INTRODUCTION AND PURPOSE

Annual audiometric screening in hearing loss prevention programs could be radically changed if pure-tone threshold assessments could be integrated with real-ear attenuation at threshold (REAT) measurements of hearing protector attenuation. NIOSH funded a contract to compare REAT measurements collected under three headphone types (FitCheck, Sennheiser HDA200 with earmcup extensions, and Beyer Dynamic DT770M) using the HPD Well-Fit™ fit-test system. As well, the unoccluded thresholds for one-third-octave noise bands that were obtained in the REAT measurements were compared to pure-tone thresholds. Results suggest that the choice of headphone should not substantially affect REAT results if a single-number attenuation rating is used, although differences in measured attenuation do exist between headphone types at specific test frequencies. Although a straightforward transformation exists between mean pure-tone thresholds obtained using standard audiometric headphones and mean unoccluded noise-band thresholds obtained using HPD Well-Fit™ in this study, large errors could potentially be introduced in individual results with its use.

PARTICIPANTS

- 12 men and 12 women (mean age = 24.0 years; range = 21 to 31 years) with normal hearing, normal middle ear function, and no tinnitus.
- 20 of the 24 participants had some experience wearing earplugs or fit-testing HPDs.
- Prior to data collection, all participants demonstrated the ability to achieve reliable results with HPD Well-Fit.
- Subjects were fitted with Westone Musician’s earplugs with the ER-9 filter and the solid plug (Full Block).

METHODS

Circumaural headphones

NIOSH used the Michael & Associates FitCheck headphones outfitted with a 10.3 TDH-39 transducer and a large volume earmcup to minimize the occlusion effect and to avoid potentially contacting earplugs during occluded testing. With a typical computer laptop output of 1 VRMS, these headphones suffer from a lack of high-level output. The Sennheiser HDA200 are 40 dB headphones that can provide higher output levels and the HPD Well-Fit™ software version used for this study did not permit selection of thresholds < 0 dB SPL. Because several of the subjects had thresholds < 0 dB SPL at one or more frequencies (especially 2000 and 4000 Hz), their unoccluded noise-band thresholds could not be measured at these frequencies. Data were excluded from analysis for these cases (see Figure 2). Current software versions allow measurement of thresholds < 0 dB SPL.

Few thresholds reached the 0-dB limit under the FitCheck headphones. The Sennheiser HDA200 headphones with extensions had 18 thresholds rejected at 2000 Hz and 6 at 4000 Hz. The Beyer Dynamic DT770M had 6, 7 and 13 rejected thresholds at 1000, 2000 and 4000 Hz, respectively. Had these thresholds been included, the observed attenuations of the earplugs would have been falsely reduced.

Personal Attenuation Ratings

As shown in Figure 3, average personal attenuation ratings (PARs) calculated for the ER-9 earplugs were 10.8, 9.9, and 10.1 dB under the FitCheck, Sennheiser, and Beyer headphones, respectively. Given the small differences in measured attenuation at individual frequencies, the <1-dB differences in PAR, and the fact that no one headphone consistently produced the largest or smallest attenuation values, we conclude that, practically speaking, the choice of headphone does not affect REAT results using HPD Well-Fit™. PARs calculated for the ER-Full Block earplugs were 22.0, 24.7, and 23.3 dB for the FitCheck, Sennheiser, and Beyer headphones, respectively. The range of PARs in this case was approximately 3 dB. Differences in NRR of 3 dB or less are considered negligible for the purpose of selecting an appropriate HPD for a given noise environment (Berger, 2000), and given that the REAT procedure for obtaining NRR is more carefully controlled than the PAR procedure in this study, a difference of 3 dB in the PAR across headphone type does not have practical significance. However, the large differences observed between headphones at the individual frequencies of 2000 and 8000 Hz do bear investigation.

Comparison of HPD Well-Fit™ and audiometric threshold RETSPLs (dB SPL):

The use of circumaural headphones presents the potential for combining audiometric testing with hearing protector fit-testing. An important consideration before the two are combined is to compensate for the differences in calibration between supra-aural and circumaural headphones. In addition, the corrections for the differences between the pure-tone and noise-band stimuli is required (Flamme et al., 2014). Examining the unoccluded noise band thresholds from HPD Well-Fit™ in Figure 4, reasonable agreement across headphones was observed at all frequencies except 125 and 4000 Hz. The RETSPL curve for the HDA200 headphones (without extensions; ANSI, 2010) is plotted and shows agreement within a few dB through 2000 Hz. The effect of the psychometric paradigm can introduce small but significant differences in threshold. HPD Well-Fit™ uses a method of adjustment paradigm which is almost assuredly different from the paradigms to determine RETSPLs.

SUMMARY / RECOMMENDATIONS

- Headphones likely do not have significant effects upon REAT measurements, subject to the attenuation of the headphone itself and isolation from background noise.
- The signal generation system must have the capacity to measure hearing thresholds for persons that have hearing better than 0 dB SPL and the ability to generate high level stimuli for subjects with a moderate hearing loss and properly-fit hearing protectors.
- Noise-band stimuli should be designed for the specific headphones to compensate for the acoustic response of the headphone.
- Further development of an integrated system needs to be conducted to demonstrate the utility of combining audiometric testing with hearing protector fit-testing. The work of Flamme et al. (2014) and this research demonstrate the potential to complete fit-testing and improve the practice of occupational hearing conservation by adding just a few minutes to the annual audiogram.

REFERENCES

