±5.08	10.64±7.18
4000 Hz	77.65±4.67	12.75±7.92
6000 Hz	70.58±4.08	12.38±8.01
REOR		
500 Hz	65.35±7.34	22.75±11.98
1000 Hz	64.95±8.1	22.13±11.98
2000 Hz	70.45±9.8	31±14.73
3000 Hz	69.38±9.13	32±14.62
4000 Hz	67.7±5.56	34.38±14.55
6000 Hz	66.68±4.01	30±18.57

Caption: MIRE = Microphone-in-real-ear; REAT = Real-ear attenuation at threshold; REUR: real ear unaided response; REOR: real ear occluded response; SD = standard deviation

Table 3. Attenuation values of hearing protectors measured by the Microphone-in-real-ear method in the Experimental and Control groups at frequencies from 500 to 6000 Hz (n=80)

	EG (dB)	CG (dB)	Df	F-test	p-value
	Mean±SD	Mean±SD			
MIRE					
500 Hz	12±9.54	4.15±6.76	1	18	<0.001
1000 Hz	13.3±7.80	5.55±8.28	1	18,52	<0.001
2000 Hz	19±8.32	9.9±10.28	1	18,9	<0.001
3000 Hz	22.87±8.37	14.22±9.77	1	18,06	<0.001
4000 Hz	12.15±7.20	9.95±5.65	1	2,308	0,132
6000 Hz	6.05±4.85	3.90±4.32	1	4,372	0,039

ANOVA (5% significance level).

Caption: MIRE = Microphone-in-real-ear; EG = experimental group; CG = control group; Df = Degree of freedom; SD = standard deviation

Table 4. Attenuation values of hearing protectors measured by the Real-ear attenuation at threshold method in the Experimental and Control groups at frequencies from 500 to 6000 Hz (n=80)

	EG (dB)	CG (dB)	Df	F-test	p-value
	Mean±SD	Mean±SD			
REAT					
500 Hz	14.25±9.97	7.0±9.11	1	11,52	0,001
1000 Hz	17.37±9.75	9.75±9.80	1	12,78	<0.001
2000 Hz	28.87±10.40	17.62±12.60	1	18,94	<0.001
3000 Hz	35.75±10.09	21.37±12.55	1	31,83	<0.001
4000 Hz	35.12±10.15	21.62±13.02	1	26,71	<0.001
6000 Hz	32.12±11.31	17.62±14.71	1	24,4	<0.001

ANOVA (5% significance level).

Caption: REAT = Real-ear attenuation at threshold; EG = experimental group; CG = control group; Df = Degree of freedom; SD = standard deviation

Table 5. Attenuation values of hearing protectors measured by the Real-ear attenuation at threshold method in the Control Group (n=40) and manufacturer values (n=20) at frequencies from 500 to 4000 Hz

	CG (dB)	Manufacturer (dB)	p-value
	Mean±SD	Mean±SD	
REAT			
500 Hz	7.0±9.11	22.1±8.1	<0.001
1000 Hz	9.75±9.80	22.6±7.2	<0.001
2000 Hz	17.62±12.60	29.9±6.1	<0.001
4000 Hz	21.62±13.02	37.8±6.7	0,05

Manufacturer: values provided by the hearing protector manufacturer (according to ANSI [1]). ANOVA (5% significance level).

Caption: REAT = Real-ear attenuation at threshold; CG: control group; freedom; SD = standard deviation

DISCUSSION

We aimed to determine the efficacy of training on insertion of hearing protectors and compare the attenuation values found in this study to those provided by a hearing protector manufacturer.

There were significant differences in attenuation values between the EG and CG measured by the MIRE and REAT methods. The EG, who had received training on the use of HPDs, exhibited significantly greater attenuation values than the CG, indicating that the training improves hearing protection, insertion and provides best hearing protection as observed in other studies(2,8,20,21).

The attenuation values measured by the REAT method in the CG were lower than those provided by the hearing protector manufacturer even when the same technique described by the manufacturer for determining frequency attenuation values was used(11,13,22), i.e., using untrained individuals who relied on the instructions provided on the hearing protector packaging for fitting the protectors.

This fact shows that attenuation values indicated by the manufacturer are overestimated for real-life situations, and if a Hearing Conservation Program uses these values for the selection of hearing protectors, the employees exposed to noise not will be protected, depending on the level of exposure. However, if we observe attenuation values obtained for the group who participated in training on the insertion of hearing protectors (EG), we found that the attenuation values obtained are close to the values provided by the manufacturer. This emphasizes the importance of training in a Hearing Conservation Program[(23)] to the reduction of the discrepancy between laboratory and real life.

Studies that compared the attenuation values of the hearing protectors by MIRE and REAT showed differences between measurements and the values obtained by REAT were larger than those obtained by MIRE[(21,24,25)]. This study also found different values obtained by REAT and MIRE and this difference may be due to two factors: background noise and physiological masking effects, especially in lower frequencies[(24,26)], as well as due to variability in the response caused by subjectivity of the procedure of REAT method.

In addition, it have been repeatedly demonstrated that earplugs have greater variation in attenuation than earmuffs and the fact that the current study tested only earplugs can also explain the variability in the REAT values, especially with regard to the greater variability of standard deviations, which are also influenced by the subjective nature of psychophysical of evaluation[(11,24,26)].

As limitations of the present study, we may cite the sample size and the equipment used to assess through the MIRE method. We suggest that, in future studies, the objective evaluations of HPD attenuation may be conducted with larger samples and with equipment which allows the measurement of MIRE in the work environment. Further, it would be also important to determine whether manual dexterity influences on the correct placement of hearing protectors.

Based on the results found in this study, two aspects should be reviewed in occupational audiology:

- Hearing protectors recommended to a person should be tested for attenuation provided because the devices may not be suited to the noise levels to which the person is exposed and attenuation values provided by manufacturers do not always correspond to the reality of all persons due to physiological and anatomical differences and individual needs in different workplaces;
- Training on the insertion of hearing protectors is essential in hearing conservation programs to ensure proper device insertion; proper insertion should be verified to ensure the efficacy of training.

CONCLUSION

Our results showed that both objective and subjective attenuation tests demonstrated the efficacy of training on the insertion of hearing protectors. The group (EG) that received training on proper hearing protection insertion exhibited higher attenuation values than the untrained group. Moreover, the attenuation values measured in the CG were not in accordance with those provided by the hearing protector manufacturer.

Finally, we emphasize the importance of conducting practical and easy training for placement of the HPD by the employee for better attenuation, which would also be useful as a way to evaluate the effectiveness of HCP.

**CHR and PT were in charge of data collection and tabulation; RRM and IFN-L collaborated with data analysis and writing; AGS accompanied collection and was responsible for data analysis, as well as general orientation of execution stages and writing.*

REFERENCES

1. Daniell WE, Swan SS, McDaniel MM, Camp JE, Cohen MA, Stebbins JG. Noise exposure and hearing loss prevention programmes after 20 years of regulations in the United States. Occup Environ Med. 2006; 63(5):343–51.
2. Nélisse H, Gaudreau MA, Boutin J, Voix J, Laville F. Measurement of Hearing Protection Devices Performance in the Workplace during Full-Shift Working Operations. Ann OccupHyg. 2012; 56(2):221-32.
3. Neitzel R, Meischke H, Daniell WE, Trabeau M, Somers S, Seixas NS. Development and Pilot Test of Hearing Conservation Training for Construction Workers. Am J Ind Med. 2008;51(2):120-9.
4. Nor Saleha IT, Noor Hassim I. A study on compliance to hearing conservation programme among industries in Negeri Sembilan, Malaysia. Ind Health. 2006;44(4):584-91.
5. Behar A. Hearing Protection Devices: Do We Choose and Use Them Properly? Hearing Review;2007.
6. Zheng Y, Giguère C, Laroche C, Sabourin C, Gagné A, Elyea M. A Psychoacoustical Model for Specifying the Level and Spectrum of Acoustic Warning Signals in the Workplace. J Occup Envir Hyg. 2007; 4(2):87-98.
7. Bramatti L, Morata TC, Marques JM. Ações educativas em Programa de Conservação Auditiva. Rev CEFAC. 2008;10(3):398-408.
8. Gonçalves CGO, Couto CM, Carraro JM, Leonelli BS. Avaliação da colocação de protetores auriculares em grupos com e sem treinamento. Rev CEFAC. 2009;11(2):345-52.
9. Berger EH. Preferred Methods for Measuring Hearing Protector Attenuation In: Internoise – environmental Noise control; 2005 Aug 7-10; Rio de Janeiro.
10. Berger EH. Introducing F-MIRE Testing - Background and Concepts. Indianapolis: E•A•R / Aearo Technologies, E•A•RCAL[SM] Laboratory; 2007.
11. Casali JG, Park MY. Laboratory versus field attenuation of selected hearing protectors. J SoundVib. 1991;25:28-38.
12. Samelli AG, Fiorini AC. Saúde Coletiva e Saúde do Trabalhador: prevenção de perdas auditivas. In: Bevilacqua MC, Martinez MAN, Balen AS, Pupo AC, Reis ACM, Frota S, eds. Tratado de Audiologia. São Paulo: Ed. Santos; 2011.
13. Berger EH, Voix J, Hager LD. Methods of fit testing hearing protectors, with representative field test data In: Hearing loss: 9th International Congress on Noise as a Public Health Problem (ICBEN). Foxwoods, CT; 2008.
14. Vergara EF, Steffani J, Gerges SNY, Pedroso M. Avaliação da exposição de operadores de teleatendimento a ruído. Rev Bras S Ocupac. 2006; 31(114):161-72.
15. Voix J, Hager LD, Zeidan J. Experimental validation of the objective measurement of individual earplug field performance. Euronoise. 2006; 1-6.
16. American National Standards Institute. (1997). Methods of Measurement of Real-Ear Performance Characteristics of Hearing Aids. ANSI S3.46-1997. New York: Acoustical Society of America.
17. Silva APR, Blasca WQ, Lauris JRP, Oliveira JRM. Correlação entre as características da ressonância e o envelhecimento da orelha externa. CoDAS. 2014;26(2):112-6.
18. Bastos BG, Ferrari DV, Blasc WQ. Ressonância natural da orelha e sua relação com os volumes equivalentes das orelhas externa e média. Int Arch Otorhinolaryngol. 2012;16(3):365-70.
19. ANSI. American national standard methods for measuring real-ear attenuation of hearing protectors. New York: American National Standards Institute; 1997.

20. Casali JG, Park MY. Attenuation performance of four hearing protectors under dynamic movement and different user fitting conditions. Hum Factors. 1990;32(1):9-25.
21. Toivonen M, Pääkkönen R, Savolainen S, Lehtomäki K. Noise Attenuation and Proper Insertion of Earplugs into Ear Canals. Ann Occup Hyg. 2002;46(6):527-30.
22. Royster JD, Berger EH, Merry CJ, Nixon CW, Franks JR, Behar A, et.al. Development of a new standard laboratory protocol for estimating the field attenuation of hearing protection devices. Part 1. Research of Working Group 11, Accredited Standards Committee S12, Noise. J Acoust Soc Am. 1996;99(3):1506-26.
23. Reddy R, Welch D, Ameratunga S, Thorne P. Development of the hearing protection assessment (HPA-2) questionnaire. Occup Med-Oxford. 2014; 64:198-205.
24. Neitzel R, Somers S, Seixas N. Variability of Real-World Hearing Protector Attenuation Measurements. Ann Occup Hyg. 2006;50(7):679-91.
25. Berger EH, Voix J, Kieper RW, Le Cocq C. Development and validation of a field microphone-in-real-ear approach for measuring hearing protector attenuation. Noise & Health. 2011;13(51):163-75.
26. Berger EH, Franks Jr, Lindgren F. International review of field studies of hearing protector attenuation. In: Axlesson A, Borchgrevink H, Hamernik RP, Hellstrom P, Henderson D, Salvi RJ, editors. Scientific basic of noise-induced hearing loss. New York: Thieme Medical Publishers, Ic.; 1996.