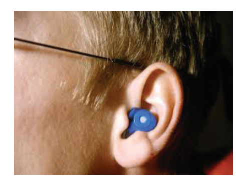
Original Article

To review this article online, scan this QR code with your Smartphone

Training in Using Earplugs or Using Earplugs with a Higher than Necessary Noise Reduction Rating? A Randomized Clinical Trial

M Salmani Nodoushan, AH Mehrparvar, M Torab Jahromi, S Safaei, A Mollasadeghi

Department of Occupational Medicine, Shahid Sadoughi University of Medical Sciences, Yazd, Iran



Abstract

Background: Noise-induced hearing loss (NIHL) is one of the most common occupational diseases and the second most common cause of workers' claims for occupational injuries.

Objective: Due to high prevalence of NIHL and several reports of improper use of hearing protective devices (HPDs), we conducted this study to compare the effect of face-to-face training in effective use of earplugs with appropriate NRR to overprotection of workers by using earplugs with higher than necessary noise reduction rating (NRR).

Methods: In a randomized clinical trial, 150 workers referred to occupational medicine clinic were randomly allocated to three arms—a group wearing earplugs with an NRR of 25 with no training in appropriate use of the device; a group wearing earplugs with an NRR of 25 with training; another group wearing earplugs with an NRR of 30, with no training. Hearing threshold was measured in the study groups by real ear attenuation at threshold (REAT) method. This trial is registered with Australian New Zealand clinical trials Registry, number ACTRN00363175.

Results: The mean±SD age of the participants was 28±5 (range: 19–39) years. 42% of participants were female. The mean noise attenuation in the group with training was 13.88 dB, significantly higher than those observed in other groups. The highest attenuation was observed in high frequencies (4, 6, and 8 kHz) in the group with training.

Conclusion: Training in appropriate use of earplugs significantly affects the efficacy of earplugs—even more than using an earplug with higher NRR.

Keywords: Ear protective devices; Education; Noise; Hearing; Hearing loss, noise-induced; Occupational injuries; Randomized clinical trial

Introduction

Noise is the most commonly encountered physical exposure in workplace. It mostly threatens hearing system. Noise-induced hearing loss (NIHL) is one of the most common occupational disease and the second most common cause of workers' claims for occupational injuries.[1] The International Organization of Safety and Health (NIOSH) has estimated that about 30 million workers in

Correspondence to Mona Torab Jahromi, MD, Department of Occupational Medicine, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
E-mail: Dr.motoj679@yahoo.com

Received: Jul 12, 2014
Accepted: Aug 31, 2014

Cite this article as: Salmani Nodoushan M, Mehrparvar AH, Torab Jahromi M, *et al.* Training in using earplugs or using earplugs with a higher than necessary noise reduction rating? a randomized clinical trial. *Int J Occup Environ Med* 2014;**5**:187-193.

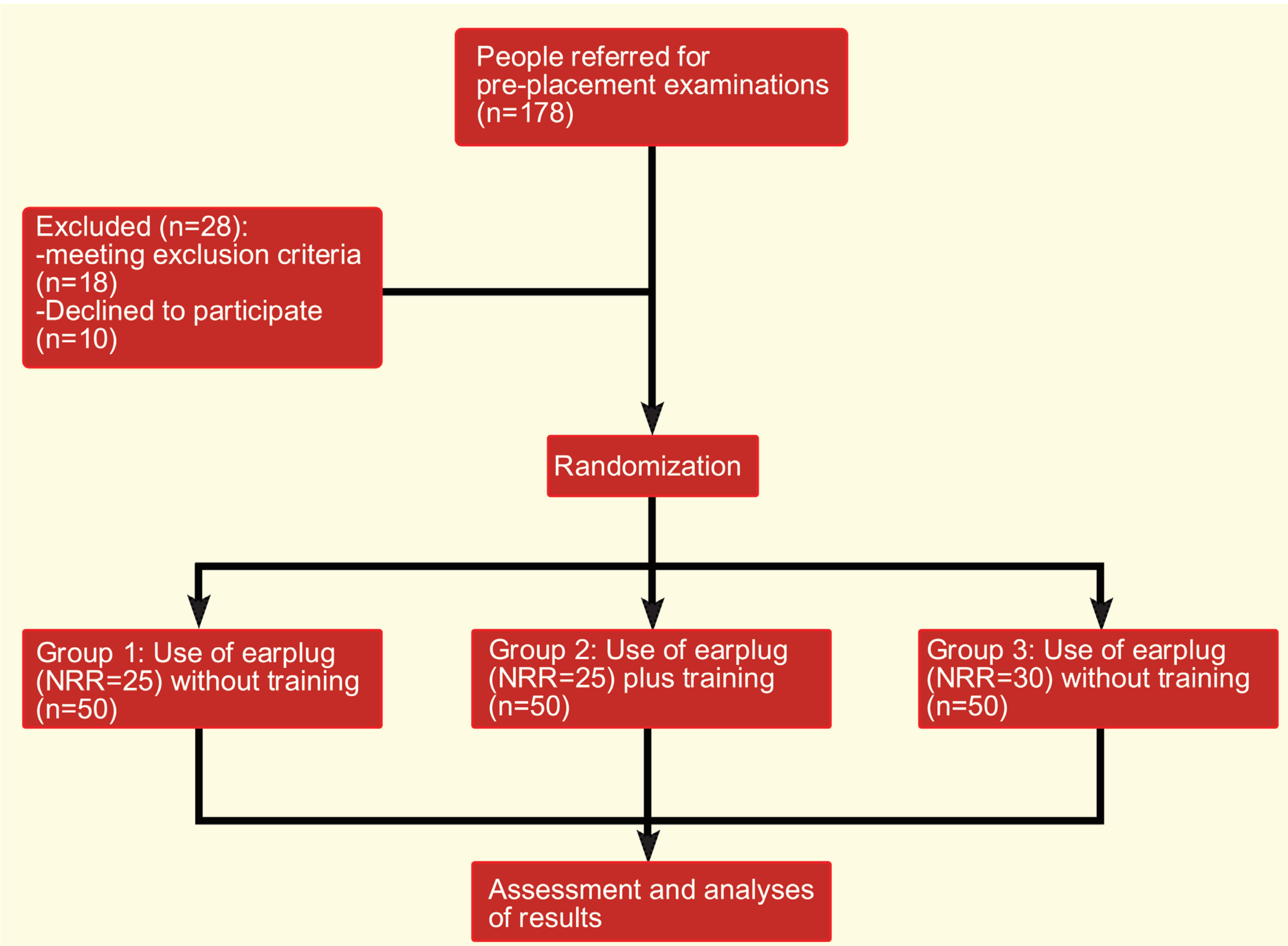


Figure 1: Study flow diagram

For more information on occupational noise-induced hearing loss see www.theijoem.com/ijoem/index.php/ijoem/article/view/36

the United States are exposed to unauthorized noise. Every year 1 628 000 persons develop NIHL worldwide—an incidence rate of 25 per 100 000 persons per year.[2]

Noise is the cause of almost 30% of hearing losses in adult population. This would impose a high economic burden to the families, industries, employers and insurance companies. A report published in 2009 showed that of 40 million Americans with hearing loss, 10 million suffer from NIHL that is associated with about US$ 242 million compensation cost due to hearing loss.[3] Although we could not find the exact rate of noise exposure in Iran, we think this problem is also important in Iran.[4]

Prevention of NIHL is beneficial for both worker and the employer, because on one hand, it may lower medical and compensation costs and on the other hand, it can play an important role in increasing productivity by decreasing occupational injuries. Although hearing protection devices (HPDs) are not the first line of hearing conservation, nowadays, due to their low cost, availability, and effectiveness, they are considered as an essential part of prevention of occupational hearing loss.[5]

Different studies have shown that the

effectiveness of earplugs in industrial workplaces is lower than expected. Training in the appropriate use of earplugs is now considered a necessity. There are many studies conducted to assess the effect of training on the efficiency of hearing conservation devices,[6-9] but we have noted that in Iran, in spite of enough training, earplugs with higher noise reduction rating (NRR) are used, *ie*, they overprotect the ears from hazardous effects of noise, without paying attention to its side effects.

One of the problems we face in industrial settings is the attitude of employers to use hearing conservation devices—many of the employers prefer to use HPDs with higher NRR rather than training workers in appropriate use of HPDs; this may in turn lead to overprotection, one of the main problems of incorrect use of HPDs.

Results of a study conducted in 2003, revealed that 90% of workers were well protected, yet many of them were overprotected. Many workers who used earplugs in a one-year period asked for earplugs with higher NRR and higher protection.[9]

Considering the high prevalence of NIHL and several reports of improper use of HPDs, we conducted this study to evaluate the effect of face-to-face training in the effectiveness of earplugs with appropriate NRR and compare the effect of training and overprotection on attenuation of workplace noise.

Materials and Methods

In a single-blinded randomized controlled trial conducted between September 2012 and December 2013, a sample was selected at random from those who attended an occupational medicine clinic for preplacement examinations. Those with one or more of the following criteria were excluded from the study: those with a history of participating in a training program on proper usage of earplugs during last two years; those with a history of wearing earplugs more than six times during the previous two years; and those with conductive or sensorineural hearing loss detected at baseline audiometry. The participants were then randomly allocated to three groups using a random digits table (Fig 1).

Baseline audiometry was performed for all participants at 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz frequency (Clinical audiometer AC40, Interacoustic, Denmark, and a headphone TDH39, Denmark) in an acoustic chamber meeting the American National Standards Institute (ANSI) 2004 criteria.[10]

The audiologist was blinded to the group the participant belonged to. Hearing threshold at all frequencies in each ear was measured for air and bone conduction. If hearing threshold at all frequencies was <25 dBA and the difference between two adjacent frequencies was <10 dBA, the audiometry was considered normal.

Two kinds of pre-molded earplugs were used in this study—one with NRR of 25 and another with NRR of 30 (Moldex Comets, EN352, USA). We did not have access to different sizes of earplugs, so we used only one size.

Sound field was measured for all participants. Threshold measurement was performed based on the ASHA criteria using REAT method.[11] The test was repeated three times. The sound stimulus was created in a narrow band by two speakers (power amplifier AP12). Speakers were placed one meter away from the subjects with an angle of 45° with the ears.[12]

Sound stimuli were ascending and were created in pulse form for 250 ms in each frequency. The pulse of the stimulus was created in the center of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz with 250 ms time interval. The stimulus was emitted at each frequency in the audible level for each individual (30 dB for normal subjects). If the participant was

For more information on the effect of noise on human performance see www.theijoem.com/ijoem/index.php/ijoem/article/view/212

Table 1: Demographic characteristics of the participants (n=150)

Group	Mean±SD age (yrs)
Group 1	
Male (n=29, 58%)	27.7±5.1
Female (n=21, 42%)	
Group 2	
Male (n=28, 56%)	28.6±5.6
Female (n=22, 44%)	
Group 3	
Male (n=31, 62%)	28.5±5.3
Female (n=19, 38%)	

unable to hearing the voice, the intensity was increased by 20 dB until the subject perceived the sound. After response to the stimulus, the intensity was decreased by 10 dB until it was un-audible. Then, it was increased in 5 dB steps until the person could hear the voice. Then again the intensity was decreased by 10 dB until the sound could not be perceived. The hearing threshold in each frequency was considered as the lowest hearing level at which the individual responded to 50% of the stimuli including two positive responses to three stimuli. After determination of the threshold in participants without wearing earplugs, the participants were randomized into three arms. Group 1 (n=50): Earplugs with NRR of 25 (Moldex Comets, EN352, USA) were given to the subjects who were asked to wear them without any training and the threshold was measured again. Group 2 (n=50): Earplugs with NRR of 25 (Moldex Comets, EN352, USA) were given to the subjects who were also trained for 15 minutes in correct methods of wearing the earplugs and were asked to wear them under supervision of a trainer. When the trainer was assured that the participants learned the correct technique, the participant was asked to wear the earplugs independently and the threshold was measured again. Group 3 (n=50): Earplugs with NRR of 30 (Moldex Comets, EN352, USA) was given to the subjects who were asked to wear them without any training. Then, the threshold was measured again. After completion of the study, all participants received the training in appropriate use of earplugs.

The gold standard test for the measurement of threshold in an industrial environment is real ear attenuation at threshold (REAT).[13] In this method, using the difference in hearing threshold between two ears in two situations (with and without wearing earplugs), the efficacy of the earplugs is measured. The acoustic chamber met the ANSI criteria.[14]

The study protocol was approved by the Ethics Committee of Shahid Sadoughi University of Medical Sciences and was registered with Australian New Zealand clinical trials Registry, number ACTRN00363175.

TAKE-HOME MESSAGE

- Noise is the cause of almost 30% of hearing losses in adult population.
- Occupational noise exposure is the most common threat to the hearing system.
- Nois-induced hearing loss imposes a high economic burden to the families, industries, employers and insurance companies.
- Effectiveness of earplugs in industrial workplaces is lower than expected.
- Earplugs are most often not appropriately used.
- Training plays a significant role in improvement of the efficacy of hearing protection devices, even in comparison to use of a device with higher noise reduction rating.

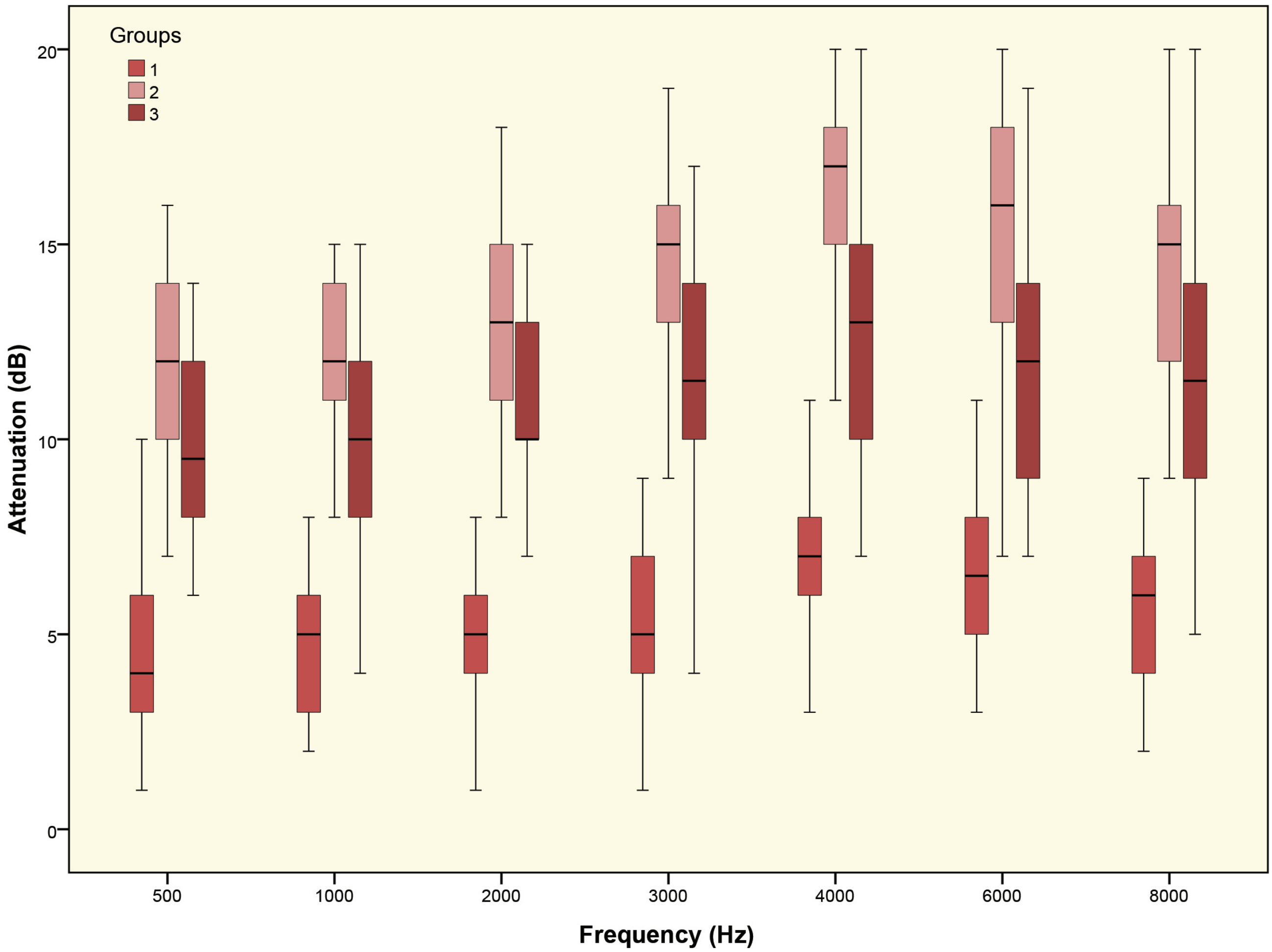


Figure 2: Box-and-whisker plot of attenuation measured by REAT method in the three studied groups. Outliers are not presented in this plot.

Informed written consents were taken from all participants.

Results

A total of 178 subjects was studied (Fig 1). Eighteen persons met the exclusion criteria and were excluded from the study—six for conductive hearing loss, five for previous exposure to noise, three for sensorineural hearing loss, and four for previous training in wearing the earplugs; 10 more persons were not willing to participate in and thus excluded before beginning of the study. None of the participants complained of the noise exposure complications (ear pain, tinnitus, and fullness in the ear) or use of earplugs (pain in ear canal).

The mean±SD age of the participants was 28.3±5.4 (range: 19–39) years. Forty-two percent of the participants were male and 58% were female. The groups were not significantly different in terms of age (p=0.97), and sex ratio (p=0.82) (Table 1).

At the end of the study, the mean±SD attenuation in groups 1, 2, and 3 was 5.54±1.50, 13.88±1.99, and 11.26±2.45 dB, respectively (Fig 2). There were significant differences between the mean attenuation between each of two groups at each frequency ($p<0.001$ for all comparisons).

Discussion

We showed that training plays a significant role in improvement of the efficacy of HPDs, even in comparison to use of HPDs with a higher NRR. The level of attenuation in those who received training was significantly higher than those who are not trained (Fig 2). This finding was in accordance with the results of previous studies and emphasizes that earplugs are most often not appropriately used.[8-15] The median attenuation measured in the second group was 13.88 dB, which was in agreement with the results of previous studies.[16,17] Neitzel, *et al*, showed that after training of workers in fitting of a foam earplug with an NRR of 29 the attenuation was 14.9 dB.[18] Joseph, *et al*, showed that face-to-face training increases the mean attenuation by 8 dB at each frequency.[15] In our study, the median attenuation after training in group 2 was 12–17 dB at various frequencies. However, Hager, *et al*, assessed the fitting of earplugs (fit-test) and found an attenuation of 11–42 dB at different frequencies[19]—after correct fitting of the earplug, it varied from 9 dB at 125 Hz to 29 dB at 3150 Hz.[19] The difference between our results and the results reported in other studies can be attributed to our limitation to use earplugs with different sizes.

For more information on vestibular symptoms in factory workers subjected to noise for a long period see www.theijoem.com/ijoem/index.php/ijoem/article/view/124

It seems that training of people in the correct method of fitting an earplug increases the attenuation at all frequencies, especially high frequencies. In the current study the highest attenuation after training was observed at high frequencies, especially 4000 Hz (≈17 dB); the lowest attenuation was measured at 1000 Hz (12 dB). In a study conducted in India to compare earplugs and earmuffs by fit-subject method, the highest efficacy of earplugs after training was however observed at low frequencies (125–250 Hz) and extended high frequencies (8000–12000 Hz).[20]

Some studies reported the highest level of attenuation at low frequencies,[21, 22] while Toivonen, *et al*, showed an almost similar level of attenuation at all frequencies.[23] These variances are probably attributed to the fact that attenuation at high frequencies is highly sensitive to physical movement of the subject; for example, change in head position might decrease the attenuation. Furthermore, attenuation at high frequencies may be affected by the depth of the ear canal where the earplug fits.

All studies emphasize on the effect of training on the improved efficacy of HPDs. Nonetheless, the observed level of attenuation is different from study to study, which can be attributed to the following reasons:

- Using different-size earplugs appropriate for the individual's ear canal and his or her comfort during use would affect the result of the test.
- The level of education as well as the learning ability of participants would affect the results of the test.
- Age and gender of the participants may also affect the subject's learning ability and cooperation with use of earplugs.

In this study, the median attenuation in group 3 was 11 dB, which was lower than the expected attenuation because the participants were wearing earplugs with a higher NRR. Murphy, *et al*, found an attenuation of 11 dB with Pura-fit earplugs with an NRR of 31 compared to 11 dB with DeciDamp earplugs with an NRR of 29.[17]

The difference between group 1 and group 3 was expectedly significant ($p<0.001$). Comparison of group 2 and group 3 shows that training was more effective than using an earplug with a higher NRR in increasing attenuation. Therefore, while training in appropriate use of earplugs is superior to administration of earplugs with higher NRR, we should consider the latter option for workers who for any reasons cannot be trained. However, it needs more evaluation to find the appropriate NRR to prevent overprotection.

Conflicts of Interest: None declared.

References

1. Hager L. BLS occupational hearing loss report for 2007. *CAOHC Update* 2009;**27**:1.
2. Centers for Disease Control and Prevention [Internet]. Washington, DC: DHHS, CDC. [update at 2001; cited 2014]. DHHS (NIOSH) Publication Number 2001-103; [about 2 screens]. Available from *www.cdc.gov/niosh/docs/2001-103/* (Accessed June 11, 2014).
3. Centers for Disease Control and Prevention [Internet]. Washington, DC: DHHS, CDC. [updated 2012; cited 2014]. Noise and hearing loss prevention; [about 1 screen]. Available from *www.cdc.gov/niosh/topics/noise/about.html* (Accessed June 14, 2014).
4. Mirmohammadi J, Baba Haji Meibodi F, Nourani F. [Investigating the hearing tolerance in the workers of the tile factory complex of Meybod]. *J Shahid Sadoughi Uni Med Sci* 2008;**16**:8-13. [in Persian]
5. Frost and Sullivan. U.S. *Markets for Industrial Hearing Protection Products*. **2009,** Available from *http://www.frost.com/sublib/subscription-index.do?pageSize=50&subscriptionId=9946-A2&page=2* (Accessed June 12, 2014).
6. El Dib RP, Verbeek J, Atallah AN, *et al*. Interventions to promote the wearing of hearing protection. *Cochrane Database Syst Rev* 2006;**2**:CD005234.
7. Tsukada T, Sakakibara H. A trail of individual education for hearing protection with an instrument that measures the noise attenuation effect of wearing earplugs. *Ind Health* 2008;**46**:393-6.
8. Murphy WJ, Stephenson MR, Byrne DC, *et al*. Effects of training on hearing protector attenuation. *Noise Health* 2011;**13**:132-41.
9. Franks JR, Murphy WJ, Harris DA, *et al*. Alternative field methods for measuring hearing protector performance. *AIHA J (Fairfax, Va)* 2003;**64**:501-9.
10. ANSI S3.6-2004. *Specifications for audiometers.* New York: American National Standards Institute; **2004**.
11. Rockville, American Speech-Language-Hearing Association. Sound field measurement tutorial II. 1990, pp 371.
12. William J, Captain M. U.S. Public Health Service, National Institute for Occupational Safety and Health, 4676 Columbia Parkway, MS C-27, Cincinnati OH 45226-**1998** USA.
13. Berger EH, Kerivan JE. Influence of physiological noise and the occlusion effect on the measurement of real-ear attenuation at threshold. *J Acoust Soc Am* 1983;**74**:81-94.
14. ANSI S12.6-1997. Methods for Measuring the Real-Ear Attenuation of Hearing Protectors. New York: American National Standards Institute, **1997**.
15. Joseph A, Punch J, Stephenson M, *et al*. The effects of training format on earplug performance. *Int J Audiol* 2007;**46**:609-18.
16. Berger, Elliott H. Preferred methods for measuring hearing protector attenuation, Proceedings of Inter Noise, Noise Control Foundation, Poughkeepsie, NY, **2005**: pp 58.
17. Murphy WJ, Davis RR, Byrne DC, Franks JR. "Advanced Hearing Protector Study," National Institute for Occupational Safety and Health, U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention, EPHB Report 312-11a, Cincinnati OH, **2006**.
18. Neitzel R, Somers S, Seixas N. Variability of real-world hearing protector attenuation measurements. *Ann Occup Hyg* 2006;**50**:679-91.
19. Hager L. Individual Fit Testing of Hearing Protectors: A Case Study. Presented at American Industrial Hygiene Conference and Expo in Minneapolis, MN, **2008**.
20. Alam N, Sinha V, Jalvi R, *et al*. Comparative study of attenuation measurement of hearing protection devices by real ear attenuation at threshold method. *Ind J Otolog* 2013;**19**:127-31.
21. Voix J, Laville F. The objective measurement of individual earplug field performance. *J Acoust Soc Am* 2009;**125**:3722-32.
22. Voix J, Laville F. New method and device for customizing in situ a hearing protector. *Can Acoust* 2004;**32**:86-7.
23. Toivonen M, Pääkkönen R, Savolainen S, Lehtomäki K. Noise attenuation and proper insertion of earplugs into ear canals. *Ann Occup Hyg* 2002;**46**:527-30.