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The effects of training format on earplug performance

Abstract

This experiment investigated the effect of small-group versus individual hearing loss prevention (HLP) training on the attenuation performance of passive insert-type hearing protection devices (HPDs). A subject-fit (SF) methodology, which gave naive listeners access only to the instructions printed on the HPD product label, was used to determine real-ear attenuation at threshold (REAT) at third-octave noise bands between 125–8000 Hz. REAT measurements were augmented by use of the Hearing Loss Prevention Attitude-Belief (HLPAB) survey, a field-tested self-assessment tool developed by the National Institute for Occupational Safety and Health (NIOSH). Participants were randomly assigned to one of four experimental groups, consisting of 25 listeners each, in a controlled behavioral-intervention trial. There were two types of HPDs (formable and premolded) and two training formats (individual and small group). A short multimedia program, including a practice session, was presented to all 100 listeners. Results showed training to have a significant effect, for both HPDs on real-ear attenuation and attitude, but, importantly, there was no difference between small-group and individual training.

Sumario

Este experimento investigó el efecto en el desempeño de la atenuación que proporcionan los dispositivos de protección auditiva de tipo inserción (HPD) con el entrenamiento individual versus en grupos pequeños para la prevención de la hipoacusia. Se utilizó una metodología hecha a la medida (SF) que daba acceso a oyentes sin experiencia, solamente a las instrucciones escritas en la etiqueta del producto HPD, para determinar el umbral de atenuación en oído real (REAT) en bandas de ruido de tres octavas entre 125–8000 Hz. Las medicines REAT fueron reforzadas por medio de la encuesta sobre actitudes y opiniones hacia prevención de hipoacusia (HLPAB), una herramienta de auto-evaluación desarrollada por el Instituto Nacional para la Seguridad y Salud Ocupacional (NIOSH). Los participantes fueron asignados al azar en grupos experimentales de 25 oyentes cada uno en un ensayo controlado de intervención conductual. Hubo dos tipo de HPD (formante y premodelado) y dos formatos de entrenamiento (individual y en grupos pequeños). Un programa multimedia corto que incluía una sesión práctica se presentó a los 100 oyentes. El resultado demostró que el entrenamiento tenía un efecto significativo en los HPD, tanto para la atenuación en oído real como en la actitud, pero fue importante ver que no hubo diferencia entre el entrenamiento individual y en grupos pequeños.

Key Words

Attenuation
Earplugs
Hearing
Noise
Protection
Training
Attitude
Survey

Abbreviations

ANOVA: Analysis of variance
ANSI: American National Standards Institute
dBA: A-weighted sound pressure level
HCP: Hearing conservation program
HLPAB: Hearing loss prevention attitude-belief
HLPP: Hearing loss prevention program
HPD: Hearing protection device
KEMAR: Knowles Electronics Manikin for Acoustic Research
MANCOVA: Multiple analysis of co-variance
MANOVA: Multiple analysis of variance
NIOSH: National Institute for Occupational Safety and Health
NRR: Noise reduction rating
OSHA: Occupational Safety and Health Administration
REAT: Real-ear attenuation at threshold
SF: Subject-fit
TWA: Time-weighted average

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The goal of any hearing loss prevention program (HLPP) is to minimize health risks and to reduce the incidence of hearing impairment and tinnitus in workers who are exposed to hazardous occupational and non-occupational noise, cochleotoxic chemicals, and medications. Ninety percent of occupational noise exposures occur at 95-dB A-weighted sound pressure level (dBA) or below (Berger, 2000; Royster & Royster, 1990), safe levels are around 80 dBA (ISO, 1990), and many hearing protectors are capable of providing 10 dB of protection (Berger, 2000; Royster, 1995). This makes hearing protection devices (HPDs) a practical means of reducing noise exposure to 85 dBA or less, which minimizes the risk of hearing loss due to noise (OSHA, 1983a). But any appropriately selected hearing protector, such as an earplug, must be worn properly when ambient noise levels equal or exceed 90 dBA (OSHA, 1983a)—or 85 dBA, according to the National Institute for Occupational Safety and Health (NIOSH, 1998)—even during non-occupational activities. Further, any worker who demonstrates hearing threshold shift when exposed to noise that exceeds 85 dBA should use HPDs on the job. Based on these considerations, the risk of hearing damage can be reduced by the effective use of personal hearing protectors.

By Federal regulation (EPA, 1979), the noise reduction rating (NRR) must be printed on the product label for HPDs sold within the US. The Occupational Safety and Health Administration (OSHA, 1983b) and NIOSH (1998) have proposed different methods of derating the NRR to estimate the attenuation that a worker might receive from a protector. The data used in calculating the NRR are strongly influenced by the experimental test procedures. Noise reduction rating data function as a point of reference for the best fit obtainable by an HPD, so they are widely regarded as useful for specifying the relative attenuation of hearing protectors. Numerous researchers have demonstrated that the manufacturers' NRRs are overestimates of real-world efficiency (Berger et al, 1996; Berger et al, 1998; Frank et al, 1997; Franks et al, 2000; Park & Casali, 1991), although this observation pertains to earplugs more than to earmuffs. Because the fitting of an earplug is more intricate and contains a larger error margin than earmuffs, training has been found to have a greater effect on earplug fitting. More specifically, earmuffs require far less training than earplugs to obtain an optimal fit (Suter, 1984). Earplugs constitute 85% of all HPDs used in American industry (Berger, 2000). The level of attenuation provided by earplugs used by untrained wearers is not routinely measured by hearing conservationists.

Royster et al (1982) demonstrated that hearing protection and hearing conservation program (HCP) education are the primary problem areas identified by OSHA inspectors. To be compliant with OSHA regulations, employees in HCPs should receive training on the use and placement of the hearing protectors available to them, the effects of noise on humans, their responsibilities in the HCP program, and results of annual audiometric testing (NIOSH, 1998; OSHA, 1983a). Hence, it is in the best interest of an employer to train and motivate noise-exposed employees to wear hearing protection properly and consistently, both at work and during recreational activities.

The OSHA regulation specifically discusses the details of annual training requirements for workers exposed to noise levels that equal or exceed an eight-hour time-weighted average (TWA_8) of 85 dBA. This project focused on the effectiveness of training as required for hearing protection programs. One-on-one (individualized) training is ostensibly more expensive than group training and clearly requires supplementary resources. Group education is thus the most common training approach in the field. Investigators have shown that instruction, practice, and motivational methods can independently affect the efficiency of a hearing protector (ANSI, 1997; Melamed et al, 1996; Rabinowitz et al, 1996). The amount of instruction impacts greatly on the performance of earplugs and the level of protection afforded by them (Casali & Epps, 1986; Casali & Lam, 1986; Merry et al, 1992).

Training is critical for HPD users (Berger, 2000; Royster et al, 1996); however, few studies have been conducted on inexperienced HPD users and individuals from non-occupational populations. Newly hired industrial employees frequently are required to attend safety indoctrination training that lacks recommended hearing loss prevention training components. Ideally, training should be aimed at improving HPD effectiveness and motivation, which, in turn, can be expected to prevent hearing loss in new employees exposed to hazardous levels of continuous, intermittent, and impulsive noise. This investigation was designed to determine, based upon real-world effectiveness measures, if and to what extent training can improve the level of protection HPD users achieve. The study also sought to clarify whether an individual's ability to insert an earplug properly is associated with his or her attitude about hearing loss prevention.

A common assumption is that each member of the HCP should be individually fitted and individually trained on the insertion and use of the selected HPD (Royster & Royster, 1990). Such a mandate produces an enormous burden on even the most effective HCPs. This study compared small-group versus individual training using a between-subject experimental design. To investigate this issue, attenuation data were obtained binaurally from a cohort of 100 subjects using a naive subject-fit protocol that was a modification of the American National Standards Institute S12.6-1997 Method B approach (ANSI, S12.6, 1997).

A functional subject-fit REAT technique was designed that incorporated the use of circumaural earphones. A complete set of REAT measurements consisted of a single trial of unoccluded and occluded REAT responses (Behar, 1985) at nine third-octave noise bands between 125-8000 Hz. No broadband fitting noise or insertion-assistance devices were available.

Twenty-five naive male and female normal listeners were randomly assigned to each experimental group, and were screened using the characteristics listed in Appendix A. When interviewed, those who reported any previous exposure to the REAT test procedure were excluded from the study. Qualified listeners were prepared for the test with a single, four-frequency narrow-band noise, unoccluded test trial. For every occluded test trial, subjects received two earplug sizes (small and medium). Coaching was not provided by the examiner while subjects engaged in earplug selection and insertion. Further, given access only to the instructions printed on the HPD product label, listeners were told to 'make an effort' whenever they asked questions during the earplug selection and fitting process. For both hearing protector types, two minutes of quiet time were allowed to permit proper earplug expansion or seating, and the examiner never visually inspected earplugs for the purpose of determining whether refitting was indicated.

The study, conducted at Michigan State University, was designed to approximate a typical hearing conservation test environment, including the type of services available in most industrial settings. The sound-field test environment is not characteristic of the field and is not representative of the variability of attenuation observed in field test environments. The focus of this study was to employ a technique that could be generalized to environments characteristic of conventional hearing conservation programs. This technique was implemented to assure that the population was indeed naive, so that an unbiased assessment of the effectiveness of the training tool on attenuation achieved by the subject groups could be administered.

Method

Participants

Participants were 100 adult listeners, recruited from the student population of Michigan State University. Bilaterally, all had normal tympanograms and had pure-tone hearing thresholds at or below (i.e. better than) 25 dB HL at audiometric frequencies of 500, 1000, 2000, and 4000 Hz re ANSI S3.6 (1996). Testing also included the octave test frequencies 125-8000 Hz and the interoctave frequencies of 3000 and 6000 Hz. Participants were screened in-depth for experience with testing and use of HPDs, and were disqualified according to criteria in Appendix A. Moreover, subjects were not told of the exact intentions of the intervention in this project due to the possibility that they might self-educate, which could result in misclassification error. Using a balanced blocked design, listeners were assigned randomly to four independent, gender-balanced groups of 25 each. Ages across groups ranged from 18–41 years, with a mean age of 21 years. The pre-training and post-training conditions within this two-by-two study design are displayed in Table 1. In the experiment, all participants in Groups 1 and 3 used the formable ear protector, the EAR® Classic® foam earplug provided by Aearo Corporation.

Groups 2 and 4 used the premolded device, the Fusion™ four-flanged premolded earplug, provided by Howard Leight Company. The E•A•R® Classic® formable earplug and the Fusion™ premolded earplug were tested in the study because of their comparable NRR values and popular usage in the industry. Attenuation measurements were made before and after training. All attenuation measurements were completed within 1–5 days of training. Groups 1 and 2 received one-on-one training and Groups 3 and 4 received small-group training.

Table 1. Two-by-two repeated measures balanced-design matrix.

Pretest-Posttest Conditions		
	Hearing protection device	
Training format	*Formable*	*Premolded*
Individual	Group 1 (n = 25)	Group 2 (n = 25)
Group	Group 3 (n = 25)	Group 4 (n = 25)

Sample size

A power analysis was conducted in advance of data collection to determine the appropriate sample size for this study (Murphy et al, 2004). The effect size estimated to drive the power analysis was derived using the earplug manufacturers' confidential subject-fit data. The power analysis suggested that 25 subjects per group would provide a large-enough sample to answer the research question, given a conventional alpha of 0.05.

Test room and equipment

Using a circumaural headphone method (NIOSH, 1976; Franks et al, 2003), binaural REAT measurements were made with the Fit-Check™ test system. Fit-Check™ software was installed on a desktop computer with a Windows® 2000 operating system. Fit-Check™ narrow-band noise WAV files were stored on the computer and played through the Fit-Check™ attenuator, a peripheral interface that was connected to the circumaural headphones via a patch panel. Participants interfaced with the system using a conventional response button.

Binaural electroacoustic calibration measurements included an exhaustive acoustic calibration of the Fit-Check™ system using an acoustic test fixture, a comparable acoustic calibration of Fit-Check™ using the Knowles Electronics Manikin for Acoustic Research (KEMAR), and daily biological calibration of the Fit-Check™ system using the Quest Technologies BA-202 bioacoustic simulator. At the stimulus intensity levels of each frequency where the BA-202 calibrator response lamps were activated, a measurement was made using KEMAR to ascertain the SPL of the stimuli prior to the collection of data. With slight modifications, the intensity range of the amplifiers and linearity of the Fit-Check™ system attenuators were calibrated using the method described by Franks and his colleagues (2003). Participants were fit-tested individually in the experiment. They were seated in a double-walled audiometric sound room and monitored visually by the examiner during testing. The Fit-Check™ REAT tests were administered binaurally to the listener through circumaural headphones, a method shown to be predictive of average REAT sound-field earplug data (Carter & Upfold, 1993; Franks et al, 2003).

Test procedures

Pre-training

To control for effects of instructions, a single set of instructions was designed and used throughout the study. After entering the sound-treated examination room, procedural instructions were read verbatim to the participant. A pair of new earplugs in unopened packages was positioned in front of each participant. The experimenter did not provide assistance or training at the time that the subject was told to insert the hearing protectors (Franks et al, 2000; Royster et al, 1996). Also, no commentary or feedback was available during the fitting, including any suggestions to use the manufacturer's directions placed in front of the subject or on the product packet.

Experimental REAT testing was limited to one set of paired unoccluded/occluded threshold responses per subject for each ear to approximate a real-world protocol. The protocol was one that used the proprietary Bekésy paradigm of the Fit-Check™ testing system. Every qualified subject completed a practice set of binaural unoccluded REATs consisting of two trials from

250-2000 Hz, a pre-training set of paired unoccluded/occluded REATs, and a post-training set of paired unoccluded/occluded REATs. The order of unoccluded/occluded test conditions was counterbalanced to control for order and practice effects, while the order of the narrow-band stimuli remained the same for all assessments (125–8000 Hz).

While the subject inserted the hearing protectors, the examiner observed the entire process from an unobtrusive position in the acoustic examination room, being careful not to alert the subject to any indication of inspection. After the protectors were inserted, the Fit-Check™ circumaural headphones were placed comfortably over the subject's ears for testing. A minimum two-minute timed interval was provided to permit earplug seating and full expansion of the earplug material in the ear canal. When the subject indicated that the process of inserting the devices was complete, the examiner informed the subject not to touch the earplugs until the threshold test was completed.

Off-line statistical analysis of the hearing threshold data was performed in a manner similar to that described in Franks et al (2003). Raw unoccluded and occluded threshold data were saved for later analysis and for calculation of the subjects' REATs.

Attitude survey instrument

Following the attenuation measurements, HPDs were discarded and listeners were instructed to read and complete the NIOSH Hearing Loss Prevention Attitude-Belief survey (Franks & Stephenson, 1994; Svensson, 2004) carefully. To avoid order effects, half of the participants were given Form A of the survey instrument first, and half were given Form B first, in counterbalanced order. The NIOSH Hearing Loss Prevention Attitude-Belief (HLPAB) instrument was administered after pre-intervention and post-intervention REAT testing. It was slightly modified to meet the needs of the population in this study. The term *co-workers*, for example, was replaced with *family*, and items from the original tryout were included in the current survey.

The NIOSH HLPAB survey is a questionnaire that was constructed (in 1994) on the premise that unless one changes the beliefs and intentions of noise-exposed workers, then no change will occur in their behaviors. It is a 28-item self-administered instrument designed to represent 10 critical content areas. The survey contains four content areas designed to evaluate the respondents' individual perceptions: perceived susceptibility to hearing loss, perceived severity of the consequences of hearing loss, perceived benefits of preventive action, and the perceived barriers to preventive action. There are four subscales for perceived barriers: comfort, muffles important sounds, communication, and convenience. These four factors conveyed the majority of commonly voiced complaints about HPDs. In addition, the survey incorporates items that assess respondents' behaviors through two scales: the social-norms scale and the behavioral-intentions scale. To recognize all of the crucial health factors in the instrument, a self-efficacy scale is included in the survey. The content areas are designed to assess the respondents' attitudes toward hearing health and the use of hearing protection using a five-point Likert response scale: *(1) Strongly Disagree, (2) Disagree, (3) Neither Agree Nor Disagree, (4) Agree, and (5) Strongly Agree*. For each of the 10 content areas, the five-point rating response from each of the applicable items is averaged to calculate the subscale score.

Intervention program

The multimedia NIOSH HLP training program consisted of one short instructional mini-movie and a HLPP motivational video, including a pre-recorded slide presentation that covered fitting verification procedures, followed by an earplug-insertion practice session. For all individualized and small-group programs, the total time for the training session was less than 20 minutes. Although the length of training was equivalent for groups, listeners in the formable-protector training group viewed a mini-movie and slide presentation that contained a different set of instructions than the premolded-protector group. Both the individual-trained and group-trained subjects were required to insert the earplugs without assistance before their training session was concluded. The principal difference between the small-group and individual training formats was the level of examiner intervention during the time allotted for practice. A representative workplace-training program that incorporated a distinctly different feature between each training format called for absolutely no examiner intervention during the small-group training sessions; however, during the individual training program, hands-on, direct examiner intervention was provided for exactly the same period of practice as the small-group program.

One-on-one training

While wearing a pair of examiner gloves, the examiner inserted the earplugs into the external auditory canals of the individually trained participants, modeling appropriate fitting techniques such as the roll-down procedure (for formable earplug users), pinna pull, tragus landmark demarcation for earplug depth, and verification techniques. This experience was designed to provide the wearer with the advantage of experiencing a sensation of acceptable earplug position. For formable earplug users, three roll-down procedures were presented: one-hand, two-hand, and the palm approach. A visual illustration of an inserted device was provided and the examiner emphasized that a minimum of 50% of the earplug should be within the ear canal after expansion of the foam devices. Using a new set of earplugs, the examiner inserted HPDs in both ears for the participant, selecting the device that appeared most appropriate in size. The tip of the tragus was established as a marker that the subject could use for determination of adequate positioning of the formable device.

Group training

Small-group sessions were approximately the same duration as the one-on-one, individual sessions. Sessions were composed of small groups of two to six participants, with a mean of five subjects per small-group session. Due to no-shows, one group session was conducted with two subjects in attendance. Participants were assigned randomly to small-group sessions scheduled throughout the week at various times. This was done to accommodate the class schedules of students selected for small-group training. No-shows were not excluded from the study, but were re-assigned to a following small-group training. During the practice portion of small-group training, the examiner consistently observed that subjects imitated the HPD-insertion behaviors of their cohorts. Some subjects modeled the roll-down procedure of a cohort who utilized an improper technique. One subject fell asleep during the small-group training session and was awakened by the investigator.

Clearly, a small group of, on average, five participants provides a context unlike an individual training session because group-training conditions facilitate inter-participant observation of HPD fitting behaviors.

Upon completion of all post-training tasks, all participants were debriefed about the experiment. The experimenter offered them an opportunity to ask general questions about the project. They were counseled in detail on their personal test results, attitudes about HLP, and ability to insert the HPDs correctly. For a more detailed report of sample size and selection, test instruments and protocol, instructions, the NIOSH HLPAB survey, and the NIOSH training program, the reader is referred to Joseph (2004).

Post-training

Because some of the students' class and activity schedules precluded same-day completion of the entire testing process, half of the listeners completed the entire procedure of pre-training tests, training program, and post-training tests within the same day, and half were scheduled for subsequent sessions. All sessions for an individual were completed within five days of the subject's first session.

Results and Discussion

Attenuation data analysis

This study investigated the effects of individual and small-group training on REAT performance measurements of formable and premolded hearing protection devices. To determine whether small-group training or individual training was more effective than no training, a series of comparisons was made. First, for subjects exposed to small-group training, the mean pre-training attenuation values were compared to the mean post-training attenuation values. Likewise, for subjects exposed to individual training, the mean pre-training attenuation values were compared to the mean post-training attenuation performance values.

The means and standard deviations of REATs were computed for evaluation of noise-reduction performance using the approach described by the Environmental Protection Agency (EPA, 1979). The within-subject factor was *time* (repeated measure), and the between-subject factors were *intervention* (training format) and *device*. The octave-band approach for estimating hearing protection, also referred to as the *long method* (Sutton & Robinson 1981), utilizes the attenuation measurements from all but two of the test frequencies in the REAT data, 3150 and 6300 Hz. Conversely, the *short method*, which is a single-number rating method, is most frequently used by the industry and is better understood by consumers of hearing protection products. Lam (1985) recommended the use of octave-band data for comprehensive calculation of HPD performance. Hence, the *long method* was selected to attain the highest resolution in this assessment.

Training effects

Mean binaural REAT data for each experimental group are displayed in Figure 1. Each graph is comprised of the group's pre-training and post-training data. The standard deviations for the pre-training and post-training measurements are also shown

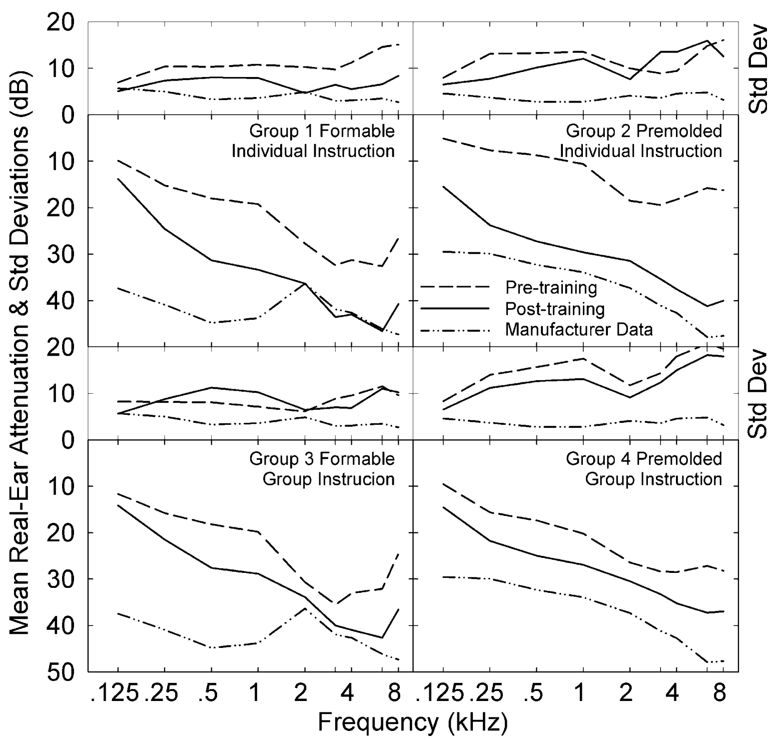

Figure 1. Mean pre- and post-training binaural REAT data for participants using the formable device and receiving individual training (Group 1), the premolded device and receiving individual training (Group 2), the formable device and receiving small-group training (Group 3), and the premolded device and receiving small-group training (Group 4). The manufacturer's experimenter-fit REAT data have been included for reference.

above the data for the respective groups. For each group, there was more attenuation in the frequency range above 1000 Hz than at and below 1000 Hz for both the pre- and post-training conditions. The standard deviations decreased between the pre- and post-training at all frequencies for groups 1, 2, and 4. Group 3 exhibited some reduction in the standard deviations only at the highest and lowest frequencies. Increased mean attenuation and decreased standard deviations led to increased group performance, as discussed later. To study the effect of both of the independent variables together, a two-way multivariate analysis of variance (MANOVA) was used in the data analysis. This enabled an analysis of the interaction effect between the variables. A subject's prior knowledge or experience was capable of exerting a confounding effect on the experiment's main outcome measurement variable; therefore, multiple analysis of covariance (MANCOVA) was used to control for that variable (Field & Hole, 2003). The MANCOVA revealed that there was no significant interaction effect for training by earplug, $F (1, 96) = 3.19$, $p = 0.0772$; or for frequency by training, $F (8, 768) = 1.77$, $p = 0.0793$. With the pre-training covariate in the model, the variance attributed to the remaining factors (after controlling for the covariate) fully accounted for the effect. At its highest hierarchical level (frequency by training by earplug), the interaction was non-significant, $F (8, 768) = 1.55$, $p = 0.1357$. Because an interaction effect did not exist for the two-way MANOVA, a more straightforward interpretation of the main effects of the model was permissible.

A one-way independent analysis of variance (ANOVA) was used to analyse the differences between the condition of no training (pre-training; $n = 100$), individual training (post-training; $n = 50$), and small-group training (post-training; $n = 50$). The issue of whether a training effect existed was addressed by computing the significance of any gain in effectiveness. The data in Figure 2 indicate that there was a statistically significant main effect for training, $F (2, 97) = 26.52$, $p < 0.0001$. The overall F statistic indicated that the two training groups were both different from the test condition in which no training had been provided. In other words, attenuation of the noise-band stimuli for the training groups was increased by a statistically significant amount, which indicates that attenuation levels after training were significantly greater than attenuation levels before training.

The significance of the observed statistic might not be considered as compelling as the size of the effect, which in this case was determined a priori to be 8 dB for naive listeners. No evidence of an existing attenuation-improvement criterion was available that could be used in this experiment. A detailed description of the rationale used to ascertain the 8-dB attenuation-improvement criterion may be found in Joseph (2004). Briefly, an analysis of the standard deviations reported in several studies that collected REAT data by circumaural headphones (Franks et al, 2003; Edwards et al, 1978; Lempert & Edwards, 1983; Padilla, 1976; Passchier-Vermeer et al, 1994) was conducted. The bold line in Figure 3 represents the mean of the standard deviation values for the selected investigations. In the low-frequency range (i.e. 500 Hz), commonly considered the energy range that is typically most poorly attenuated by ear protectors, the mean REAT standard deviation for the data set was approximately 8 dB. From this analysis, the criterion for effective training was determined to be 8 dB. In other words, if an individual's attenuation threshold was improved by 8 dB or greater, such growth could be interpreted as a change within a distribution of thresholds of at least one standard deviation. This established a population-based target that was applied in the power calculation and used to reflect a reasonably large change in the REAT as a result of the intervention presented in the experiment.

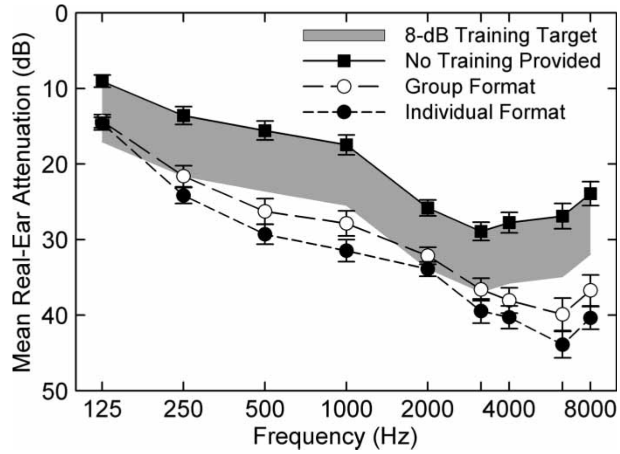

Figure 2. Mean binaural REAT data and standard errors for participants receiving no training, individual training, and small-group training, irrespective of HPD group. An overlay of 8 dB is included for assessment of training effectiveness.

Certainly, the ability to improve protection by an entire standard deviation could be considered sizable in the realm of noise reduction. For that reason, 8 dB, which is the equivalent of a decrease in sound power level by a factor of 6.3, was established at a criterion level for this exploratory research. Most importantly, an 8-dB improvement across the REATs is equivalent to an exposure that is 6.3 times longer, when a 3-dB exchange rate is applied. Although a frequency-by-frequency improvement of 8 dB is a considerable change in attenuation that may be unachievable in experienced HPD users, it was established as a viable target in a population of inexperienced listeners (Joseph, 2004).

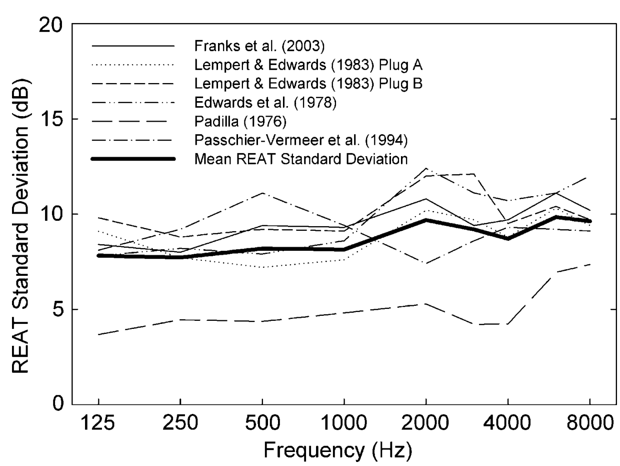

Figure 3. Five data sets that reported REATs obtained using circumaural earphones with subjects wearing earplugs (bold line depicts the average SD across each frequency for all data); the low-frequency value was used to derive a training target (8 dB).

Because a well-designed training program was used, the difference between no training and training (small group and individual) was expected to exceed the 8-dB criterion, whereas it is more difficult to speculate about the small group versus individual training. Neither training format satisfied the improvement criterion at 125 Hz, and the small-group training condition failed to improve by at least 8 dB at 2000 Hz. All other frequencies equaled or exceeded the 8-dB population-based improvement criterion. Overall, the training data exceeded targeted levels and there was appreciably more attenuation at higher frequencies, when compared to lower frequencies.

Randomization is designed to produce evenly balanced groups, and it is usual, therefore, to compare arms of a trial without adjustment. However, randomization is a probabilistic procedure that sometimes composes groups that are not identical on all factors, especially when numbers are small (Elwood, 2000). The results of trials are generally presented without adjustment for pre-training differences, since adjustment for covariates in effect converts an experimental study into a longitudinal observational study. Nonetheless, we also performed an ANOVA that adjusted for baseline variables, and the effect of treatment remained highly significant.

Protector effects

Having established a behaviorally and statistically significant main effect due to training, an equally substantive analysis entailed yet another study of group means, namely, whether any of the means were significantly different for the protector groups in the pre-training versus post-training comparison. The instructions for insertion and verification of fitting for the hearing protectors used in this study were moderately different and the earplugs required fundamentally different methods to achieve proper insertion; therefore, a comparison of the mean pre-training and post-training REAT values as a function of type of protector was conducted to determine if a significant difference in performance existed between devices.

A one-way independent ANOVA was used to analyse the significance of differences between the formable and premolded protector for the first measurement (pre-training; $n = 50$) and the repeated measurement (post-training; $n = 50$). As expected, there were mean differences in the REAT measurements because of the different attenuation characteristics of the protectors. The graph in Figure 4 illustrates that, on average, the pre-training measurements of formable-earplug users yielded considerably more attenuation across the entire frequency range than for premolded-earplug users. Mean attenuation for the formable device exceeded the premolded earplug by 3.4 dB (125 Hz) to 10.9 dB (6300 Hz).

In the post-training condition, the differences initially seen between the formable and premolded devices were diminished. Although the formable protector produced the highest attenuation after training, the premolded values showed substantial convergence toward the formable-earplug values, particularly in the low-frequency range. Furthermore, Figure 5 shows that the mean high-frequency performance of the hearing protectors did not converge in the same way as did the low-frequency responses. This observation suggests an interaction effect for frequency. Significant differences existed across the pre-training earplug variable [$F(1, 98) = 7.38$, $p < 0.01$]. A test of the post-training measurement resulted in a non-significant F statistic,

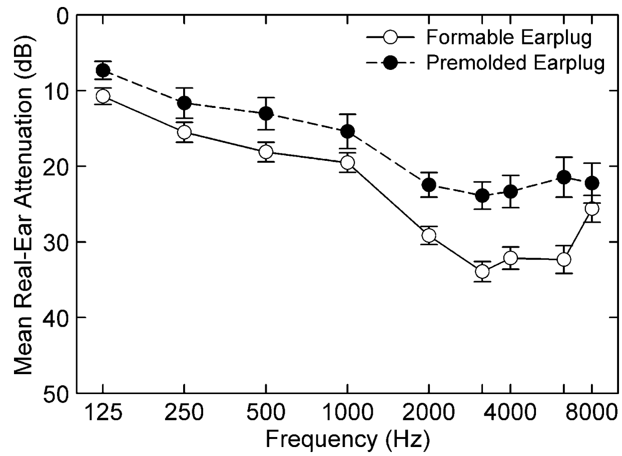

Figure 4. Mean binaural REAT data and standard errors for participants wearing premolded earplugs or formable earplugs for the pre-training test, irrespective of training group.

revealing that the earplugs attenuated similarly across frequency [$F(1, 98) = 3.03$, $p = 0.0847$].

Overall, the two earplug types did not attenuate equally across frequencies in the pre-training condition, and became more similar on the post-training phase. The analysis supports the presumption that the attenuation offered by earplugs is frequency dependent and that the frequency response of each type of device is different. Users realized a larger improvement from HLP training in the low frequencies than in the high frequencies, possibly due to enhancement of depth and seal of the earplug. Thus it is apparent that training minimized the differences between formable and premolded earplugs in the low frequencies, enabling listeners wearing different devices ultimately to obtain comparable attenuation.

Survey data analysis

The NIOSH HLP attitude-belief survey was used to study differences in attitudes toward individualized intervention vs. small-group intervention across protector types. It was especially

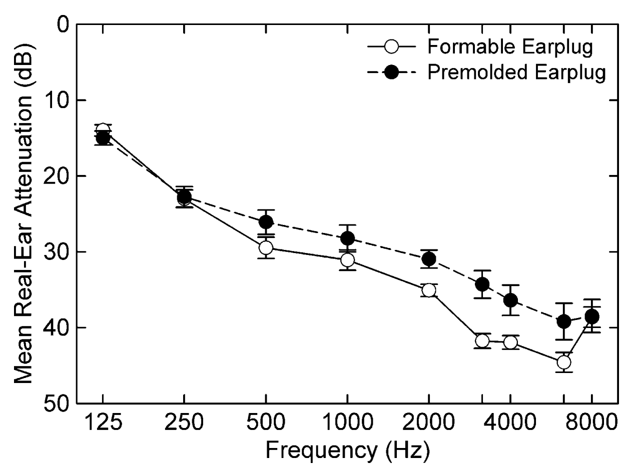

Figure 5. Mean binaural REAT data and standard errors for participants wearing premolded earplugs or formable earplugs for the post-training test, irrespective of training group.

of interest to determine if training produced differences in beliefs and attitudes toward hearing loss prevention. Psychometric analysis of the survey data obtained using two parallel forms was administered using WINSTEPS (Linacre, 2002). The data were assessed to determine if a significant training effect could be identified using the overall attitude score generated from the NIOSH HLPAB survey.

Attitude change was assessed by comparing the scores on the scales from pre-training and post-training. The mean score obtained from the population in the pre-training condition was essentially zero (0.0009), or Neither Agree nor Disagree, and the standard deviation was .38. After training, the HLPAB showed, on average, that subjects adopted a positive change in attitude that was not large enough to encompass an entire category on the response scale, but it departed from zero by approximately half of a category-unit distance. The training-by-earplug interaction effect was found to be non-significant ($p = 0.29$), and there was no effect for training or protective device ($p = 0.56$ and 0.93, respectively). Despite absence of a between-subject effect, attitude score did change by a statistically significant amount [$F(1,96) = 182.19$, $p < 0.0001$]. The significant effect resulting from the intervention provided evidence that the NIOSH HLP training program had motivational merit, and that the survey instrument was sensitive to the effect of the intervention.

Attenuation vs. attitude correlation analysis

A final analysis of the data included an assessment of the relationship between attenuation and attitude using an inter-correlation procedure. Two commonly assessed REAT frequencies, 500 and 1000 Hz, were correlated with the HLPAB attitude scores for the population. These analyses were conducted for both the pre-training and post-training data. Attenuation values at 500 Hz and 1000 Hz were not predictive of attitude score.

The correlation coefficients for the dependent variables were used to ascertain the extent of any relationship between the specified outcomes. The low coefficients of 0.02 and 0.01 (as shown in Table 2) provide evidence that levels of attenuation at 500 and 1000 Hz were not related to the attitude score in any predictable way. Hence, it does not appear that a wearer's attitude is associated with the ability to insert the earplug.

Summary and Recommendations

This study was designed to answer the questions of whether small-group hearing loss prevention training is as effective as individual intervention, and furthermore, whether formal training is more effective than no training. If a training condition would be capable of improving HPD attenuation by at least a difference of one standard deviation (8 dB), when compared to another training condition, that intervention could be regarded as superior. In this experiment, we found no behavioral or statistical difference between small-group and individual HPD training. Of equal importance, the extent to which 20 minutes of HPD training enhanced attenuation performance was considerable for both the formable and premolded devices selected.

Table 2. Population r^2 statistics for pre-training and post-training data using the dependent variables REAT (500 and 1000 Hz), and attitude score for regression computations.

	Coefficients of Determination (r^2)	
	Pre-training attitude	*Post-training attitude*
REAT @ 500 Hz	0.02	0.02
REAT @ 1000 Hz	0.01	0.02

Frequency dependency of the attenuation of earplugs was evident in this investigation, which demonstrated agreement with other studies (Casali & Berger, 1996; Franks et al, 2003; Lam, 1985; Paakkonen & Tikkanen, 1991). The attenuation increased as a function of frequency, also in agreement with other studies (Martin, 1982; Royster et al, 1996). There was clear evidence of a training effect for both small-group and individual formats, but no significant overall difference between the small-group and individual formats. The pre-training earplug effect was indicative of differences in frequency-dependent attenuation obtained by naive listeners. Training nearly eliminated this difference, while improving the amount of attenuation performance for both devices.

The NIOSH HLP training program was offered to a sample of college students with no industrial background or recent experience with earplugs to study the potential effects of small-group versus individual training on attitude. In this investigation, the HLPAB survey was not proven a feasible independent fit-test instrument; nonetheless, further research might support its use with a sample of industrial HPD wearers. In a sample of inexperienced HPD users, the HLPAB did not predict REAT. The HLPAB does, however, provide a valid criterion for the evaluation of HLP interventions. For example, the attitude score may be used to assess the extent to which a given HLP intervention affects the attitudes of an individual who has participated in HLP intervention. Clearly, the statistically significant change in attitude on the HLPAB provides evidence that the motivational messages included in the NIOSH HLP training program were effective. Of equal importance is that no significant difference was found between attitude scores of participants who were trained individually and those trained in a small group, failing to document an expected advantage of individual training (Royster & Royster, 1990).

Although the actors in the training videos used in this study were carpenters, it appears that the hearing conservation message was effectively conveyed to this non-occupational population. College students, particularly those from major institutions such as Michigan State University, might be especially proficient at individualized or small-group instruction. In this investigation, the study population was highly educated and motivated and did show improved attenuation after training. This is contrary to the opinion that HCP training should always be representative of the population, or, specifically, the workers for whom it is intended (Lusk et al, 1998). Nonetheless, the argument might still be raised that more representative actors might have intensified the motivational HLP message presented to volunteers in this study, although it appears that such actors were not necessary. The point remains that training does not have to be aimed specifically at an educated and motivated population, and can be remarkably effective even when actors do not closely resemble HCP trainees.

Questions in the NIOSH HLPAB survey were phrased to address conditions of recreational noise, whereas the minimovies were directed to an audience exposed to occupational hearing hazards. In the case of the main mini-movie, the settings were a small carpenter shop and the home of one of the workers. The vast majority of the actors in the NIOSH training video were middle-aged males, which may have generated little enthusiasm for HLP from young female participants, or young participants in general. Evidence suggests that measuring HLP behavioral change in a population of young students by the use of a questionnaire is difficult (Weichbold & Zorowka, 2003).

The common assumption in hearing conservation programs is that individual training is more effective than group training, and that individual training should be used when its costs are not prohibitive. In this study, individual training was not significantly different from small-group training with respect to performance data on hearing protection devices when a formable earplug (E•A•R® Classic® by Aearo Corporation, NRR 29 dB), and a premolded device (Fusion™ four-flanged earplug by Howard Leight Company, NRR 27 dB) were utilized. Therefore, individual training should probably be required only when a worker exhibits significant threshold shift. It is certainly possible that a more rigorous individualized training process might have yielded a more substantial effect; however, for this study, the use of training sessions of a reasonable duration, correspondence of the two training formats, and real-world generalization were considered more-critical characteristics of the intervention design. As discussed, training has the capacity to optimize the level of protection that is available to HPD users, and this can be verified through real-world effectiveness measures. Royster and Royster (1990) recommended that all employees should be trained individually on the proper use of HPDs. This approach, though, is not cost-effective for large HCPs. The present investigation suggests that training all workers individually may not be necessary.

The issue of whether these listeners are capable of demonstrating the same level of REAT improvement for extended follow-up periods remains undetermined. For some listeners, there was a delay between NIOSH HLP training and post-training measures, and there was variability across subjects with respect to the time taken for completion of the trial. Predominantly, the procedures used for this study were appropriate in satisfying the demands of the real world, and the results do support field-attenuation testing and some method of HLP training as necessary elements of an effective HCP. Even so, improved attenuation may lead to excessive sound reduction for some workers, which is likely to introduce problems with detection of warning signals and speech intelligibility (Abel & Odell, 2006).

This study attempted to identify whether attitude-belief scales are capable of predicting attenuation, and psychophysical measurements were found to be uncorrelated with attitude. Longitudinal investigations have reported relationships among attitude, behavioral intentions, and actual HPD usage behaviors (Lusk et al, 1997a,b), so a longitudinal investigation using a wider array of earplugs with larger-sized training groups should be completed to corroborate our findings. In addition, further work must be done to authenticate these conclusions in populations that demonstrate minimal experience with group or individual instruction.

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Appendix A

Exclusionary Criteria

- Pass a hearing screening at 25 dB HL at 250–4000 Hz (ANSI S3.6, 1996)
- Normal pinnae and ear canals, free of pathology as verified by otoscopic examination
- No cerumen impaction (experimenter did not clean the ears of subjects)
- No health problems (dizziness, fever, nausea, middle ear involvement)
- No existing hearing problems or tinnitus, and no recent ear surgery
- No problems indicated in manual dexterity with small objects
- Read English in the small print typically found on HPD packaging
- English was first language learned and is the language spoken at home
- No prior experience with HPDs, including swim plugs, in past 12 months
- Never received instruction on the use of insert hearing protection
- No HPD testing experience
- No discussion with another study participant who revealed details about the project
- Available for all phases of required testing and intervention