La Medicina del Lavoro

Med Lav 2019; 110, 4: 304-311
DOI: 10.23749/mdl.v110i4.8214

Longitudinal evaluation of a hearing protector fit training program

Caio Henrique de Carvalho Assunção[1], Júlio César Trabanco[1], Raquel Fornaziero Gomes[1], Renata Rodrigues Moreira[2], Alessandra Giannella Samelli[1]

[1] Curso de Fonoaudiologia, Departamento de Fisioterapia, Fonoaudiologia e Terapia Ocupacional, Faculdade de Medicina da Universidade de São Paulo (FMUSP), São Paulo, Brazil

[2] Hospital Universitário da Universidade de São Paulo, São Paulo, Brazil

Key words: Hearing; noise-induced hearing loss; occupational health; personal protective equipment; hearing protection devices

Parole chiave: Udito; ipoacusia da rumore; salute sul lavoro; dispositivi di protezione personale; dispositivi per la protezione dell'udito

Summary

Objective: *The present study evaluates a training program for fitting different hearing protection devices (HPDs) based on personal attenuation rating (PAR) before, immediately after, and six months after training.* **Methods:** *A total of 67 workers from a public university in the city of São Paulo, Brazil, were invited to participate in the measurement of PARs for foam and silicone protectors through the 3M™ E-A-Rfit Validation System. Two evaluations were performed for each protector at each sampling date: one after reading printed material (the package instructions) and another after being trained by an audiologist. The same procedures were repeated after six months. The final sample consisted of 30 individuals. ANOVA was used for statistical analysis.* **Results:** *Larger PAR values were observed after training by the audiologist, and smaller values were observed after six months. Then, after re-training, the values increased again. There were no statistically significant differences in PAR among the HPDs tested. Even after the two training sessions, 23 to 27% of the subjects did not obtain adequate PAR values.* **Conclusion:** *These findings emphasize the need for continual worker training in the correct fit of earplug HPDs and the importance of longitudinal PAR monitoring. In addition, some workers, despite the training provided, did not adapt to the HPDs used. Therefore, it is essential that other protection methods and/or other HPD types are made available to these individuals.*

Riassunto

«*Valutazione longitudinale di un programma di addestramento all'uso di dispositivi di protezione uditiva*». **Obiettivi:** *Valutare un programma di addestramento all'uso di diversi tipi di dispositivi di protezione individuale uditivi (DPI-u) sulla base dell'indice di attenuazione personale (PAR) prima, immediatamente dopo e sei mesi dopo la formazione dei lavoratori che li indossano.* **Metodi:** *67 lavoratori di un'università pubblica della città di São Paulo, Brasile, sono stati invitati a partecipare alla misurazione dei PAR per DPI-u in schiuma e silicone effettuata il sistema di validazione 3M™ E-A-Rfit. Per ogni DPI-u sono state effettuate due misurazioni: una dopo la lettura delle istruzioni sulla confezione, l'altra dopo la formazione effettuata da un audiologo. La stessa procedura è stata*

Pervenuto il 13.2.2019 - Revisione pervenuta il 7.6.2019 - Accettato il 24.6.2019

Corrispondenza: Alessandra Giannella Samelli, Department of Physical Therapy, Speech-language Pathology and Audiology, and Occupational Therapy, Faculty of Medicine (FMUSP), University of São Paulo. Rua Cipotânea, 51, São Paulo, Brazil, CEP: 05360-160 Tel. (55) (11) 30918442 - E-mail: alesamelli@usp.br

ripetuta dopo sei mesi. Il campione allo studio risulta composto da 30 soggetti. Per l'analisti statistica è stata effettuata l'analisi della varianza (funzione ANOVA). **Risultati:** *I valori di PAR più alti sono stati registrati dopo la formazione da parte dell'audiologo, quelli più bassi a distanza di sei mesi dopo la formazione. In seguito alla nuova sessione di formazione, si è registrato un nuovo aumento dei valori PAR. Non si sono rilevate differenze statisticamente rilevanti tra i diversi DPI-u testati. Anche dopo le due sessioni di training, dal 23 al 27% dei partecipanti non hanno raggiunto livelli di PAR adeguati.* **Conclusioni:** *Questi risultati sottolineano la necessità di una formazione continua dei lavoratori al corretto uso dei DPI-u e l'importanza del monitoraggio longitudinale dei PAR. Inoltre, alcuni lavoratori, nonostante la formazione ricevuta, non si sono abituati al DPI-u usato. Di conseguenza, è essenziale mettere a disposizione di questi individui altri metodi di protezione e/o altri tipi di DPI-u.*

Introduction

Occupational noise is present in diverse occupations. Noise exposure can lead to extra-auditory changes, including sleep, vestibular, behavioral, neurological, and cardiovascular problems (2, 15, 17, 22) as well as auditory problems such as tinnitus, difficulties in speech intelligibility, and hearing loss induced by high sound pressure levels (noise-induced hearing loss) (1, 11).

In the United States, occupational hearing loss is a major work-related disease. According to the United States Centers for Disease Control and Prevention, 22 million American workers are exposed to potentially harmful occupational noise levels (18).

In Brazil, the Ministry of Health has made reporting occupational hearing loss mandatory (7). Still, underreporting makes it difficult to fully grasp the scope of this problem and prevents workplace inspections and the development of effective public policies for disease prevention (13).

To safeguard the health of workers exposed to noise, a legal framework has been established in Chapter 5 of the Consolidation of Labor Laws, which addresses Occupational Safety and Health (3).

To comply with the legal requirements, a multidisciplinary team responsible for workers' health and safety must assume oversight of harmful elements in the workplace and guarantee the protection of employees following the risk control hierarchy established by Regulatory Standards (RS), RS-09 (4), which prioritizes collective protection measures as a first line of defense. When there are demonstrated technical limitations to the adoption of such measures, risks can be managed at the individual level by providing Personal Protective Equipment.

The RS-07 requires the establishment of a *Hearing Conservation Program* (HCP) (5), which is a set of measures designed to promote the auditory health of workers exposed to high sound pressure levels. An effective HCP includes monitoring risks and workers' hearing, providing protective measures for workers, providing necessary training for all involved, and continually evaluating the actions implemented to achieve the program objectives (21).

Among its various functions, the HCP must include evaluating the suitability of hearing protection devices (HPDs) for individual workers and functions and monitoring the proper use of these devices. These factors are fundamental to the success of the program. The key to proper and effective HPD use is worker training (12, 23).

Numerous studies have shown the importance of continual training (12, 19, 25). According to the United States National Institute for Occupational Safety and Health (NIOSH) (19), the HCP should encompass measures to determine the frequency, methodology, and themes of such training; the ongoing development of educational strategies; and the dissemination of each step of the program.

More recently, technology has been applied to improve the selection processes of HCPs. Equipments enable to measure simultaneously the sound pressure levels outside and inside the ear canal and differences between these two measures, conveniently corrected, indicate the attenuation of HCPs. This procedure - Field-Microphone-in-real-ear (F-MIRE) technique - can be obtained with just one measurement as opposed to insertion loss-based procedures, which require two measures with and without the HPD in place, in two separate measurements (20). Such equipment determines the personal attenuation rating (PAR) of each device and can be used to train workers in proper HPD fit and to record the activities involved in training these individuals (14).

The present study evaluates a training program for fitting different HPDs based on PAR before, immediately after, and six months after training.

Methods

Case series

The present study was designed as a longitudinal descriptive study. The subjects were 67 workers at a public university in the city of São Paulo.

The workers were invited to participate on a voluntary basis, randomly, in periodic audiometric testing. After the study objectives and procedures were explained, those who agreed to participate signed the Terms of Informed Consent approved by the Research Ethics Committee of the institution, number 858/08.

The inclusion criteria for the study were a minimum age of 18 years, being exposed to occupational noise, use hearing protection devices, absence of obstruction in the external auditory meatus, and absence of alteration in the middle ear.

Procedures

The occupational, audiological, and overall health history of each participant was taken. A routine audiological field examination for noise-exposed workers was then performed, including otoscopy, acoustic immittance testing, and tonal threshold audiometry. If any external and/or middle ear changes were observed, the individual was excluded from the study and referred for otorhinolaryngological assessment and treatment.

The F-*MIRE* technique (2) was used to collect PARs using the *3M™ E-A-Rfit Validation System*. Two different earplug HPDs (foam: 3M*™ 1100,* and pre-molded silicone: *3M™ Pomp Plus)* were evaluated by means of two microphones, one external and one internal to the ear canal. The HPDs are adapted to connect to the internal microphone by means of a silicone tube that passes through them, making it possible to capture the difference in sound pressure level between the internal and external environments after positioning the protector. These levels, obtained from the two microphones for each octave bands from 125 Hz to 8 kHz, are automatically corrected to consider various issues (ear canal amplification, probe tube attenuation, etc).

Each participant was instructed to sit 30 centimeters from a speaker that, when triggered by the researcher, generated noise (white noise) of 100 dB SPL, which was picked up by the microphones. E-A-Rfit® software version 3M.4.4.17.0 then calculated the mean attenuation value - PAR - of the HPD for each ear and for both ears combined (binaural PAR value).

Two measurements were obtained for each HPD. First, the participant was asked to fit the HPD according to the package instructions provided by the manufacturer (Step One). The second measurement was taken after the researchers provided guidelines and demonstrated the best way to fit each HPD (Step Two).

The results obtained were classified automatically by the software as "Approved" (Pass - Green display) or "Disapproved" (Fail - Red display). This classification was based on the protection level achieved with the HPD fit. Because the noise emission value is known (100 dB SPL) and captured by the external microphone, it can be compared to the value captured by the internal microphone to obtain the protection value. If this value brings the test subject to the minimum level of hearing protection (target minimum attenuation), the test is considered "Approved"; otherwise, it is "Disapproved."

After six months, all participants were invited to repeat the same procedures followed in the first evaluation: one measurement after reading the package instructions (Step One) and another after training in the correct fit of each HPD (Step Two).

Of the 67 participants in the first evaluation, 30 attended the second evaluation (45%); the remaining individuals declined to participate of the second part of the study, claiming disinterest or job change.

Thus, comparisons were made using data from the 30 individuals who participated in both stages.

A description of the procedures is given in figure 1.

The training (educational intervention) addressed the following elements (24):

- Awareness of auditory and extra-auditory impairment caused by continuous noise exposure and forms of protection;
- Specific instructions for the correct fit of each HPD evaluated;
- Information on the proper cleaning and maintenance of each HPD;
- Durability of each HPD type;
- Awareness of the importance of replacing the HPD within the established period; and
- Awareness of use during the workday.

Data Analysis

The data were analyzed by paired Analysis of Variance (ANOVA) to compare the four evaluations of each HPD. The ANOVA test was also used for independent variables in the comparison of HPD types. A significance level of 0.05 was used.

Results

The 30 individuals in this study were between 27 and 65 years old (48.53±8.48) and included three women (10%) and 27 men (90%).

Comparing PARs between the four evaluations (table 1), statistically significant differences were observed between the 1st and 2nd evaluations and between the 3rd and 4th evaluations for both protectors. The PAR values were larger in the 2nd and 4th evaluations (after the training).

No statistically significant differences in PAR were observed between the two HPDs (table 2).

Table 3 shows the test results, classified as "pass" or "fail", from the pre- and post-training evaluations during the two stages of the study. During both stages, the number of passing results increased after training for both protectors (figure 2). However, even after training, a certain percentage of individuals failed to adequately fit both HPD types (approximately 23% for Pomp Plus and 23% to 27% for 1100).

Discussion

Worker training and education are fundamental to the successful use of hearing protection devices (24). The Ministry of Health, through the Department of Strategic Programmatic Actions of the Secretariat of Health Care, has prepared a booklet (6) emphasizing the importance of continual education for workers exposed to noise. The present study confirms the relevance of guidance and training by a competent professional: PAR values were significantly larger after professional intervention (comparing PARs from the 1st to the 2nd evaluation and from the 3rd to the 4th evaluation).

Participants (n)	Steps	Foam HPD	Silicone HPD
67	One	Package instructions	
		1st PAR evaluation	
	Two	HPD fit training (educational intervention)	
		2nd HPD evaluation	
Six-month interval and invitation to participate in the second stage			
30	One	Package instructions	
		3rd PAR evaluation	
	Two	HPD fit training (educational intervention)	
		4th HPD evaluation	

Figure 1 - Description of the procedures

Table 1 - Comparison of binaural personal attenuation ratings among the four evaluation times

	3M™ 1100					
	1st vs. 2nd		2nd vs. 3rd		3rd vs. 4th	
Mean (dB)	20.1	22.6	22.6	21.1	21.1	24.3
Standard Deviation (dB)	4.1	4.3	4.3	8.1	8.1	6.2
p-value	0.010*		0.403		0.041*	
Differences between evaluations (dB)	2.4		-1.4		3.2	
	3M™ Pomp Plus					
	1st vs. 2nd		2nd vs. 3rd		3rd vs. 4th	
Mean (dB)	20.3	22.3	22.3	20.6	20.6	23.6
Standard Deviation (dB)	5.3	4.0	4.0	7.5	7.5	5.0
p-value	0.045*		0.244		0.036*	
Differences between evaluations (dB)	1.9		-1.6		2.9	

Legend: dB=decibel; *p<0.05

Table 2 - Comparison of personal attenuation ratings between hearing protector types at each sampling date

Evaluation Protector	1st		2nd		3rd		4th	
	1100	PPlus	1100	PPlus	1100	PPlus	1100	PPlus
Mean (dB)	20.1	20.3	22.6	22.3	21.1	20.6	24.3	23.6
SD (dB)	4.1	5.3	4.3	4.0	8.1	7.5	6.2	5.0
p-value	0.860		0.807		0.807		0.605	

Legend: PPlus= Pomp Plus; SD=standard deviation; dB=decibel

Table 3 - Distribution of the results (absolute numbers and percentages) classified as Pass or Fail for both protectors

	3M™ 1100								3M™ Pomp Plu							
Evaluationt resul	F-F		F-P		P-P		P-F		F-F		F-P		P-P		P-F	
1st - 2nd	5	(17%)	9	(30%)	13	(43%)	3	(10%)	4	(13%)	6	(20%)	19	(64%)	1	(3%)
3rd - 4th	4	(13%)	11	(37%)	12	(40%)	3	(10%)	7	(23%)	7	(23%)	16	(54%)	0	(0%)

Legend: F-F=refers to the value (absolute and %) of "fail" in the 1st and 2nd (first row) and in the 3rd and 4th (second row); F-P=refers to the value (absolute and %) of "fail" in the 1st and "pass" in the 2nd (first row) and "fail" in the 3rd and "pass" in the 4th (second row); P-P=refers to the value (absolute and %) of "pass" in the 1st and 2nd (first row) and in the 3rd and 4th (second row); P-F=refers to the value (absolute and %) of "pass" in the 1st and "fail" in the 2nd (first row) and "pass" in the 3rd and "fail" in the 4th (second row)

These results are in accordance with previous studies that 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 through both objective (F-MIRE) and subjective (Real ear attenuation at threshold) tests (9, 24).

To verify the efficacy of the training program over time, PARs were compared before and after six months. Between the 2nd and 3rd evaluations, the PARs of both protectors declined, although this re-

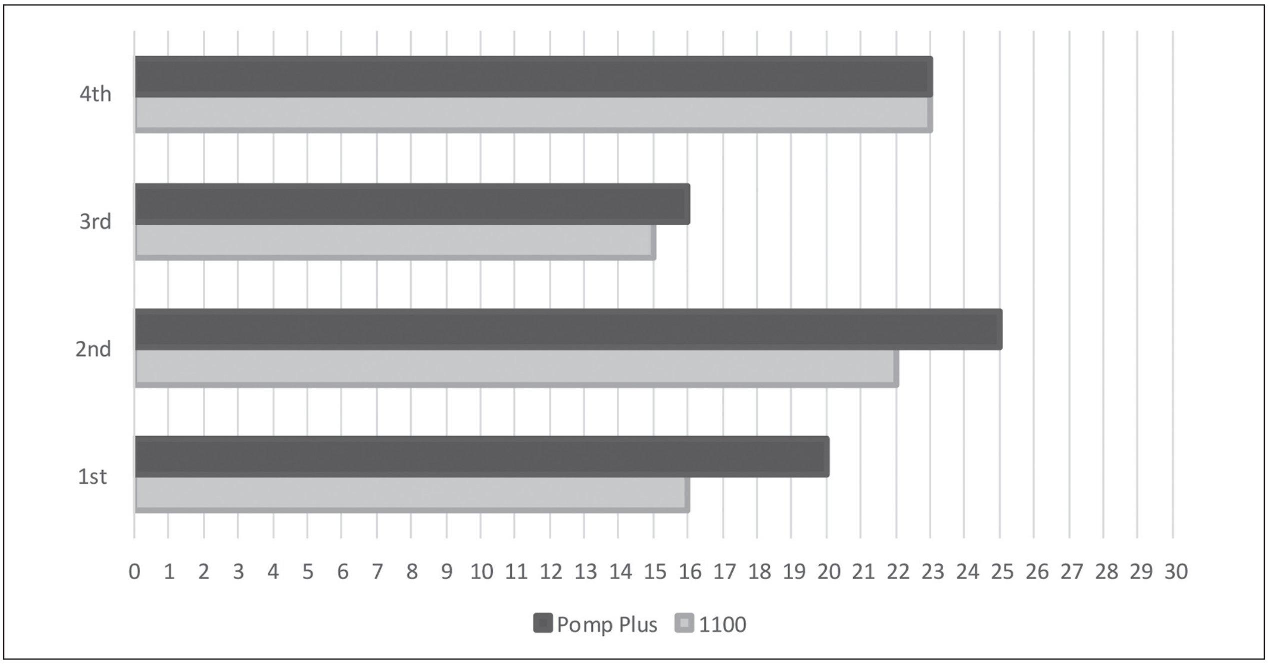

Figure 2 - Distribution of tests (n) resulting in passing values in relation to evaluation time

sult was not statistically significant. This observation emphasizes the need for constant training of noise-exposed workers who use earplug hearing protection devices (25).

No statistically significant differences were found between the two HPDs at the various evaluations, suggesting that the individuals behaved similarly in the evaluations regardless of the HPD tested. For both HPDs, the largest PARs were obtained after active guidance and training by a professional audiologist, as has been observed in other studies (12, 24).

With regard to protector type, the difference in PAR values between the 1st and 2nd evaluation (foam: 2.4 dB; silicone: 1.9 dB) and between the 3rd and 4th evaluation (foam: 3.2 dB; silicone: 2.9 dB) was greater for the foam protector than for the silicone protector. This difference was probably due to the greater difficulty in handling and positioning the foam HPD, which requires previous molding by the user, in contrast to the silicone HPD, which has a less complex fit (10). Therefore, training made a greater difference in the proper fitting of the foam HPD.

The pass/fail results showed that even after training, some individuals failed both post-training (2nd and 4th) evaluations. This fact suggests that HPD noise attenuation depends on other variables besides knowledge about correct HPD fit, such as ear shape and geometry and mechanical HPD design, as reported by other studies (10, 27). In these cases, the professional involved in the occupational health team should find alternatives for the hearing protection of these individuals, such as another HPD type or changes in work organization, thus ensuring the effectiveness of the HCP.

Some individuals passed the pre-training (1st and 3rd) evaluations but failed the post-training (2nd and 4th) evaluations, indicating the need for additional and ongoing training. Similar results were observed in another study evaluating HPD attenuation, in which some individuals had difficulties with HPD fit even after training (27).

Thus, our findings show the importance of longitudinal monitoring of HPD fit, as well as continual training, to ensure that these devices provide adequate attenuation. Our data show increased PARs after training by a competent professional and suggest that this intervention should be repeated due to the decline in PAR within six months.

These results also highlight the importance of monitoring the PARs of noise-exposed workers in an effective HCP. Such objective evaluation measures have great potential to help the professional responsible for the program to ensure its effectiveness, being used to selecting HPD, documenting the PAR achieved by each worker and to worker training (16).

The limitations of this study include its sample size, which decreased during the study. The decrease in the initial sample is expected in longitudinal studies (8). Therefore, further studies are needed to assess HPD PARs, including follow-up surveys over periods greater than six months and additional efforts to ensure maximal retention of participants, to provide a more scientific foundation for occupational health programs.

In spite of the limitations, the results obtained in the present study should be considered, once long-term studies regarding the training for proper insertion of the HPDs are scarce, but fundamental for the progress of interventions aimed at the prevention of noise-induced hearing loss (26).

Conclusion

Our findings confirm the positive effect of training on the fit of earplug HPDs and the need for continual worker training in this area. These results also emphasize the importance of longitudinal monitoring of PAR. Finally, some workers, despite the training provided, had difficulties to tolerate their HPDs. Therefore, it is essential that other protection methods and/or other HPD types are made available to these individuals.

No potential conflict of interest relevant to this article was reported by the authors

References

1. Araújo SA: Noise-induced hearing loss in metallurgical workers. Rev Bras Otorrinolaringol 2002; 68: 47-52
2. Berger EH: Introducing F-MIRE testing: background and concepts. Indianapolis: EAR/Aearo Technologies, EARCAL Laboratory; 2007
3. Brasil. Ministério do Trabalho e Emprego. Consolidação das Leis do Trabalho; Decreto-Lei n. 5452. Brasil: Diário Oficial; 1º de maio de 1943
4. Brasil. Ministério do Trabalho e Emprego. NR 09 – Programa de Prevenção de Riscos Ambientais – PPRA. Brasil: Diário Oficial; 1978
5. Brasil. Ministério do Trabalho e Emprego. NR 07 - Programa de Controle Médico de Saúde Ocupacional – PCMSO. Brasil: Diário Oficial; 1996
6. Brasil. Ministério da Saúde. Secretaria de Atenção à Saúde. Departamento de Ações Programáticas Estratégicas. Perda auditiva induzida por ruído (PAIR). Brasília: Editora do Ministério da Saúde, 2006
7. Brasil. Ministério da Saúde. Portaria nº 1984. Brasil: Diário Oficial; 15 de setembro; 2014
8. Caruana EJ, Roman M, Hernández-Sánchez J, Solli P: Longitudinal studies. Journal of Thoracic Disease 2015; 7: E537-E540
9. Cassano F, Aloise I, Labianca G, et al: The role of information and training for workers on the correct use of earplugs in assessing real noise attenuation with E-A-RfitTM system. Med Lav 2015; 106: 284-293
10. Gerges SNY: Hearing protectors. Ed. UFSC, Florianópolis, Brasil, 2003
11. Gonçalves CGO, Iguti AM: Analysis of hearing prevention programs in four metallurgical industries in Piracicaba, São Paulo, Brazil. Cad Saude Publica 2006; 22: 609-618
12. Gonçalves CGO, Couto CM, Carraro JM, et al: [Evaluation of hearing-protector insertion in groups with and without training]. Rev CEFAC 2009; 11: 345-352
13. Gonçalves CGO, Souza MT: Worker's Health and Speech-Language Pathology - perspectives and challenges. In Marchesan IQ et al (org): Tratado das Especialidades em Fonoaudiologia. São Paulo: Guanabara, 2014
14. Hager LD: Fit-testing hearing protectors: An idea whose time has come. Noise Health 2011; 13: 147-151
15. Leão RN, Dias FAM: Audiometric profile of individuals exposed to noise at the occupational health center of a Montes Claros hospital – MG] Rev CEFAC 2010; 12: 242-249
16. Madison T: Selecting Hearing Protectors - It's the Fit That Counts. Occup Health Saf 2016; 85: 38-42.
17. Marques FP, Costa EA: Exposure to occupational noise: otoacoustic emissions test alterations. Rev Bras Otorrinolaringol 2006; 72: 362-366
18. Masterson EA, Tak S, Themann CL, et al: Prevalence of Hearing Loss in the United States by Industry. Am J Ind Med 2013; 56: 670-681
19. National Institute for Occupational Safety and Health. Preventing Occupational hearing loss – a practical guide. DHHS Pub 1996;96-110

20. Nélisse H, Le Cocq C, Boutin J, et al: Systematic evaluation of the relationship between physical and a psychoacoustical measurements of hearing protector´s attenuation. J Occup Environ Hyg 2015; 12: 829-844
21. Occupational Safety and Health Administration. Hearing Conservation. US Department of Labor – OSHA 3074. 2002. Available from: https://www.osha.gov/Publications/osha3074.pdf
22. Ogido R, Costa EA, Machado HC: Prevalence of auditory and vestibular symptoms in workers exposed to occupational noise. Rev Saude Publica 2009; 43: 377-380
23. Samelli SG, Moreira RR: Hearing health of the worker: a necessary intervention. In: Marchesan IQ, Silva HJ, Tomé, MC (Org). Tratado das especialidades em fonoaudiologia. São Paulo: Guanabara Koogan; 2014: 1046-1052
24. Samelli AG, Rocha CH, Theodósio P, et al: Training on hearing protector insertion improves noise attenuation. CoDAS 2015; 27: 514-519
25. Schulz, TY: Individual fit-testing of earplugs: A review of uses. Noise Health 2011; 13: 152-162
26. Tikka C, Verbeek JH, Kateman E, et al: Interventions to prevent occupational noise-induced hearing loss. Cochrane Database Syst Rev 2017; 7: CD006396
27. Toivonen M, Paakkonen R, Savolainen S, et al: Noise attenuation and proper insertion of earplugs into ear canals. Ann Occup Hyg 2002; 46: 527-530