Clinical Forum

Reference Threshold Levels for an ER-3A Insert Earphone

Tom Frank*
Michael J. Vavrek*

Abstract

The purpose of this study was to obtain normal hearing thresholds for an ER-3A insert earphone as a contribution for future standardization and for comparison with previous studies and interim ANSI and ISO insert earphone reference equivalent threshold sound pressure levels (RETSPLs). Hearing thresholds were obtained on each ear of 48 normal-hearing subjects from 125 to 8000 Hz using ER-3A and TDH-49P earphones referenced to a Bruel and Kjær DB-0138 HA-2 and NBS-9A acoustic coupler, respectively. The mean unadjusted and adjusted ER-3A thresholds were in very good agreement with the mean thresholds averaged over eight other studies. Further, the mean adjusted ER-3A thresholds were in very good agreement with the interim ANSI RETSPLs while the mean unadjusted ER-3A thresholds were slightly higher than the ISO RETSPLs. Also, mean ER-3A thresholds averaged over a nine study data base were in closer agreement with the interim ANSI than the ISO RETSPLs. Overall, the interim ANSI insert earphone RETSPLs were recommended for clinical use.

Key Words: Insert earphone, normal hearing, standards

In 1984, Etymotic Research introduced the ER-3A insert earphone as an alternative to supra-aural earphones for audiometry (Killion, 1984). Since then, E-A-R Division of the Cabot Corporation has also begun to manufacture an insert earphone, known as the EARTONE™ 3A. The ER-3A and EARTONE 3A are functionally equivalent because they are built to identical specifications. The insert earphones consist of a shoulder mounted transducer coupled to the ear canal via a sound tube attached to a connecting nipple and then to an eartip tube which runs through a foam eartip. It has been suggested that the ER-3A or EARTONE 3A earphones offer several advantages compared with traditional earphones mounted in supra-aural cushions. These advantages include: (1) elimination of a headband (Killion, 1984); (2) elimination of electrical artifacts in ABR testing (Killion, 1984; Clemis et al, 1986); (3) prevention of collapsing ear canals (Killion, 1984; Clemis et al, 1986); (4) increased attenuation of ambient noise (Clemis et al, 1986; Berger and Killion, 1989; Frank and Wright, 1990); (5) increased interaural attenuation by air conduction (Killion et al, 1985; Sklare and Denenberg, 1987); and, (6) increased effectiveness in hearing aid prescription and selection (Clemis et al, 1986).

Whenever a new earphone is introduced for audiometry, there is a need and a generally accepted method for establishing reference equivalent threshold sound pressure levels (RETSPLs) for that earphone (ISO 389, 1985; ANSI S3.6-1989, Appendix C). RETSPLs are equal to the sound pressure levels produced by an earphone in a specified coupler at electrical input levels directly corresponding to subjectively measured thresholds of otologically normal listeners. Interim insert earphone RETSPLs have been specified by ANSI (S3.6-1989, Appendix G) referenced to a hearing aid type 1 (HA-1) coupler (ANSI S3.7-1973) and to an occluded ear simulator (ANSI S3.25-1989). Insert earphone RETSPLs have also been specified by

The purpose of the present study was two-fold: (1) to report ER-3A thresholds for normal-hearing listeners as a contribution for future ANSI and ISO standardization efforts, and (2) to compare the normative ER-3A thresholds with thresholds reported in previous studies and with the interim ANSI and ISO insert earphone RETSPLs.

**METHOD**

**Subjects**

Forty-eight subjects (11 male, 37 female) ranging in age from 18 to 27 years of age having a mean age of 21.2 years (SD of 2.4 years) voluntarily participated. Each subject had pure-tone air-conduction thresholds ≤ 15 dB HL (re: ANSI S3.6-1989) from 125 to 8000 Hz, normal tympanograms, and ipsilateral acoustic reflex thresholds in each ear.

**Instrumentation**

Each subject was tested in an audiometric test booth (Suttle, 3-B) having ambient noise levels suitable for ears open testing (ANSI S3.1-1977). Air-conducted pure tones at 125, 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz were generated and gated (25 to 35 msec rise/fall time, 1.5 sec on time) by an audiometer (Madsen, OB-822). The audiometer output was directed to a switching box (custom built) and then to a pair of ER-3A or TDH-49P earphones in supra-aural cushions (Telephonics, 51) located in the test booth. When the ER-3A earphones were used, two 20-dB attenuators (custom built), one for each ER-3A, were placed between the output of the switching box and plug end of each ER-3A. This was necessary to compensate for the higher sound pressure levels normally produced by the ER-3A compared with the TDH-49P in the lower frequencies.

Prior to, two times during, and at the end of data collection, the instrumentation was calibrated for frequency, distortion, linearity, and output using Bruel and Kjaer (B&K) instrumentation including an acoustic coupler (4152), HA-2 coupler with rigid tube attachment (DB-0138), 1-inch microphone (4144), pre-amplifier (2619), measuring amplifier (2113), and a Scientific Atlanta signal analyzer (SD380). The instrumentation remained in calibration (re: ANSI S3.6-1989) throughout data collection including the output (± 1.2 dB) of each earphone.

**Procedure**

Each subject participated in two 1-hour sessions separated by at least 2 but no more than 7 days. The first session was used to obtain test while the second session was used to obtain re-test thresholds. Each subject was tested according to a schedule listing a counterbalanced order for ear, earphone type, and a randomization without replacement for frequency. The right and left ER-3A and TDH-49P earphones were always used to test each subject’s right and left ear.

The transducers were fitted on each subject by one experimenter. For the TDH-49P earphones, the experimenter positioned the diaphragm over the entrance of each subject’s ear canal and then tightened the headband. The subjects were not permitted to move the headband assembly once it was positioned. The static headband force was measured prior to, midway through, and at the end of data collection, using the procedure and instrumentation described by Frank and Wright (1990), and remained stable (± 0.3 N) relative to the initial measurement of 5.0 N. For the ER-3A earphones, an Earlink™ 3A eartip was attached to the connecting nipple, rolled and compressed, and inserted into the subjects’ ear canal by the experimenter so that its outer end was flush or just inside the bowl of the concha (approximating a 0- to 1-mm insertion depth) and held in place for 30 seconds to allow it to expand. Then the position of the eartip was checked for insertion depth and if necessary re-inserted. For eight ears, an Earlink 3A could not be inserted to the desired depth because the ear canals were too small. For these ears, a smaller eartip (Earlink 3B) was employed. The choice of a 0- to 1-mm insertion depth was based on the results of a survey of the insertion depth employed by 20 everyday users of insert earphones and our own clinical experiences.

Instructions for responding at threshold were given to each subject. Threshold determination consisted of initially presenting a pure tone at a level thought to be loud enough for the subject to respond. If the subject did not respond the level was increased in 10 dB steps until a response occurred. Once an initial response occurred, the level was decreased in 10 dB steps until no response occurred and then...
increased in 2-dB steps until the subject responded. This procedure (10 down and 2 up) continued until six ascending thresholds were obtained. Threshold was defined as the mean of the six ascending thresholds.

RESULTS

The subject's thresholds in dB SPL (re: μ20 Pa) referenced to an NBS-9A acoustic coupler (B&K, 4152) for the TDH-49P and to an HA-2 coupler (B&K, DB-0138) for the ER-3A earphones were analyzed using a three-factor analysis of variance with repeated measures (ANOVA-R) at each frequency (N = 9). The factors were earphone type, ear, and test versus re-test. Not surprisingly, a significant (p < .05) main effect was found for earphone type while nonsignificant (p > .05) main effects were found for ear and test versus re-test and all interactions. Table 1 shows the mean and median ER-3A and TDH-49P thresholds and standard deviations (SD) collapsed across ear at each frequency. For each earphone type, the mean and median thresholds were in good agreement at each frequency. The mean and median thresholds were higher for the TDH-49P than for the ER-3A at each frequency. The standard deviations shown in Table 1 were generally similar across frequency for each earphone type. However, the standard deviations were lower for the ER-3A than for TDH type earphones except at 1000 Hz. The standard deviations obtained in the present study for the ER-3A were in general agreement and for the TDH-49P were generally slightly higher compared with the average standard deviations reported by Wilber et al (1988).

Table 1 also shows TDH-49P RETSPLs (ANSI S3.6-1989) and the TDH-49P RETSPL differences. The mean TDH-49P thresholds were in good agreement with the TDH-49P RETSPLs causing the differences to be very small. Finally, Table 1 shows the mean ER-3A thresholds corrected or adjusted by the difference between the mean TDH-49P minus the TDH-49P RETSPLs at each frequency.

DISCUSSION

Comparison with Other Studies

Table 2 shows the mean unadjusted and adjusted ER-3A thresholds obtained in the present study and in eight other studies referenced to a B&K DB-0138 HA-2 coupler. For comparison purposes, the ER-3A thresholds shown in Table 2 reported by O'Connor and Wilber (1985), Wilber (1986), Clark and Roesser (1988), and Larson et al (1988), which referenced ER-3A thresholds to an HA-1 coupler, were corrected using coupler correction levels reported by the manufacturer (Table II in Wilber et al, 1988), which have been verified by Frank and Richards (in press). Further, the thresholds shown in Table 2 reported by Clark

<table>
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<tr>
<th>Earphone Measure</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
<th>8000</th>
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<tr>
<td>ER-3A Mean</td>
<td>28.4</td>
<td>16.0</td>
<td>8.1</td>
<td>3.3</td>
<td>5.5</td>
<td>3.6</td>
<td>7.4</td>
<td>5.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Median</td>
<td>27.8</td>
<td>15.9</td>
<td>7.8</td>
<td>3.2</td>
<td>5.1</td>
<td>2.9</td>
<td>7.2</td>
<td>6.2</td>
<td>1.7</td>
</tr>
<tr>
<td>SD</td>
<td>5.1</td>
<td>5.6</td>
<td>5.8</td>
<td>5.6</td>
<td>5.4</td>
<td>6.2</td>
<td>6.0</td>
<td>5.6</td>
<td>5.8</td>
</tr>
<tr>
<td>TDH-49P Mean</td>
<td>48.9</td>
<td>27.6</td>
<td>14.0</td>
<td>7.3</td>
<td>12.1</td>
<td>8.7</td>
<td>11.5</td>
<td>14.7</td>
<td>14.5</td>
</tr>
<tr>
<td>Median</td>
<td>49.2</td>
<td>27.0</td>
<td>13.7</td>
<td>7.0</td>
<td>11.7</td>
<td>7.9</td>
<td>11.1</td>
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<tr>
<td>SD</td>
<td>8.1</td>
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<td>6.8</td>
<td>7.0</td>
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<td>7.2</td>
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<td>TDH-49P RETSPL</td>
<td>47.5</td>
<td>26.5</td>
<td>13.5</td>
<td>7.5</td>
<td>11.0</td>
<td>9.5</td>
<td>10.5</td>
<td>13.5</td>
<td>13.0</td>
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<td>TDH-49P minus RETSPL</td>
<td>1.4</td>
<td>1.1</td>
<td>0.5</td>
<td>-0.2</td>
<td>1.1</td>
<td>-0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>1.5</td>
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<tr>
<td>Adjusted ER-3A Mean</td>
<td>27.0</td>
<td>14.9</td>
<td>7.6</td>
<td>3.5</td>
<td>4.4</td>
<td>4.4</td>
<td>6.4</td>
<td>4.6</td>
<td>0.0</td>
</tr>
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</table>

Tabled values are in dB SPL (re: 20 mPa).
Table 2  Mean Unadjusted and Adjusted ER-3A Thresholds Obtained in the Present Study and in Eight Other Studies and the Mean, Median, Standard Deviations, and Range Scores across the Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size</th>
<th>Frequency in Hertz</th>
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<td></td>
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<td>125</td>
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<tr>
<td><strong>Unadjusted Thresholds</strong></td>
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<td>Present Study</td>
<td>48</td>
<td>28.4</td>
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<td>O'Connor &amp; Wilber (1985)</td>
<td>17</td>
<td>30.6</td>
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<tr>
<td>Wilber (1986)</td>
<td>28</td>
<td>16.5</td>
</tr>
<tr>
<td>Clemis et al (1986)</td>
<td>8</td>
<td>25.0</td>
</tr>
<tr>
<td>Clark &amp; Roesser (1986)</td>
<td>12</td>
<td>17.8</td>
</tr>
<tr>
<td>Larson et al (1988)</td>
<td>90</td>
<td>41.7</td>
</tr>
<tr>
<td>Arlinger &amp; Kinnelors (1989)</td>
<td>18</td>
<td>26.0</td>
</tr>
<tr>
<td>Goran &amp; Frank (1990)</td>
<td>24</td>
<td>29.5</td>
</tr>
<tr>
<td>Brinkman &amp; Richter (1990)</td>
<td>23</td>
<td>26.4</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td>29.7</td>
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<tr>
<td><strong>Median</strong></td>
<td></td>
<td>28.4</td>
</tr>
<tr>
<td><strong>SD</strong></td>
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<td>5.7</td>
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<tr>
<td><strong>Adjusted Thresholds</strong></td>
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<td>Present Study</td>
<td>48</td>
<td>27.0</td>
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<td>Clemis et al (1986)</td>
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<td>12</td>
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<td>Arlinger &amp; Kinnelors (1989)</td>
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<td>21.7</td>
</tr>
<tr>
<td>Goran &amp; Frank (1990)</td>
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<tr>
<td>Brinkman &amp; Richter (1990)</td>
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<td>6.1</td>
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<td><strong>Range</strong></td>
<td></td>
<td>18.7</td>
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</tbody>
</table>

Tabled values are in dB SPL (re: 20 mPa) referenced to a B&K DB-0138 HA-2 coupler.

and Roesser (1986) and Larson et al (1988) were also corrected for an eartip insertion depth of 2 to 3 mm beyond the floor of the concha using the corrections reported by Wilber et al (1988, Table II). In the present study and in the study by Goran and Frank (1990), the outer edge of the eartip was inserted to approximate a 0- to 1-mm insertion depth relative to the floor of the concha and were not corrected for a 2- to 3-mm insertion depth. This occurred because the corrections for a 0- to 1-mm to a 2- to 3-mm insertion depth would have produced no more than a 0.5 dB threshold increase.

Table 2 also shows the unadjusted and adjusted mean and median ER-3A thresholds, standard deviations, and range scores across all of the studies. These values were determined with equal weight given to each study (which is the current practice used by ANSI and ISO). Further, Wilber et al (1988) pointed out that “in the face of unknown experimental bias across laboratories, treating each laboratory as an equally probable and independent estimator of the true average is obtained by using groups of data (unweighted for sample size) rather than grouped data (weighted for sample size)” (p. 670).

Inspection of Table 2 reveals that the unadjusted and adjusted ER-3A thresholds obtained in the present study were in good agreement (about ± 3 dB) with the unadjusted and adjusted mean and median thresholds across all of the studies, especially from 250 to 4000 Hz and at 8000 Hz where the agreement was less than ± 2 dB. As such, the unadjusted and adjusted thresholds obtained in the present study were judged to be a valid representation of normative ER-3A thresholds.

Unfortunately, the number of published studies specifying ER-3A thresholds is minimal and not all of the studies used the same methodology, which created variables such as...
the method of coupling the ER-3A to the ear canal (impedance tip or foam eartip) and insertion depth. Also, inspection of Table 2 reveals that not all of the studies obtained thresholds at 125, 2500, and 6000 Hz and some studies used a much smaller sample size than others. Finally, there are some very significant ER-3A threshold discrepancies between studies causing large standard deviations and range scores especially for the lower and higher frequencies. For example, inspection of Table 2 reveals that at 125 Hz the unadjusted and adjusted thresholds had standard deviations of 5.7 and 6.1 dB and range scores of 16.7 and 18.7 dB, respectively, and the adjusted thresholds at 6000 and 8000 Hz had standard deviations of 6.8 and 5.0 dB and range scores of 18.8 and 17.5 dB, respectively.

The exact reason for these threshold discrepancies across studies is not known. However, closer inspection of Table 2 reveals that at 125 Hz the unadjusted and adjusted thresholds reported by Larson et al. (1988) were higher than the thresholds reported in other studies. Larson et al. (1988) speculated that, in part, their use of impedance tips resulted in a shallow insertion depth and large residual ear canal volume, which created higher levels of low-frequency physiologic noise than using foam eartips having a 2- to 3-mm insertion depth. As a result, physiologic masking may have elevated their ER-3A thresholds at 125 Hz. The adjusted ER-3A thresholds shown in Table 2 reported by Clark and Roeser (1986) at 6000 and 8000 Hz were higher and the adjusted ER-3A threshold reported by Arlinger and Kinnefors (1989) at 6000 Hz was lower than the thresholds reported in the other studies. These threshold discrepancies were probably the result of adjusting ER-3A thresholds by the amount that their TDH earphone thresholds differed from RETSPLs. The Clark and Roeser (1986) TDH-50 thresholds were −4.7 and −2.4 dB HL at 6000 and 8000 Hz (Table III in Wilber et al., 1988) and their unadjusted ER-3A thresholds were 6.2 and 8.4 dB SPL at 6000 and 8000 Hz (Table 2). As a result of adjustment, the adjusted ER-3A thresholds were 10.9 and 10.8 dB SPL at 6000 and 8000 Hz. The Arlinger and Kinnefors (1989) TDH-39 threshold was 5.7 dB SPL at 6000 Hz and their unadjusted ER-3A threshold was −2.2 dB SPL at 6000 Hz (Table 2). Consequently, their adjusted ER-3A threshold was −7.9 dB SPL at 6000 Hz. Brinkman and Richter (1990) have also reported ER-3A threshold discrepancies at 3000 and 6000 Hz across three studies used for developing the ISO RETSPLs. They were uncertain as to the cause but reported that threshold discrepancies have occurred in other databases used for standardization and that relatively same sample sizes may also be a factor. Hopefully, with the addition of more studies to the ER-3A threshold database, threshold discrepancies across studies will become smaller so that a truer estimate of ER-3A RETSPLs will be available for future standardization efforts.

Comparison with Interim ANSI and ISO RETSPLs

The interim ANSI and ISO RETSPLs and the ANSI minus ISO RETSPL differences are shown in Table 3. For comparison purposes, the interim ANSI RETSPLs were referenced to a B&K DB-0138 HA-2 coupler. If the interim ANSI and ISO RETSPLs would be in perfect agreement, the ANSI minus ISO RETSPL differences would be equal to 0 dB at each frequency; however, inspection of Table 3 reveals that the interim ANSI RETSPLs were higher than the

<table>
<thead>
<tr>
<th>Source</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
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<th>4000</th>
<th>6000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interim ANSI RETSPLs</td>
<td>27.0</td>
<td>15.0</td>
<td>8.0</td>
<td>3.5</td>
<td>6.5</td>
<td>6.0</td>
<td>7.0</td>
<td>3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>ISO RETSPLs</td>
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<td>14.0</td>
<td>5.5</td>
<td>0.0</td>
<td>3.0</td>
<td>3.5</td>
<td>5.5</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>ANSI minus ISO RETSPLs</td>
<td>1.0</td>
<td>1.0</td>
<td>2.5</td>
<td>3.5</td>
<td>3.5</td>
<td>2.5</td>
<td>1.5</td>
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<td>0.0</td>
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<tr>
<td>Mean, adjusted ER-3A</td>
<td>27.0</td>
<td>14.9</td>
<td>7.6</td>
<td>3.5</td>
<td>4.4</td>
<td>4.4</td>
<td>6.4</td>
<td>4.6</td>
<td>0.0</td>
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<tr>
<td>Mean, unadjusted ER-3A minus ANSI</td>
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<td>0.4</td>
<td>0.4</td>
<td>0.0</td>
<td>-2.1</td>
<td>-1.6</td>
<td>0.6</td>
<td>1.6</td>
<td>0.0</td>
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<tr>
<td>Mean, unadjusted ER-3A</td>
<td>28.4</td>
<td>16.0</td>
<td>8.1</td>
<td>3.3</td>
<td>5.5</td>
<td>3.6</td>
<td>7.4</td>
<td>5.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Tabled values are in dB SPL (re: 20 mPa) referenced to a B&K DB-0138 H-2 coupler.
ISO RETSPLs from 125 to 6000 Hz causing the
differences to range from 1.0 dB at 125, 250, and
6000 Hz to 3.5 dB at 1000 and 2000 Hz. The
interim ANSI minus the ISO RETSPL differ-
ences can be related to the data base from which
they were developed and whether or not the ER-
3A thresholds were adjusted.

The interim ANSI RETSPLs were based on
indirect threshold measurements supplied by
the manufacturer using estimates of eardrum
SPLs for supra-aural earphones and free-field
threshold data (Killion, 1978, 1984). The manu-
facturer's indirect threshold measurements
were later verified by Wilber et al (1988), who
reported direct ER-3A threshold measurements
for five independent studies. For comparison
purposes, the ER-3A thresholds in each study
were referenced to the same coupler (HA-1),
insertion depth (2 to 3 mm), and adjusted by the
subject's mean supra-aural earphone hearing
level (re: ANSI S3.6-1969). They found that the
mean adjusted ER-3A thresholds averaged
across the five studies did not exceed the manu-
facturer's indirect threshold measurements
by more than 1.5 dB at any frequency. As such,
Wilber et al (1988) recommended using the
manufacturer's indirect or provisional thresh-
olds. The ISO RETSPLs were based on direct
ER-3A threshold measurements using the
thresholds reported by Wilber (1986), Arlinger
and Kinnefors (1989), and Brinkman and Richt-
er (1990) referenced to an HA-2 coupler, 2-to-3-
mm insertion depth, and were not adjusted by
the subject's supra-aural earphone hearing lev-
els.

Even though the interim ANSI RETSPLs
were not derived using a direct measurement
threshold data base, the five study data base
reported by Wilber et al (1988) verified the
manufacturer's indirect threshold measure-
ments (i.e., interim ANSI RETSPLs). However,
the data base used by Wilber et al (1988) did not
contain the ER-3A thresholds reported by
Arlinger and Kinnefors (1989) and Brinkman
and Richter (1990) because they were not avail-
able. The three study data base used to develop
the ISO RETSPLs employed only one of the five
studies contained in the Wilber et al (1988) data
base. This occurred because only the Wilber
(1986) study had similar subject selection crite-
ria and experimental conditions compared with
the studies by Arlinger and Kinnefors (1989)
and Brinkman and Richter (1990). Thus, an
almost entirely different data base was used to
verify the interim ANSI RETSPLs and develop
the ISO RETSPLs.

Since Wilber et al (1988) did not have con-
trol of the subject selection in each of the five
studies, the ER-3A thresholds in each study
were adjusted as a means to equate and com-
pare the ER-3A thresholds across the five stud-
ies. In theory, adjusting ER-3A thresholds by an
amount equal to a subject group's mean supra-
aural earphone threshold deviations from nor-
mal (i.e., RETSPL for a supra-aural earphone)
should have the effect of eliminating any bias in
ER-3A threshold levels due to supra-aural ear-
phone threshold differences between subject
groups. If this is true, then the adjusted should
be more consistent than the unadjusted ER-3A
thresholds across subject groups. Inspection of
Table 2 reveals that the standard deviations
and range scores were smaller for the adjusted
than for the unadjusted ER-3A thresholds from
250 to 4000 Hz. However, at 125, 6000, and 8000
Hz the adjusted were larger than the unadjusted
ER-3A standard deviations and range scores,
especially at 6000 and 8000 Hz.

Alternatively, one could argue that for stand-
ardization purposes there is no a priori reason
for adjusting ER-3A thresholds if experimental
subject groups truly had normal hearing as
recommended by ANSI (ANSI S3.6-1989, Ap-
pendix C) and ISO (ISO 389, 1985). Further,
there is no a priori reason to believe that ER-3A
and supra-aural earphone thresholds should be
the same. This occurs because different ear-
phone to outer ear pathways and coupling and
different reference couplers are involved for
ER-3A compared with supra-aural earphones.

Table 3 also shows the mean unadjusted
and adjusted ER-3A thresholds obtained in the
present study and threshold level differences.
Inspection of Table 3 reveals that the mean
adjusted ER-3A thresholds were in very good
agreement with the interim ANSI RETSPLs.
The mean adjusted ER-3A thresholds minus
the interim ANSI RETSPLs ranged from −2.1
dB at 2000 Hz to 1.6 dB at 6000 Hz and were
within ±0.6 dB at 125, 250, 500, 1000, 4000, and
8000 Hz. This finding would support the results
reported by Wilber et al (1988) confirming that
subjectively measured adjusted ER-3A thresh-
olds are equivalent to the manufacturer's provi-
sional ER-3A thresholds (i.e., interim ANSI
RETSPLs). Further inspection of Table 3 re-
vals that the mean unadjusted ER-3A thresh-
olds obtained in the present study were higher
than the ISO RETSPLs at each frequency. That
is, the mean unadjusted ER-3A thresholds mi-
us the ISO RETSPLs ranged from 0.1 dB at
3000 Hz to 3.8 dB at 6000 Hz. The reasons for
these differences, especially the differences $\geq 2.5$ dB, are unknown.

**Comparison of Data Base with Interim ANSI and ISO RETSPLs**

Table 4 shows the interim ANSI and ISO RETSPLs referenced to a B&K DB-0138 HA-2 coupler (previously shown in Table 3), the mean adjusted and unadjusted ER-3A thresholds averaged over the nine-study data base (previously shown in Table 2), and threshold level differences. The threshold level differences between the interim ANSI RETSPLs minus the mean nine-study data base adjusted thresholds ranged from $-0.6$ dB at 8000 Hz to $1.7$ dB at 4000 Hz and the average difference across frequency was $0.8$ dB. The threshold level differences between the ISO RETSPLs minus the mean nine-study data base unadjusted thresholds ranged from $-4.1$ dB at 1000 Hz to $-0.5$ dB at 3000 Hz and the average difference across frequency was $-2.6$ dB. Thus, strictly on the basis of a standard to data base comparison, the interim ANSI RETSPLs are in closer agreement than the ISO RETSPLs with the existing ER-3A threshold data base. However, it should be noted that the interim ANSI RETSPLs were derived using a larger number of the data base studies compared with the ISO RETSPLs, which would bias this type of comparison.

Working groups charged with developing and revising insert earphone RETSPLs must keep in mind that standard thresholds lend stability and reliability to clinical measurements. They should be practical and useful and be based on the best available research. It could be that the differences between the interim ANSI minus the ISO RETSPLs (Table 3) and the differences between the interim ANSI and ISO RETSPLs minus the mean data base thresholds (Table 4) may not be clinically significant. Nevertheless, there is a definite need for further research to increase the ER-3A data base and for providing additional information for specifying ER-3A RETSPLs. It would be highly desirable for both ANSI and ISO to specify the same insert earphone RETSPLs. However, this will require that national and international working groups resolve issues dealing with experimental differences between studies and the theory of adjusting ER-3A thresholds.

**Clinical Implications**

We have been using ER-3A earphones calibrated to the interim ANSI RETSPLs corrected for a B&K DB-0138 HA-2 coupler in conjunction with TDH type earphones for about 1 year. Since we do our own calibration and like to be as precise as possible, we do not use the manufacturer’s suggested ER-3A “plug-in” correction values. During this time we have not observed clinically significant threshold differences for adults between ER-3A and TDH type earphones, except for three ears having a conductive loss caused by a collapsing ear canal. This clinical finding has also been reported by Clemis et al (1986) and Borton et al (1989). Perhaps more importantly, the use of ER-3A earphones has eliminated almost all of our overmasking dilemmas. Also, we have not observed that repeated placement of an ER-3A in an adult patient’s ear canal produces higher or lower threshold repeatability than repeated placement of a TDH earphone. This clinical finding confirms the experimental results reported by Lindgren (1990) that intrasubject threshold

<table>
<thead>
<tr>
<th>Frequency in Hertz</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>6000</th>
<th>8000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interim ANSI RETSPLs</td>
<td>27.0</td>
<td>15.0</td>
<td>8.0</td>
<td>3.5</td>
<td>6.5</td>
<td>6.0</td>
<td>7.0</td>
<td>3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Mean Adjusted Nine Study Data Base</td>
<td>25.9</td>
<td>14.9</td>
<td>7.2</td>
<td>3.1</td>
<td>5.2</td>
<td>4.5</td>
<td>5.3</td>
<td>2.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Interim ANSI minus Data Base</td>
<td>1.1</td>
<td>0.1</td>
<td>0.8</td>
<td>0.4</td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
<td>0.9</td>
<td>-0.6</td>
</tr>
<tr>
<td>ISO RETSPLs</td>
<td>26.0</td>
<td>14.0</td>
<td>5.5</td>
<td>0.0</td>
<td>3.0</td>
<td>3.5</td>
<td>5.5</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Mean Unadjusted Nine Study Data Base</td>
<td>29.7</td>
<td>17.8</td>
<td>9.3</td>
<td>4.1</td>
<td>6.5</td>
<td>4.0</td>
<td>7.2</td>
<td>3.7</td>
<td>1.2</td>
</tr>
<tr>
<td>ISO minus Data Base</td>
<td>-3.7</td>
<td>-3.8</td>
<td>-3.8</td>
<td>-4.1</td>
<td>-3.5</td>
<td>-0.5</td>
<td>-1.7</td>
<td>-1.3</td>
<td>-1.2</td>
</tr>
</tbody>
</table>

Tabled values are in dB SPL (re: 20 mPa).
reliability for an ER-3A was equivalent to a TDH type earphone.

It should be noted that our clinical experiences have been primarily with adults having sensorineural hearing loss. Research concerning ER-3A versus TDH type earphone thresholds on normal-hearing children, children with conductive loss, and adults with conductive loss is very limited. Baranak, Konkle, and Knightly (1985) reported that mean ER-3A thresholds on children occur at slightly lower hearing levels than for adults and suggested that each clinic testing children establish its own ER-3A to TDH type earphone correction factors. In a follow-up study, Knightly, Konkle, and Baranak (1986) found very good agreement between mean TDH-39 and ER-3A thresholds when the ER-3A thresholds were corrected to their child norms. However, they also reported excessive variability between TDH-39 and ER-3A thresholds for some children having middle ear fluid. This finding was also reported by Larson et al (1986) for some adult ears with middle ear pathology. The reason for these findings is unknown but is probably related to an impedance mismatch between the source and load impedance of individual ears having middle ear pathology. In any event, it would appear that more research is needed to determine the influence of middle ear pathology on ER-3A compared with TDH type earphones in children and adults.

CONCLUSIONS

The mean unadjusted and adjusted ER-3A thresholds obtained in the present study were in good agreement with the mean ER-3A thresholds reported in eight other studies and with the interim ANSI RETSPLs. Even though there are some very significant ER-3A threshold discrepancies between studies comprising the current database at 125, 6000, and 8000 Hz, we would recommend that the interim ANSI RETSPLs be used. Averaged over the existing data base, the mean ER-3A thresholds were in closer agreement with the interim ANSI compared with the ISO RETSPLs. More research is needed for specifying normative ER-3A thresholds in adults and children and to compare ER-3A with TDH type earphone thresholds for children and adults having different types of middle ear pathology.

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