The effect of an insertion lubricant on the noise attenuation of foam earplugs

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ABSTRACT

Real-world levels of attenuation from hearing protection devices are usually much lower than the rated values obtained under near-ideal circumstances. The shortfall is even more extreme for earplugs than it is for earmuffs, primarily because of the complicated process of fitting the plugs within the ear canal. This study examines the use of a commercially-available lubricant for hearing aids to determine whether it would facilitate improved fit and attenuation for earplugs. In this experiment, ten participants inserted earplugs with and without using the lubricant. Average attenuation was assessed with the Real-Ear-Attenuation-at-Threshold (REAT) technique, and showed over 5 dB improvement when the lubricant was used. Participants obtained an 85% mastery rate using the lubricant versus a 50% mastery rate without. These results indicate several possible applications for improved earplug performance in real-world settings where hazardous noise is unavoidable and effective hearing protection is necessary.

1. INTRODUCTION

Formable earplugs are commonly used to reduce the risk of noise-induced hearing loss, but users have long needed better field performance from their earplugs. The problem of poor field performance with earplugs is well documented, especially real-world noise attenuation that is far below ideal levels.[1] Coaching, instruction, and practice can lead to higher attenuation values,[2] but the results still fall short of the manufacturers' rated Noise Reduction Rating (NRR) derived under ideal laboratory conditions following the ANSI S3.19-1974 protocol.[3]

This study investigated the use of an ear canal lubricant to improve the attenuation of foam earplugs, especially for workers who are currently getting a poor fit. The lubricant makes it easier to achieve a good fit and may also seal small openings between the plug and the ear canal. The specific lubricant used in this study (Westone Oto-Ease[*]) is a commercially-available product that is currently sold to ease insertion of in-ear hearing aids.

2. TEST METHOD AND MATERIALS

Ten participants were recruited among employees at the National Institute for Occupational Safety and Health (NIOSH), Pittsburgh Research Laboratory following federal regulations for recruiting and testing human subjects (45 CFR 46).[4] With this relatively small sample size of ten individuals (20 ears), a large attenuation change would be needed to reach statistically significant levels. However, the benefit would ultimately need to be relatively large for real-world earplug

[*] Mention of specific products does not imply endorsement by the authors or the National Institute for Occupational Safety and Health.

users to take the extra effort to obtain and apply the lubricant. The limited sample size in this study was consistent with this objective.

Prior to the testing, all of the participants were screened for normal hearing and middle ear function. An otoscopic inspection was conducted to ensure a clear ear canal. Subjects were also given an audiometric evaluation to ensure that they had normal hearing sensitivity (thresholds $\leq$25 dB at 250, 500, 1000, and 2000 Hz). Normal middle ear function was determined through tympanometry. Participants were then randomly assigned to one of two experimental groups: lubricant-first or dry-first. All participants then underwent two sessions of earplug fit testing on adjacent days to allow dissipation of the lubricant for those subjects who use it on their first day.

For a "dry" test, the subject was shown the three-step instructions printed on the earplug box and told to insert the earplugs accordingly. For a "lubricant" test, the subject was told to first place some lubricant in both of his/her ear canals with a finger, then, in turn, roll each plug down, place some more lubricant on the plug, and then insert the plug.

Earplug attenuation measurements were performed with a Michael & Associates FitCheck apparatus.[5] This apparatus measures real-ear attenuation at threshold (REAT) by conducting open (no earplug) vs. occluded (earplug) test pairs; the difference in threshold levels is equal to the attenuation provided by the earplug. When performing earplug attenuation measurements, one-third octave bands of noise at different center frequencies (250, 500, 1000, and 2000 Hz) are routed to a set of headphones. Testing was limited to this range because of high inter-frequency correlations which meant that little additional information on fit is gained by assessing additional frequencies. By limiting the tested range to 2000 Hz and below, screening for subjects with "normal" hearing in the tested range was less restrictive than if the higher frequencies that could be affected by noise or aging had been assessed. The device identifies hearing thresholds through an automatic Békésy tracking-type procedure. Participants indicate their hearing threshold by pressing a response button whenever a stimulus sound is audible, and releasing it when the sound becomes inaudible. As the subject presses and releases the response button, the FitCheck apparatus cycles back and forth through the audible threshold level several times at each frequency, changing the level by 1.5dB/second, and then calculates an average value based on these measurements. The software in the apparatus then calculates and stores the degree of attenuation provided by the earplug (in decibels) at each frequency. This emulates the REAT procedure in ANSI method S12.6-1997,[6] with the main exceptions that the stimuli are presented via headphones rather than a loudspeaker-generated sound field and the frequency range was limited to 250-2000Hz to evaluate fit rather than the full 250-8000Hz used to evaluate hearing protector performance. The FitCheck software also applies an empirically derived correction factor to compensate for the difference between near-field headphone testing and diffuse field loudspeaker testing.

Each ear was tested separately. Fit-test sessions consisted of "open" tests without earplugs alternated with "occluded" tests in which earplugs, either dry or lubricated, were worn. The type of initial test (open or occluded) was randomized to minimize order effects, and the initial ear tested (right or left) was randomized to minimize handedness and dexterity effects. Participants were given fresh, unused earplugs for each occluded test. For those sessions in which the lubricant was used, participants were provided with fresh lubricant for each test. The same earplug model, the MAX-1 earplug from Howard Leight, which has an advertised overall noise reduction rating (NRR) of 33 dB, was used with all participants.

3. RESULTS

The data were first examined for spurious learning or dexterity (preferred hand) effects. Only small differences (on the order of 1 dB) were found between the mean attenuation for the first versus the second day of testing, indicating that there was not a significant learning or order effect. There was also no significant difference between attenuation for the ear on the same side versus the opposite side from the subject's preferred hand.

We then calculated the average improvement in attenuation for the 20 ears, at each frequency tested. At every frequency, the lubricated earplugs gave 5 to 6 dB better attenuation than the dry earplugs. Based on this result, and findings by others[1] that good attenuation at low frequencies is highly correlated with overall attenuation, we concentrated on a low frequency, 500 Hz, for further examination. Figure 1 shows the improvement in attenuation (lubricated minus dry) versus the dry attenuation value for each of the 20 ears. The group's median dry attenuation value, 23.5 dB, is indicated.

The notable feature of Figure 1 is that points below the median tend to show much higher improvement than those above. When averaged separately, ears with test results less than 23.5 dB dry showed a 13 dB average improvement while those with test results more than 23.5 dB showed a -0.5 dB "improvement." This is a common sense result; given that there is a ceiling on earplug performance, ears that have low "dry" values have more room for improvement.

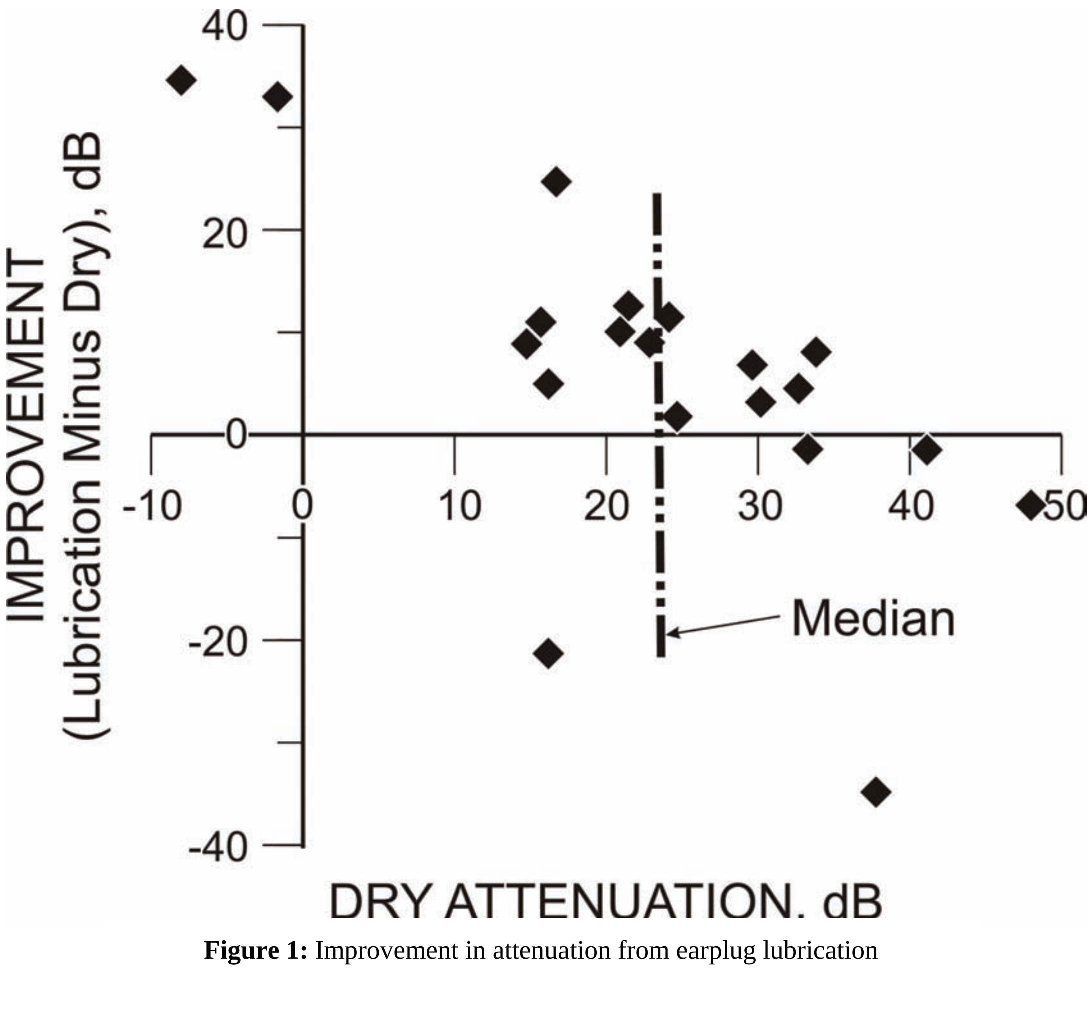

Figure 1: Improvement in attenuation from earplug lubrication

Another way to look at the results is to count the number of ears that achieved a given attenuation level, for convenience termed a "mastery" level. We selected the dry attenuation median of 23.5 dB as the mastery level. From the results, 10 ears achieved the mastery level with dry earplugs and 17 ears achieved the mastery level with lubricated earplugs (Table 1).

Table 1: Number of ears achieving mastery level for dry and lubricated earplugs

	Dry earplugs	Lubricated earplugs
Below mastery	10	3
Above mastery	10	17
Total	20	20

This result was deemed to be statistically significant. Specifically, the null hypothesis of even distribution among the cells could be rejected ($\chi^2 = 5.585$, $p = 0.018$).

4. DISCUSSION AND CONCLUSIONS

The promising results of this initial study lead us to conclude that lubrication of earplugs merits further investigation. In this study, the attenuation level was more likely to exceed the mastery level when the lubricant was used. Also, individuals with the poorest "dry" attenuation appeared to benefit most from using the lubricant.

The NIOSH employees in the study were a relatively skilled population, familiar with earplug use. As a result, the median dry attenuation of 23.47 dB at 500Hz was relatively high. For example, using less skilled subjects,[7] obtained 17 dB using the same model of earplug. Since the benefits of lubrication were greatest for those with low "dry" attenuation values, more improvement might be seen with a less skilled population.

Further study with less experienced earplug users will help to reveal the ultimate benefit of using a lubricant. It would also help identify the extent to which the improved attenuation was due to improved sealing, easier insertion, or a combination of the two.

The long-term performance of the lubricant was not assessed in this study. Since we have shown that the lubricant provides a benefit when the earplugs are initially inserted, future studies should assess whether this benefit persists over time as the lubricant is absorbed and the wearer moves about. We would also like to test the lubricant on a broader range of earplugs to determine the extent to which the results apply to different earplug designs.

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