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Applications of Hearing Protector Fit Testing – Outcomes of the International Hearing Protector Fit-Testing Symposium

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Shortly after the U.S. Environmental Protection Agency (EPA) promulgated the regulation that required labeling of all hearing protection devices (HPDs) with the Noise Reduction Rating (NRR), studies were undertaken to examine methods that could be used to estimate workers' noise exposures. The NRR was shown to overestimate the attenuation that workers were likely to achieve in everyday environments. While various approaches to derate the attenuation rating have been recommended and required by institutions and national bodies, the derating fails to accurately estimate exposures for most persons. With untrained workers, attenuations can frequently be less than the derated value. Conversely, trained workers have been shown to achieve attenuation that is more than derating would predict. Individualized experiential fit training in the proper donning of earplugs, has been demonstrated as an important method to develop the "muscle memory" necessary to consistently fit earplugs. An evidence-based intervention demonstrated a 20% improvement in a study within a military occupational health clinic providing services to both civilian and defense workers. Challenges associated with the NRR and derating, and the benefits of hearing protector fit testing (HPFT) will be reviewed.

1. INTRODUCTION

The American Standards Association published the first standard for testing hearing protectors, USAS Z24.22-1957. Measurements were made in an anechoic space with a pure-tone stimulus in a free-field condition. The American National Standards Institute (ANSI) later published a method to measure the real-ear attenuation at threshold (REAT) with a diffuse sound field and one-third octave-bands of noise at nine frequencies: 125, 250, 500, 1000, 2000, 3150, 4000, 6300, and 8000 Hz (ANSI S3.19-1974). Noise bands provided the benefit of being less likely to excite resonances of the occluded volumes of the HPDs and the reverberant sound field is considerably easier to create in an audiometric test room as opposed to maintaining an anechoic chamber. The S3.19 standard has undergone significant revisions to become ANSI S12.6-1984, ANSI S12.6-1997, ASA/ANSI S12.6-2008 and ASA/ANSI S12.6-2016. The qualifications and instructions for the subjects are the primary differences between these standards. ANSI S3.19-1974 has a subject-fit and experimenter-fit protocols. ASA/ANSI S12.6-2016 includes both the Trained-subject fit (Method A) and Inexperienced-subject fit (Method B) protocols. Other differences include the specifications for the sound field, modifications to the subject requirements and reuse of subjects, more detailed instructions for the Békésy testing paradigm, and inclusion of an uncertainty annex.

The U.S. Environmental Protection Agency (EPA) embodied the ANSI S3.19 standard into its regulation 40 CFR 211 Subpart b for product noise labeling of hearing protective devices (EPA, 1979). The EPA adopted one of the methods proposed by NIOSH (Kroes et al., 1975) to become the Noise Reduction Rating (NRR). The NRR was designed to provide the consumer with a simple metric that described the noise reduction of a protector. If one knew the noise exposure level, then the NRR could be subtracted directly from the C-weighted equivalent sound pressure level to estimate the A-weighted exposure level when hearing protection was worn. Although the EPA's labeling rule applies to all HPDs entered into commerce in the U.S., the NRR did not describe the attenuation for devices that have level-dependent attenuation or which have active noise reduction (ANR). The EPA proposed a revised regulation in 2009 that described methods to measure the attenuation of ANR earmuffs and earplugs and methods to assess the impulse noise reduction of passive nonlinear HPDs and electronic level dependent HPDs (Environmental Protection Agency, 2009).

A. WILLIAM J. MURPHY, "TO DERATE OR NOT DERATE: ESTIMATING NOISE EXPOSURES OF WORKERS WHEN HEARING PROTECTION IS WORN."

This presentation provided a historical review of the development of hearing protection rating standards and the implications of testing methods that led to derating recommendations. The NRR represents the best attenuation that a hearing protector might be expected to be achieved. If individuals have little or no training, then they are unlikely to insert earplugs correctly and may fit earmuffs in a compromised manner. To alleviate the application of a population statistic to an individual, personal attenuation ratings (PARs) can account for the discrepancies between real-world and laboratory-measured attenuations. These PAR measurements allow the hearing conservation professional to better serve the needs of the worker and to assure that they can properly wear the protectors they have been issued.

Shortly after the promulgation of the EPA's regulation to label HPDs (40 CFR 211(b)), NIOSH collaborated with researchers to conduct real-world evaluations of HPDs worn by workers using a portable fit-testing system installed in a mobile van. The field data did not match the laboratory data. Not only were the mean field-measured attenuations less than the laboratory-measured attenuations, but the field data standard deviations were 3 to 5 times larger. If one uses the NRR formula to describe the group data, there is a likelihood that the field NRR would be negative. Berger et al. (1998) compared the field-measured attenuation data from several HPDs collected in 22 real-world studies to laboratory-measured attenuations. In Figure 1, the laboratory attenuation and subject fit NRR (NRR_{SF}) evaluations of 13 HPDs tested in NIOSH laboratory studies are presented. The averaged percentages of the NRR_{SF} relative to the NRR rating for the
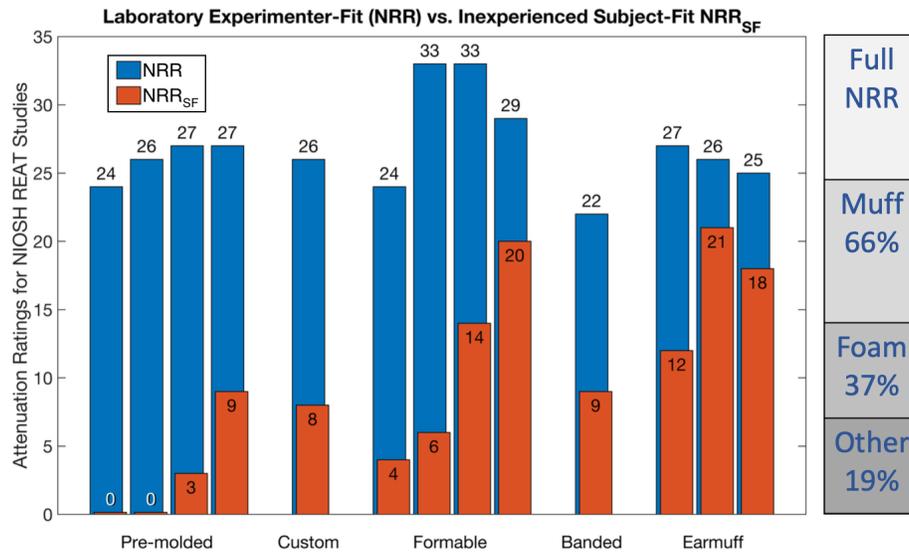
Figure 1:   Comparison of the attenuation ratings from experimenter-fit data (NRR) and inexperienced subject-fit data (NRR$_{SF}$) for real ear attenuation at threshold tests conducted in the NIOSH laboratory. Negative NRR$_{SF}$ values are listed as 0 dB. The average of the ratios of NRR$_{SF}$ to NRR for the different categories of protectors (muffs, formable/foam, and other HPDs) are given in the sidebar. (Figure from Themann et al. (2023)).

different categories of HPDs are given in the bar to the side of the figure (e.g. $0.66 = \text{avg}\left[\frac{12}{27}, \frac{21}{26}, \frac{18}{25}\right]$). NIOSH (1998) proposed that a variable derating factor be applied to the NRR. The NRRs for earmuffs are derated by 25%, formable earplugs by 50%, and other earplugs by 70%. OSHA applies a 50% derating of the NRR to HPDs.   In two recent publications (Berger and Voix, 2022; Murphy et al., 2022), the derating schemes from several countries are presented. The various countries' derating schemes are summarized in Table 1.

Murphy et al. (2016) conducted fit tests with off-shore oil rig engineers and inspectors. The nominal PAR these workers needed was 25 dB. In 2012, 75 workers were fit tested and 30 (39%) did not achieve the target PAR. In 2013, 86 workers were fit tested and 38 (44%) did not achieve the target PAR. With training that included fitting techniques and changing the workers' earplugs, 89% (68) and 85% (73) of the workers achieved the target PAR. This performance was not atypical.

Murphy et al. (2022) evaluated four hearing protector fit testing (HPFT) studies where workers were evaluated multiple times. In Figure 2, the before and after results are presented where the difference between the subject's PAR and the derated NRR for the earplug is plotted on the ordinate. In the NIOSH advanced HPD study (panel A), no intentional training was provided, and no target PAR was established. Workers were tested with their earplug of choice. The initial (blue symbols) and final PARs (gold symbols) are compared and exhibited essentially the same distribution of PARs. For the Chinese Worker Study in panel B, workers that failed to achieve the target PAR established for their particular job were provided additional training in fitting the earplugs and were evaluated after the training. The majority of the 878 Chinese workers were able to exceed the derated SNR. In the two U.S. Marine Corps recruit studies, the target PAR for the foam earplug was set at 25 dB. Those recruits that failed to achieve 25 dB are plotted on the left side of each panel C-F. The post-training results are shown in gold symbols on the right side of each panel C-F. Three approaches for training were provided to the recruits: an informative video, experiential training with a trained administrator, and a combination of the experiential and video-based training. The training that

Table 1: Hearing protector derating schemes from several countries (Table adapted from Murphy et al. (2022)).

	Earmuffs	**Formable earplugs**	**All other earplugs**	**Comments**
United States OSHA	$(\mathrm{NRR} - 7)/2$ for dBA exposure levels			7-dB conversion between C- and A-weighted noise
United States NIOSH	$(\mathrm{NRR} \times 0.75) - 7$	$(\mathrm{NRR} \times 0.5) - 7$	$(\mathrm{NRR} \times 0.3) - 7$	To estimate TWA in dBA
Canada CSA Z94.2	$(\mathrm{NRR} \times 0.7) - 3$	$(\mathrm{NRR} \times 0.5) - 3$	$(\mathrm{NRR} \times 0.5) - 3$	$((\mathrm{NRR} + 5) \times 0.65) - 3$ dual protection, 3 dB conversion L_{Ceq} to L_{Aeq}
Australia, New Zealand, Brazil	No derating applied. AUS/NZ uses SLC_{80}. Brazil uses NRR_{SF}.			Naïve subject fit
China before January 2021	$(\mathrm{SNR} \times 0.6)$			Single Number Rating (SNR)
China after January 2021	No derating applied			$L_{Aeq} < 95$ dBA, SNR 17-34 $L_{Aeq} \geq 95$ dBA, SNR > 34
Italy	$\mathrm{SNR} \times 0.75$	$\mathrm{SNR} \times 0.5$	$\mathrm{SNR} \times 0.3$	SNR
Germany	$\mathrm{SNR} - 5$	$\mathrm{SNR} - 9$	$\mathrm{SNR} - 5$	SNR−3 custom earplugs
France (prop.)	$\mathrm{SNR} - 5$	$\mathrm{SNR} - 10$	$\mathrm{SNR} - 10$	SNR−5 custom earplugs
Unit. Kingdom	$\mathrm{SNR} - 4$ dB			SNR

incorporated the experiential element demonstrated superior improvements over merely watching a video.
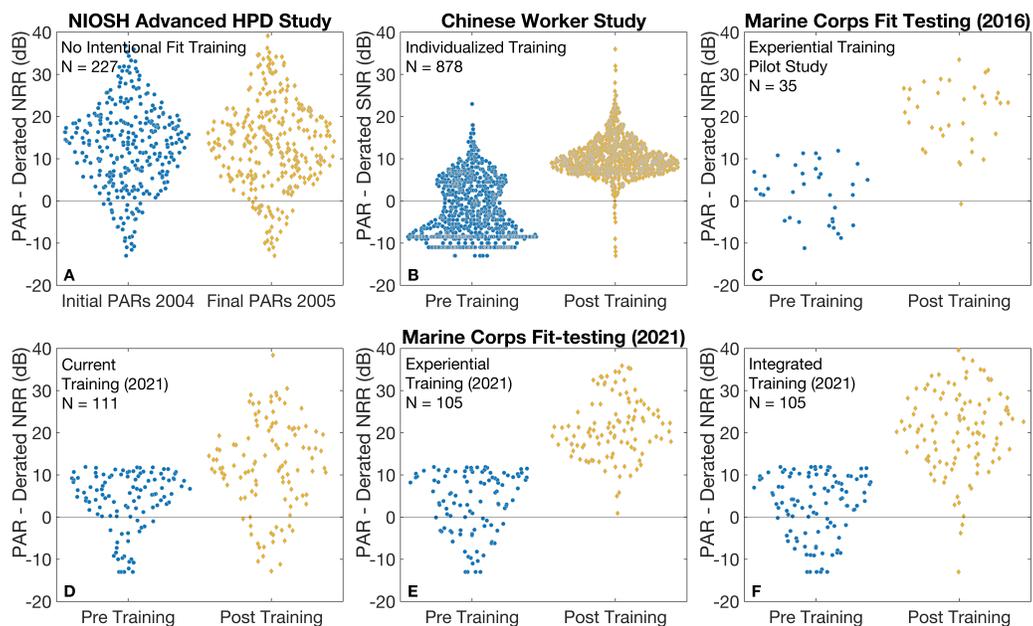

Figure 2: Pre-training and Post-training swarm plots illustrate the effect (or lack of effect) of training on the PARs relative to the derated NRR or the derated SNR (Chinese Worker Study). OSHA derating and C-A correction was applied. The blue symbols are the initial fit tests before training. The gold symbols are the post-training PARs. (Figure from Murphy et al. (2022)).

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Lastly, Murphy discussed the results of how hearing protection maintained (or didn't maintain) its attenuation over the course of a 2-hour work shift (Gong et al., 2023). Workers were tested before and after a work shift to determine whether PAR values decreased. The median and mean PAR values decreased by 1 to 2 dB. The premolded earplugs were more susceptible to having the earplug loosen significantly or fall out of the ear canal during the work shift.

To summarize Murphy's presentation, the NRR informs the user about the attenuation capability of the hearing protector. Hearing protector deratings do not provide specificity for estimating protected exposures. Derating can give a false sense of security and still results in both over protection and under protection. HPFT identified persons who didn't achieve the target attenuation. HPFT can be accompanied with training to improve reliable protection from noise exposure.

B.   STEPHANIE J. KARCH, "EHPD FIT-TRAINING & YOU."

Successfully fitting earplugs is not an intuitive user skill with which someone is born. Rather, the user needs to receive focused training on how to properly fit the issued device and to be informed of any special features or characteristics of the HPD. The topic of this presentation discussed an experiential three-step HPD fit-training method developed and first reported by Federman and Duhon (2016). This method is now known as the experiential HPD (eHPD) fit training and it utilizes HPFT to verify and validate fit at the time of product issuance.

The term experiential HPD (eHPD) fit training first appeared in the literature in an article by Federman et al. (2021), however the technique was first described by Federman and Duhon (2016) as "ear canal muscle memory." This training method was developed in response to the question, what do you do when the target PAR is not achieved? The obvious answer is to train or retrain the individual. However, in dynamic occupational environments, one might not be able to pivot to traditional training methods. The eHPD fit training method is unique in that it is a focused training method specific to the individual that is less than one minute at its core. Central to this training approach is the provision of an experiential learning opportunity for the employee that addresses not only how to handle and fit the earplug, but how that earplug feels in the ear when donned properly. Since properly fit HPD can only be quantified via HPFT, HPFT is used as a tool to verify the earplug fit at every stage of the training method. The procedural steps of the eHPD method are discussed in the remainder of this section and can be viewed in whole in Figure 3.
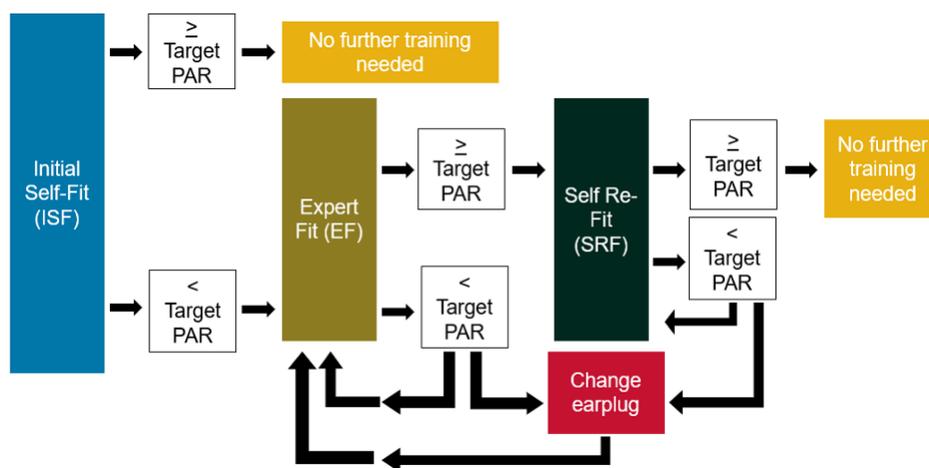

Figure 3: eHPD fit-training method flow chart.

The eHPD fit-training method can be used in two dynamic approaches. That is, either as a method to

train all employees regardless of baseline HPD fitting skill, or as a method to identify and train only those employees who demonstrate the inability to fit and achieve the target PAR. Regardless of chosen approach, the first step of the method requires a baseline measure of HPD fit skill, or the initial self-fit (ISF). During this step, after the open-ear trial (i.e., unoccluded or with no earplugs) is completed, the employee is asked to insert the earplugs in their ears to the best of their ability based on manufacturer provided instructions or prior trained knowledge. The closed-ear trial (i.e., occluded or with earplugs) is then completed, and the achieved PAR is reviewed by the trainer while the employee removes their earplugs. If the goal of the trainer is to identify and train only those employees who require training, any employee whose PAR values are equal to or greater than the target PAR can be excused from further testing/training. If all employees are to be trained regardless of achieved PAR, this step could be skipped. However, the ISF PAR values allow the trainer to evaluate and measure training effectiveness, so baseline testing is encouraged.

The second step of the eHPD method is the expert fit (EF). In the truest sense, the EF step could be viewed as the "training" portion of this method. While the expert fits the earplug for the employee in the employees' ears, the trainer simultaneously explains what they are doing. That is, the proper handling and roll-down technique (assuming it is a foam earplug being fit) for the earplug used, how to straighten the ear canal, and how to insert and hold the earplug in place while it expands in the ear. An example of the language used while completing this would be:

> *"You're going to take one earplug, put it between your thumb, pointer, and middle fingers to roll down the earplug to as small as you can get it. Make sure there are no creases in its sides. To insert the earplug, you want your ear canal to be straight. For this ear, that means you need to pull your ear straight back. After you insert the earplug, you need to lightly hold the end of the earplug, so it doesn't push out while it expands."*

Once the expert has fit both ears with the earplugs, and the two-minute dwell time (if appropriate based on earplug type) is complete, the closed ear trial is completed. The employee can then be instructed to remove their earplugs and the achieved PAR is be reviewed by the trainer. It is worthy to note, that depending on test system, it may be possible to reuse the initial open-ear trial (e.g., the ISF baseline) from the same day if additional tests are necessary.

The next step is contingent on the achieved EF PAR. If the PAR meets or exceeds the target value, the employee can proceed to the final step of the eHPD method, the self-refit (SRF). However, if the employee's PAR is less than the target, the options to choose from are either to refit (and therefore retest) the same earplug or change the earplug (and retrain then retest). By having an expert fit the product, the influence of knowledge and/or fitting skill of the earplug have been eliminated, and one can evaluate if earplug performance (e.g., attenuation) is due to product size, design, or style. That is, if the expert's fit also results in a PAR less than the target, the cause likely lies not with fit but with the product size or design, and another product is warranted. As shown in 3, if that were the case and another earplug needs to be chosen, then the expert must repeat all steps of the EF.

Variations in EF training approach may be needed and are encouraged based on the unique circumstances of the individual employee. That is, if the employee has limited mobility or use of their hands/arms due to injury (e.g., hand in a cast or fingers in a splint), they may not be able to use their thumb or fingers to roll down the earplug or reach over the head to pull on the opposite ear. Pivoting to what the employee can do will work best, and result in a successful training where the target PAR is achieved. Additional tips for success, include standing to the back and side (i.e., between 3 to 5 o'clock or 7 to 9 o'clock) of the employee while manipulating their ear to view the orientation of the ear canal while in movement. To aid in achieving a deep fit with the earplug, using a slight circular rotation while inserting the earplug will help release any experienced friction between the ear canal and earplug. A deeper fit of the earplug will aid in greater achieved attenuation. When fit correctly, the end of the earplug should sit behind the edge of the tragus.

The last step of the eHPD method is the SRF. In this step, the employee is asked to insert their earplugs the same way they were just shown. That is, to replicate the fitting experienced in the EF step. Observation of how the employee dons the earplug during this step is important as this information can be used should the fit not result in a PAR that meets or exceeds the target. Upon completing the closed ear trial, the employee can remove their earplugs while the tester reviews the calculated SRF PAR. If the target PAR is met or exceeded, no further training is needed, and the employee can be excused. However, if the SRF PAR is less than the target, this suggests continued difficulty with fitting the product. At this point, the trainer can decide if "coaching" the employee (e.g., statements such as "make sure to pull back on the ear", "try holding the earplug this way") would result in a fitting technique that would achieve the target PAR or if another earplug is warranted. If the trainer decides to change the earplug, they must return to and repeat the EF and SRF steps with the new earplug(s).

At this point, the presenter discussed what makes an expert an "Expert" in the context of this training method. She stated that the Naval Submarine Medical Research Laboratory's Hearing Conservation Program of Record has executed investigative efforts with Occupational Audiologists, Navy Hospital Corpsmen, and Hearing Conservation Technicians as "Experts." In fact, eHPD method trained Audiologists, Corpsmen, and Hearing Conservation Technicians were able to successfully train participants to achieve the minimum target PAR value at SRF.

The use and implementation of eHPD fit training in military occupational environments has been investigated by the Naval Submarine Medical Research Laboratory's Regional Hearing Conservation Team over the past 10 years. And while outside the scope of the current presentation, attendees were encouraged to consult additional resources for those interested in topics areas such as development (Federman and Duhon, 2016), effectiveness (Federman et al., 2021), generalizability (Federman et al., 2017), training skill retention (Federman et al., 2022), adaption and implementation in occupational environments (Karch et al., 2023), and the effect of dynamic movement on earplug stability (Karch et al., 2023).

C.   MELANIE EZELL HAYES, "IMPLEMENTING HPD FIT TESTING IN A MILITARY OCCU-PATIONAL HEALTH CLINIC: A QUALITY IMPROVEMENT PROJECT."

This presentation included results of a quality improvement (QI) project to implement HPFT in a military occupational health/hearing conservation clinic (Hayes et al., 2022). Occupational noise induced hearing loss has significant socioeconomic, health and quality of life impacts. Military and civilian defense workers are especially at risk given the frequency and duration of hazardous noise exposure throughout their careers. Hearing loss and tinnitus accounted for 3.4 million claims (one-third of the top ten disability claims) with the U.S. Veterans Administration in 2019 (Veterans Benefits Administration, 2020). Given the significant impact of noise exposure on this population, a QI project was implemented to address gaps in current practices. In addition to the need to implement effective training in HPD use and fit, the clinic had recently acquired a Field Attenuation Estimation System (FAES) and needed to train staff to use the equipment and inform standard operating procedures for HPFT.

An evidence-based intervention (EBI) to train U.S. Marines recruits to properly insert earplugs was identified (Federman and Duhon, 2016; Federman et al., 2021) and implemented to assess the feasibility and utility of the EBI in this setting. The EBI consisted of a "trained-user" HPD fitting in the worker's ear and reassessment of PAR to ensure the target PAR was reached. Then, the worker was asked to do a "self-fit" and replicate the feel of the properly inserted HPD prior to reassessment of PAR. The "Plan, Do, Study, Act" (PDSA) model as shown in Figure 4 was utilized to guide the project.

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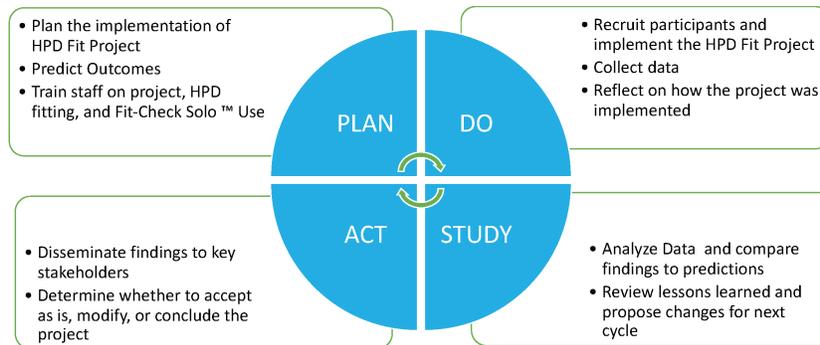
QI Model - PDSA Cycle

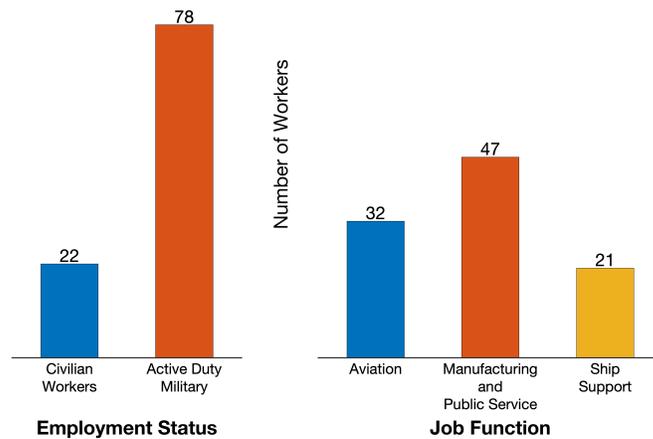*Figure 4: Quality Improvement Model – Plan, Do, Study, Act Cycle.*

Figure 5: Demographics for baseline testing. The mean age of the 100 workers who were tested was 33.9 y, minimum age was 19 y, maximum age was 68 y. Baseline testing required 10 minutes to collect demographics, baseline audiometric tests, occluded tests and post-test record keeping. Figure adapted from Hayes et al. (2022).

For the QI project, one hundred workers were recruited for the project at the time of their annual audiograms. A variety of occupations were represented, including ship building trades, aviation and aviation support, industrial trades and first responders. Since noise exposure measurements were not available for each work center, a target PAR of 20 dB was chosen to allow adequate protection throughout the range where single hearing protectors were required to be used, 85-104 dBA (Dept. of Defense, 2023). Military and civilian defense workers of all genders and races who were 18-70 years old, proficient in English, enrolled in a hearing conservation program due to noise exposure > 85 dBA TWA, and agreed to participate

were included in the project. Workers with hearing loss > 55 dB in either ear at 500, 1000, or 2000 Hz, or who had ear complaints that required medical evaluation, were excluded from the project (Hayes et al., 2022).

An occupational health nurse practitioner performed daily calibration of the FAES prior to conducting HPFT on participants who were seated in a quiet room. Three frequencies were tested (500, 1000, and 2000 Hz). An unoccluded measurement was obtained first, then a second measurement after workers inserted ear plugs in their usual fashion. The FAES system calculated the baseline PAR based on these measurements. Seventy-one workers achieved the target PAR with this initial "self-fit" (Hayes et al., 2022). Figure 5 shows the demographics of the baseline testing.

Table 2: Demographics of intervention group ($n = 27$). (Table used with permission, Hayes et al. (2022).)

Demographic	Frequency	Percent
Gender		
Male	22	81.5
Female	5	18.5
Race		
Caucasian	17	63.0
African American	5	18.5
Other	5	18.5
Work status		
Active duty	24	88.9
Civilian	3	11.1
Workplace		
Aviation/Aviation support	11	40.7
Fleet/fleet support	4	14.8
Other	12	44.4

Of 29 workers who did not achieve the target baseline PAR, 27 workers received the EBI and were re-tested. Demographics of this intervention group ($n = 27$) are shown in Table 2 while descriptive statistics of PAR results of the group are shown in Table 3. Table 4 shows the "trained-user" and post-EBI "self-fit" PAR results for the intervention group (Hayes et al., 2022).

Table 3: Descriptive statistics of participants who received the evidence-based intervention ($n = 27$). (Table used with permission, Hayes et al. (2022).)

Variable	Mean	Std. Deviation	Range	Minimum	Maximum
Age	31.07	9.88	40.00	19.00	59.00
Baseline "Self-fit" PAR	10.35	5.89	19.00	0.70	19.70
"Trained-user" PAR	28.00	8.39	28.90	13.50	42.40
"Self-fit" PAR after EBI	25.73	8.12	34.50	5.70	40.20

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Table 4: *"Trained-user" PAR and post-EBI "self-fit" PAR in intervention group* ($n = 27$)*. (Table used with permission, Hayes et al. (2022).).*

Result		"Trained-User" PAR		Total
		Achieved Target PAR	Did Not Achieve Target PAR	
"Self-Fit" PAR after EBI	Achieved Target PAR	18 (66.7%)	2 (7.4%)	20 (74.1%)
	Did Not Achieve Target PAR	4 (14.8%)	3 (11.1%)	7 (25.9%)
Total		22 (81.5%)	5 (18.5%)	27 (100%)

The project demonstrated the EBI is feasible in a hearing conservation clinic and results showed a 20% improvement in workers' ability to properly fit ear plugs after the EBI. Differences between baseline "self-fit" PAR and post-EBI "self-fit" PARs were statistically significant ($p < .001$) with a large effect size (Cohen's $d = 1.566$). Military personnel ($n = 24$) achieved target PAR post-EBI ($n = 20, 76.4\%$) more frequently than their civilian counterparts in the intervention group ($n = 3, 0\%$) although two-thirds of civilians met target PAR with "trained-user" fit. While small sample size prohibits generalization of results, motivation may have played a role. Unidentified factors requiring further research may also have contributed. Furthermore, results indicated that age showed a negative correlation to "self-fit" PAR after EBI ($p < .001$). Younger participants achieved target PAR ($n = 20, M = 28.2$ years, SD = 7.9) compared to those who did not ($n = 7, M = 39.4$ years, SD = 10.7) post-EBI. Young military personnel were more likely to achieve target PAR. These finding underscore the need to train workers early in their careers (Hayes et al., 2022).

The project also demonstrated that HPFT is an effective "train the trainer" tool and can be utilized to train hearing conservation technicians, nurses, and other health and safety personnel to perform HPFT in the workplace. The presenter noted that achievement of target PAR set for this project may result in overprotection of some workers. Ideally, noise exposure monitoring results for individual workers in a work site should be available so that PAR results can be tailored to the worker's exposure using the actual HPDs available in the workplace. Since safety professionals in the workplace are most likely to have noise exposure data and be involved in providing a suitable selection of HPDs to protect workers, they are ideal candidates to conduct HPFT. Workers who do not achieve the needed PAR after fit testing could be referred to the occupational health clinic for further evaluation and training to properly fit HPDs. A comprehensive team approach that includes stakeholder buy-in is critical for successful implementation of HPFT in a safety program (Hayes et al., 2022).

D. WEI GONG, THAIS MORATA, "NOISE ATTENUATION FROM HEARING PROTECTION FIELD ATTENUATION ESTIMATION SYSTEMS AND ASSOCIATED TRAINING: A SYSTEMATIC REVIEW."

This presentation included two main topics. The first topic consisted of a brief introduction to systematic reviews (Cumpston et al., 2023), their contributions to evidence-based recommendations, the review procedure (see Figure 6), and the motivation for conducting this review. The review protocol was published in 2021 (Morata et al., 2021).
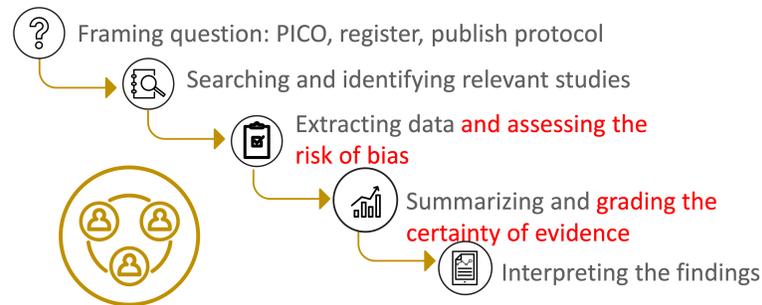
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Figure 6:   The steps in the process of conducting a systematic review. PICO stands for Population of interest, Intervention, Control, and Outcome.

The provision of HPDs is the most common approach to reduce noise exposure at work. Technically, most hearing protectors can attenuate noise exposure enough to prevent hearing disorders. In the United States, the NRR is required to be measured in the laboratory and published on the primary label of every HPD by the U.S. EPA. The NRR is then used to assess the adequacy of the attenuation of a hearing protector for a given noise exposure. Consequently, in the industrial setting, the published NRR value often guides decisions on HPDs to be purchased and provided to workers to ensure an efficient noise reduction. In practice, this theoretical reduction is rarely achieved because of improper application of the devices (see Figure 7 from Gong et al. (2021)).
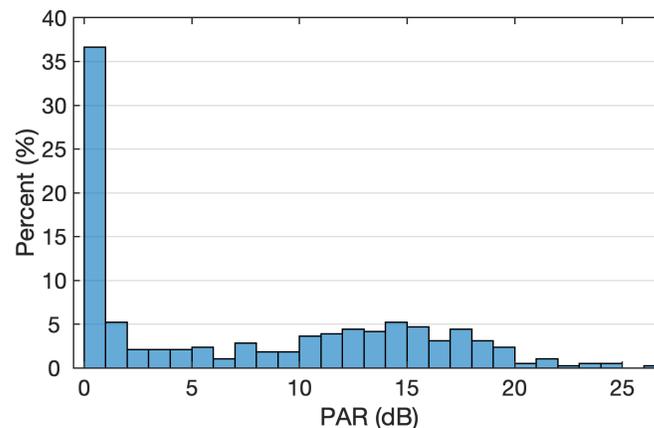
Figure 7:   A graph of the distribution of personal attenuation ratings (PARs) achieved by percentage of the noise-exposed workers ($n = 385$) in an auto parts factory. Noise exposures ranged from 77 to 102 dBA. The average 8-hour equivalent A-weighted exposure level, $L_{Aeq,8h}$, of noise-exposed workers was 87 dBA. Workers were required to wear a pre-molded earplug with an NRR of 25 dB. (Figure from Gong et al. (2021).)

In the past decade, research has accompanied the implementation of FAES (known as hearing protection fit-test systems). They measure the noise attenuation obtained by individual workers using HPDs.

The second part of the presentation covered the preliminary results from the systematic review of the HPFT effectiveness. The objectives of this review were to assess the effects of FAESs and associated training on the noise attenuation obtained by workers using HPDs and if this intervention affects the adherence to hearing protection use. The review question was: "Can fit-testing associated with training improve the personal noise attenuation from HPD for workers exposed to noise levels greater than 80 dBA TWA?"

We conducted a literature search to examine various databases, types of studies and the latest publications (up to August 2022). No language restrictions were imposed.

- **Database**: MEDLINE, Embase, PsycINFO, CENTRAL, CINAHL, Scopus, NIOSHTIC-2, Clinical-Trials.gov, ICTRP, Trip database, NHS Evidence - Ear, Nose, Throat and Audiology

- **Studies**: Randomized Control Trials (RCT), Controlled Before-After studies (CBA), Interrupted Time-series (ITS)

- **Language**: publication year and type: no restrictions

- **Last search**: August 7, 2022

Two review authors independently assessed study eligibility, risk of bias, and extracted data. We categorized interventions as fit testing of HPDs with instructions of different levels (no instructions, simple instructions, and extensive instructions) and fit testing of HPDs with different NRRs.

Four randomized controlled trials (RCTs) were included in the review: Park and Casali (1991), Federman et al. (2021), Murphy et al. (2007), and Salmani et al. (2014). These studies examined the effects of different instruction methods used with HPFT. We found two studies that examined the effects of fit testing of HPDs with different labeled NRRs, with extensive or no/simple instructions. Preliminary results indicated that HPFT accompanied by simple instructions probably does not improve PAR from foam and pre-molded earplugs in the short-term and long-term after the test. Fit testing associated with extensive instructions probably improves PAR largely from foam and pre-molded earplugs immediately after the test. The effects of HPFT with associated training to improve PAR values may depend on type of HPDs and training methods. The review is expected to be completed in 2024, when final results will be made available.

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