Effects of Pre-existing Hearing Loss on Proposed ANSI S12.13 Outcomes for Characterizing Hearing Conservation Program Effectiveness: Follow-up Investigation

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Abstract

Draft ANSI S12.13 1991 Standard Evaluating the Effectiveness of Hearing Conservation Programs presents statistical protocols purportedly sensitive to temporary threshold shift (TTS) in occupational hearing conservation program (HCP) audiometric databases. Because it is well established that less TTS is found in humans with hearing loss than in those with essentially normal hearing, one might predict baseline hearing level to be a confounding variable in interpreting ANSI S12.13 outcomes, with better-hearing industrial populations tending to demonstrate greater year-to-year audiometric variability than poorer-hearing groups. However, in a large industrial sample from the public domain audiometric database, poorer-hearing groups systematically demonstrated greater audiometric threshold variability than better-hearing groups, and ANSI S12.13 outcome magnitudes were highly positively correlated to baseline hearing levels. These findings generally do not support notions that ANSI S12.13 outcomes clearly provide indirect measures of TTS. HCP managers should exercise extreme caution in interpreting ANSI S12.13 outcomes to rate overall program performance. In particular, HCP managers should not rely upon these outcomes for decisions regarding hearing protection policies without careful consideration of pre-existing hearing loss in the populations involved.

Key Words: Audiometric threshold variability, hearing conservation program, percent better or worse sequential, percent worse sequential, pre-existing hearing loss, temporary threshold shift

Abbreviations: ANSI = American National Standards Institute, HCP = hearing conservation program, HPD = hearing protective device, NTIS = National Technical Information Service, OSHA = Occupational Safety and Health Administration, TTS = temporary threshold shift, TWA = time-weighted average, %BWs = percent better or worse sequential, %Ws = percent worse sequential

Pre-existing hearing status is an important factor in predicting noise-induced temporary threshold shift (TTS) in human subjects. Both laboratory and field studies of TTS indicate inverse relationships between hearing level and TTS: as hearing levels increase, TTS decreases (Nixon and Glorig, 1962; Satloff et al, 1962; Hetu and Parrot 1978; Melnick, 1978).

Draft American National Standard Evaluating the Effectiveness of Hearing Conservation Programs proposes year-to-year measures of audiometric threshold variability as indirect measures of TTS. If poor audiometric testing practices can be ruled out as contributing to unacceptable variability in annual audiograms, the audiometric database is thought to be...
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contaminated with TTS. Furthermore, acceptable levels of audiometric variability presumably indicate both reliable testing practices and adequately protected employees (ANSI, 1991).

Amos and Simpson (1995) reported direct relationships between baseline hearing levels and ANSI S12.13 variability outcomes, findings generally not supporting the notion that ANSI S12.13 outcomes are indirect reflections of TTS. In a sample from the public domain audiometric database upon which the draft ANSI standard is based, they found increasing levels of audiometric variability with increases in baseline hearing threshold level. Characterizing their results as “preliminary,” they pointed out major limitations in their study as being (1) a small sample size, (2) limited in scope to only baselines and first subsequent annual audiograms, and (3) retrospectivity (Amos and Simpson, 1995).

The primary purpose of the present investigation was to examine the entire ANSI S12.13 audiometric database for possible relationships between baseline hearing level and ANSI S12.13 outcomes. If ANSI S12.13 outcomes are sensitive to TTS, one would expect them to decrease with increases in baseline hearing levels. That is, better-hearing populations should be expected to yield greater audiometric variability than poorer-hearing populations. The study was undertaken with the informal assumption that, if sensitive to TTS, ANSI S12.13 outcomes would be greater in magnitude for subject groups with less pre-existing hearing loss.

Specifically, this study was undertaken to:

1. Examine the public-domain audiometric data set directly underpinning Draft ANSI S12.13–1991 Standard Evaluating the Effectiveness of Hearing Conservation Programs for potential relationships between pre-existing hearing loss and audiometric variability outcomes, concentrating on the subset of data for employees exhibiting eight serial audiograms from which the ANSI Working Group based their criteria for “acceptable,” “marginal,” and “unacceptable” hearing conservation program (HCP) performance.

2. Restrict the available data set by occupational noise exposure and use of hearing protective devices (HPDs) in an attempt to determine if pre-existing hearing loss is potentially a confounding variable in the use of ANSI S12.13 outcomes in formulating hearing protection policies.

MATERIALS AND METHOD

Audiometric data were selected from the public domain database underpinning the ANSI S12.13 draft standard. The entire database includes over 140,000 audiometric records from 22 HCPs and is available in magnetic format from the National Technical Information Service (NTIS).* Of the 22 HCPs, 4 were characterized by ANSI investigators as “controls” due to known excellence in all phases of their programs. The remaining 18 HCPs were simply classified as “noncontrols” because less was known about these programs (ANSI, 1991). Whereas Amos and Simpson (1995) sampled only from control HCPs, the present investigation sampled both control and noncontrol HCPs.

Original ANSI S12.13 classification groups (i.e., control and noncontrol) were maintained in this investigation to characterize overall group performance.

Data Selection and Preparation

Data were selected and prepared for this investigation by the following five-step process:

1. A subset of data consisting of employees demonstrating eight serial audiograms was extracted from the NTIS database. The extracted data set contained audiometric records for 3958 employees representing 19 HCPs.

2. Individual HCP data sets were eliminated if year-to-year shifts in mean audiometric thresholds exceeded calibration tolerance limits of accepted audiometer standards (ANSI, 1989). This step eliminated HCPs with wildly fluctuant threshold shifts that were likely contaminated by audiometer calibration artifacts. The remaining data set represented 3337 employees from three control and seven noncontrol HCPs (ANSI, 1991).

3. Raw audiometric thresholds resulting from self-recording (i.e., Bekesy) audiometers were rounded to the nearest 5-dB step. This “normalization” of thresholds from 1-dB to 5-dB increments allowed greater generalization of outcomes to occupational HCPs collecting audiometric data in 5-dB steps (Simpson et al, 1993).

*National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. NTIS catalog no. PB88-117916/KHX (Industrial Audiometric Data).
4. Test 1 was designated as baseline. A 12-frequency average of binaural baseline hearing thresholds (0.5–6 kHz) was computed for the entire data set. Individual employees whose mean binaural baseline hearing levels were less than or equal to 14.25 dB (median) fell into “better”-hearing groups, while employees demonstrating binaural baseline hearing levels greater than 14.25 dB were placed in “poorer”-hearing groups. No consideration was given to noise exposure, hearing protector type, or hearing protector usage patterns for this data set.

5. An additional subset of audiometric data was extracted from this restricted database to assess ability of ANSI S12.13 outcomes to distinguish between protected and unprotected employee populations. Extracted records demonstrated (1) reported use of hearing protectors either greater than or less than 50 percent of the workday and (2) time-weighted-average (TWA) noise exposure potentials greater than or equal to 85 dB (A).

ANSI S12.13 Analysis

Percent worse sequential (%Ws) outcomes were calculated for sequential test comparisons 1–2, 2–3, 3–4, 4–5, 5–6, 6–7, and 7–8 for better- and poorer-hearing control and noncontrol groups. As prescribed in the draft standard, percent better or worse sequential (%BWs) outcomes were calculated only for sequential test comparisons 5–6 and greater (ANSI, 1991). Standard deviation of difference outcomes were not calculated as these protocols are in the process of being deleted from the draft ANSI S12.13 standard (LH Royster, personal communication). ANSI S12.13 outcomes were determined as follows, unless otherwise indicated:

**Percent Worse Sequential (%Ws):** The population percentage demonstrating a 15-dB or greater change toward worse hearing at any test frequency (0.5–6 kHz) in either ear between two sequential audiograms.

**Percent Better or Worse Sequential (%BWs):** The population percentage demonstrating a 15-dB or greater change toward either better or worse hearing at any test frequency (0.5–6 kHz) in either ear between two sequential audiograms.

Raw ANSI outcomes were compared for systematic changes in magnitude as a function of hearing level groups. Also, raw outcome values were compared to published criterion ranges of “acceptable,” “marginal,” and “unacceptable” HCP performance to assess potential impact of baseline hearing level on ANSI S12.13 interpretations. Because ANSI S12.13 provides no criterion performance ratings for sequential test comparison 4–5, criterion ranges for earlier sequential comparisons (i.e., tests 1–2, 2–3, and 3–4) were used to characterize test 4–5 performance outcomes for better- and poorer-hearing control and noncontrol subjects.

Because of small sample sizes in the data set selected for hearing protector use and occupational noise exposure, ANSI S12.13 outcomes were calculated for employee groupings collapsed across sequential test comparisons. Thus, a single subject may have yielded more than one outcome (e.g., tests 1–2 and 7–8), and ANSI S12.13 outcomes for %Ws and %BWs were calculated for percent of audiograms, not percent of employees.

Mean elapsed time (in years) between serial audiograms was calculated for control and noncontrol groups, and correlation coefficients were calculated to determine the nature and strength of relationships between ANSI S12.13 outcomes and mean binaural baseline hearing levels for the 10 HCPs making up the restricted data set. Significance testing, where appropriate, was performed at p < .05 unless otherwise indicated.

RESULTS

Table 1 summarizes mean age and hearing levels at baseline for HCP performance and hearing level groups. The majority of control group records (60%) fell into the better-hearing category, while 70 percent of noncontrol records fell into the poorer-hearing group. No significant difference in age was found between better-hearing controls and noncontrols; however, poorer-hearing controls were found to be significantly younger (mean age of 34.6 years) at baseline than noncontrols (mean age of 36.1). Also, better- and poorer-hearing controls demonstrated significantly less pre-existing hearing loss at baseline than their noncontrol counterparts. Finally, controls demonstrated significantly less elapsed time between consecutive audiograms than noncontrols. Table 2 is included for informational purposes only and breaks down data from Table 1 by individual HCP. The ANSI HCP number in Table 2 corresponds to HCP identification numbers from the original NTIS data.
Table 1  Mean and Standard Deviation Age and Binaural Bearing Levels (0.5–6.0 kHz) at Baseline and Elapsed Time between Consecutive Audiograms for HCP Performance and Hearing Level Groups

<table>
<thead>
<tr>
<th>HCP Performance Group</th>
<th>Hearing Level Group</th>
<th>n</th>
<th>Baseline Age (Yr) Mean (SD)</th>
<th>Basinal Baseline Hearing Levels Mean (SD)</th>
<th>Elapsed Time (Yr) Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Better</td>
<td>1323</td>
<td>28.9 (8.3)</td>
<td>8.2* (3.4)</td>
<td>1.1* (0.7)</td>
</tr>
<tr>
<td></td>
<td>Poorer</td>
<td>885</td>
<td>34.6* (9.3)</td>
<td>23.6* (8.1)</td>
<td></td>
</tr>
<tr>
<td>Noncontrol</td>
<td>Better</td>
<td>342</td>
<td>28.7 (9.0)</td>
<td>9.7 (3.1)</td>
<td>1.3 (0.9)</td>
</tr>
<tr>
<td></td>
<td>Poorer</td>
<td>787</td>
<td>36.1 (9.5)</td>
<td>28.7 (11.9)</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at p < .05.

tape. Inferential analyses were performed only for pooled data from Table 1; no inferential analyses were performed for individual HCPs in Table 2.

Figure 1 summarizes %Ws (top) and %BWs (bottom) outcomes as a function of sequential test comparisons for HCP performance (CONtrol and NONcontrol) and hearing level (Better and Poorer) groups. Horizontal axes in Figure 1 denote sequential test comparisons. Cross-hatched and black bars depict better- and poorer-hearing control outcomes, respectively; white and gray bars depict better- and poorer-hearing noncontrol outcomes, respectively. ANSI S12.13 ratings for “A”cceptable, “M”arginal, and “U”nacceptable HCP performance appear next to each bar.

Poorer-hearing groups generally demonstrated greater ANSI S12.13 outcome magnitudes for both control and noncontrol HCP performance categories. This hearing level effect upon ANSI S12.13 outcome magnitudes was quite systematic, with 90 percent of Figure 1 outcomes demonstrating increased audiometric variability with increased baseline hearing level. Only %Ws outcomes for sequential test, T₁₂ comparisons (T₁₂) did not demonstrate a hearing level effect.

Systematic hearing level effects resulted in a number of ANSI S12.13 performance rating changes for control and noncontrol groups. For example, changes in %BWs outcomes for control subjects at T₆₋₇ (circled in Fig. 1, bottom) resulted in better-hearing controls to be rated “acceptable” and poorer-hearing controls to be rated “marginal” in HCP performance. This pattern of change in performance ratings occurred six times for control outcomes and four times for noncontrol outcomes in Figure 1, representing 50 percent of total comparisons.

Changes in performance ratings resulted in a number of performance rating ambiguities between poorer-hearing control and better-hearing noncontrol HCP groups. For example, poorer-hearing controls and better-hearing noncontrols were both rated as “marginal” by %Ws outcomes.

Table 2  Mean and Standard Deviation Age and Binaural Hearing Levels (0.5–6.0 kHz) at Baseline and Elapsed Time between Consecutive Audiograms for the 10 HCPs

<table>
<thead>
<tr>
<th>HCP Performance Group</th>
<th>ANSI HCP #</th>
<th>n</th>
<th>Baseline Age (Yr) Mean (SD)</th>
<th>Binaural Baseline Hearing Levels Mean (SD)</th>
<th>Elapsed Time (Yr) Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>001</td>
<td>103</td>
<td>34.1 (8.5)</td>
<td>15.2 (9.5)</td>
<td>1.0 (0.1)</td>
</tr>
<tr>
<td>Control</td>
<td>002</td>
<td>1927</td>
<td>30.8 (9.1)</td>
<td>14.3 (9.4)</td>
<td>1.1 (0.8)</td>
</tr>
<tr>
<td>Control</td>
<td>005</td>
<td>178</td>
<td>33.5 (9.4)</td>
<td>14.8 (9.8)</td>
<td>1.0 (0.3)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>003</td>
<td>55</td>
<td>28.1 (8.4)</td>
<td>16.1 (10.1)</td>
<td>1.1 (0.7)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>004</td>
<td>470</td>
<td>34.0 (9.5)</td>
<td>24.7 (12.5)</td>
<td>1.3 (0.8)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>006</td>
<td>84</td>
<td>33.1 (11.1)</td>
<td>31.8 (20.9)</td>
<td>1.2 (1.2)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>009</td>
<td>77</td>
<td>28.2 (8.7)</td>
<td>18.8 (10.2)</td>
<td>1.3 (1.1)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>010</td>
<td>246</td>
<td>34.1 (10.0)</td>
<td>19.8 (11.2)</td>
<td>1.4 (0.8)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>011</td>
<td>75</td>
<td>34.4 (8.7)</td>
<td>25.4 (11.9)</td>
<td>1.6 (1.2)</td>
</tr>
<tr>
<td>Noncontrol</td>
<td>017a</td>
<td>122</td>
<td>39.1 (9.9)</td>
<td>20.2 (13.4)</td>
<td>1.2 (0.6)</td>
</tr>
</tbody>
</table>
at T_2-3 (circled in Fig. 1, top). This pattern recurred at T_4-5, T_5-6, and T_6-7 for %Ws outcomes, representing performance rating ambiguities for 57 percent of %Ws outcomes and 40 percent of all control/noncontrol comparisons in Figure 1.

Figure 2 summarizes %Ws (top) and %BWs (bottom) outcomes as a function of reported use of HPDs by HCP performance and hearing level groups. Horizontal axes in Figure 2 denote reported percentage of time HPDs were used during employment (less than 50% or greater than 50% of the workday). The number of sequential test comparisons associated with each %Ws outcome is in parentheses; this number was the same for %BWs outcomes and is therefore not repeated in the lower half of Figure 2. Because sequential test comparisons were collapsed across subjects, outcome magnitudes (in percent, vertical axes) represent percentages of audiograms, as the same subject may have yielded multiple test comparisons. ANSI S12.13 performance ratings (A, M, and U), though technically not applicable to audiogram percentages, appear adjacent to each outcome. Data in Figure 2 are reported only for audiometric records indicating occupational noise exposure greater than or equal to a TWA of 85 dB (A).

Hearing level effects were also present for ANSI S12.13 outcomes in Figure 2, and performance rating "changes" resulting from this effect are circled. Control outcomes in Figure 2 displayed a clear pattern toward reduction in audiometric variability with increased reported use of HPDs. That is, control outcomes were clearly smaller in magnitude for sequential test comparisons associated with reported HPD use greater than 50 percent of working hours. Though less dramatic, the same pattern is present for better-hearing noncontrol outcomes (white bars); however, poorer-hearing noncontrol outcomes (gray bars) demonstrated modestly greater audiometric variability in the more protected group. No HCP performance ambiguities occurred in Figure 2, as there were clear distinctions between performance ratings for poorer-hearing controls (black bars) and better-hearing noncontrols (white bars). Figure 2 also reveals a wide range in sample size, from a minimum of 62 sequential test comparisons for poorer-
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Table 3 summarizes correlation coefficients characterizing relationships between ANSI S12.13 outcomes and mean binaural baseline hearing levels (from Table 2) for the 10 HCPs from this study. Outcomes were highly positively correlated, with correlations ranging from 0.6 at T2-3 for %Ws to 0.9 at T7-8 for the %BWs outcome. All %BWs and five of seven %Ws outcomes were significantly positively correlated to baseline hearing levels for the 10 HCPs.

**DISCUSSION**

This investigation confirms preliminary findings by Amos and Simpson (1995) by revealing systematic relationships between ANSI S12.13 outcome magnitudes and pre-existing hearing loss in the public domain audiometric database. Better-hearing groups consistently yielded "better" (i.e., smaller magnitude) outcomes than poorer-hearing groups, and ANSI outcome magnitudes were positively correlated with baseline hearing levels. If year-to-year audiometric variability were an indirect reflection of TTS, one would expect negative correlations between ANSI outcomes and baseline hearing levels and better-hearing groups to yield systematically greater audiometric variability than poorer-hearing groups (Nixon and Glorig, 1962; Sataloff et al, 1962; Hetu and Parrot 1978; Melnick, 1978). Taken in sum, these findings do not support assumptions that ANSI S12.13 outcomes clearly provide indirect measures of TTS.

Systematic hearing level effects resulted in numerous changes in ANSI S12.13 performance ratings. Control ratings often changed from "acceptable" to "marginal" and noncontrol ratings often changed from "marginal" to "unacceptable" when hearing level classifications changed from better to poorer. In turn, performance rating changes led to several performance ambiguities between control and noncontrol subjects, with poorer-hearing controls often receiving the same performance rating as better-hearing noncontrols. Furthermore, increased intertest intervals (see Table 1) may...
Table 3  Correlation Coefficients (Pearson r) Characterizing Relationships between ANSI S12.13 Outcome Magnitudes and Mean Baseline Hearing Levels for the 10 HCPs

<table>
<thead>
<tr>
<th>Test Comparison</th>
<th>1-2</th>
<th>2-3</th>
<th>3-4</th>
<th>4-5</th>
<th>5-6</th>
<th>6-7</th>
<th>7-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI S12.13 Protocol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%Ws</td>
<td>0.67*</td>
<td>0.60</td>
<td>0.81*</td>
<td>0.66*</td>
<td>0.62</td>
<td>0.67*</td>
<td>0.81*</td>
</tr>
<tr>
<td>%BWs</td>
<td>0.72*</td>
<td>0.78*</td>
<td>0.90**</td>
<td>0.72*</td>
<td>0.78*</td>
<td>0.90**</td>
<td>0.90**</td>
</tr>
</tbody>
</table>

*Significant at p < .05; **significant at p < .01.

have resulted in increased ANSI S12.13 outcome magnitudes for noncontrol subjects (Thomas, 1985). When hearing level and intertest interval differences between control and noncontrol groups are considered (see Table 1), it is not unreasonable to hypothesize that overall group differences in ANSI S12.13 outcomes are as likely to be explained by these factors as they are by differences in overall HCP performance.

Amos and Simpson (1995) reported ANSI S12.13 outcomes for only T1-2 comparisons and speculated that arbitrarily high numbers of invalid baselines may have contributed to greater audiometric variability in poorer-hearing groups. The present investigation demonstrates hearing level effects to persist well beyond T1-2 comparisons, long after increased subject test-taking sophistication would tend to resolve the issue of invalid baselines exaggerating variability outcomes for poorer-hearing groups in earlier sequential test comparisons.

Full-Shift Testing and TTS

Draft ANSI S12.13-1991 Standard Evaluating the Effectiveness of Hearing Conservation Programs recommends "full-shift" testing to enhance possibility for TTS in industrial audiograms. That is, the draft standard recommends that employees be tested throughout the workshift with no extraordinary efforts to enforce HPD use on the day of the test. For annual audiograms, this practice is allowed by Federal Regulations (OSHA, 1983) and encouraged by the National Institute for Occupational Safety and Health (Suter and Franks, 1990). The rationale for this practice is that appropriate intervention for TTS will likely prevent or slow progression of permanent hearing loss (Thomas, 1985).

Though the premise is reasonable that full-shift testing enhances the likelihood for TTS, little is known about how this testing strategy affects audiometric data. The ANSI Working Group reported similar degrees of annual audiometric variability in low noise-exposed and well-protected populations for control HCPs with full-shift testing programs (ANSI, 1991), but no studies have directly compared audiometric variability outcomes in the same industrial population for full-shift versus "beginning of shift" testing programs. Humans exhibit high within-subject and between-subject TTS variability in well-controlled laboratory studies of TTS (Melnick, 1978). It is not unreasonable to suppose that full-shift industrial testing programs, with little or no control over noise exposure variables, add a great deal of complexity to tasks of identifying and interpreting TTS findings in the audiometric database. Personal experience of the first author with large "in-house" HCPs with full-shift testing programs suggests that test scheduling in full-shift programs is not random. That is, it is very likely that whole manufacturing departments are scheduled annually on the same month, week, and time of day. If groups of employees tend to be tested at approximately the same time during the workshift on two annual audiograms, it is very possible that "acceptable" threshold variability could result from approximately the same amount of TTS evident in both annual data sets. HCPs relying upon mobile van testing services face additional problems not encountered by in-house programs. Highly fluctuant test results may reflect different annual audiometers or test locations for the mobile van. It may be unrealistic to expect that TTS can be reliably identified and interpreted in industrial populations, given the complexities and vagaries of industrial testing programs. It is clearly unrealistic to expect annual variability outcomes to yield the same kind of data produced by field studies designed to identify TTS by comparing pre- and post-workshift thresholds (Nixon and Glorig, 1962; Sataloff et al, 1962; Hetu and Parrot, 1978).
Several other investigations have reported higher audiometric threshold variability in populations exhibiting greater degrees of pre-existing hearing loss (Chen and Pell, 1989; Robinson, 1991); however, no detailed explanations have been given for these findings. Amos and Simpson (1995) speculated that several factors may have contributed to reduced threshold variability in better-hearing groups. High ambient noise in audiometric test environments may have masked 15-dB shifts for the better in employee groups with less pre-existing loss, and failure of many industrial audiometers to measure below audiometric zero may also have contributed to this “floor effect” for better-hearing groups (OSHA, 1983; Franks et al, 1992). Poorer-hearing subjects also may have been less motivated to respond reliably and also were more likely to exhibit tinnitus and other otologic conditions associated with poor test reliability and fluctuant hearing levels (Gelfand, 1981; Chung et al, 1984).

ANSI S12.13 Outcomes and HPD Enforcement Policies

Reliance upon ANSI S12.13 outcomes to drive decisions regarding HPD policies is particularly problematic in light of hearing level effects identified by this investigation. If industrial populations with essentially normal hearing tend to yield “better” ANSI S12.13 results, unmerited confidence may be placed in HPD programs for these groups, placing them at risk for permanent hearing loss. On the other hand, if older populations with impaired hearing tend to yield “poorer” results, overzealous HPD enforcement policies may result in over-attenuation of these groups, resulting in potential safety hazards in noisy production areas where it is necessary to hear verbal instructions and warning signals.

Several examples potentially involving HPD policies are evident in Figure 2. Circled items in Figure 2 identify changes in performance ratings as a function of baseline hearing level. Both %Ws and %BWs outcomes in Figure 2 suggest “acceptable” and “marginal” performance for better- and poorer-hearing control subjects, respectively, who reported use of HPDs less than 50 percent of the time. The logical HCP management decision here would be to strengthen HPD enforcement for the “marginal” poorer-hearing group and not modify current policies for the “acceptable” better-hearing group.

It should be mentioned that %Ws and %BWs outcomes in Figure 2 do discriminate HPD usage patterns for all controls and better-hearing non-control subjects: all outcomes for these groups demonstrated greater audiometric variability for less protected (i.e., HPD <50%) groupings. However, magnitudes of change as a function of HPD use are approximately equal to changes as a function of hearing level group in Figure 2. At minimum, Figure 2 demonstrates that pre-existing hearing loss should be considered before ANSI outcomes are used in HPD policy-making decisions.

Future of ANSI S12.13 Protocols

More information on the reliability and validity of ANSI protocols is necessary before formal adoption of Draft ANSI S12.13-1991 Standard Evaluating the Effectiveness of Hearing Conservation Programs. To date, no data have been published indicating repeatable ANSI S12.13 outcomes under HCP conditions that have not changed. If ANSI protocols are reliable, they should produce consistent results from year to year when employee testing and risk factors remain unchanged. If the protocols are valid, they should reflect major programmatic changes such as noise reduction programs and improved HPD enforcement and fitting policies.

Although this investigation has raised serious questions as to the validity of ANSI S12.13 outcomes as indirect measures of TTS, evidence has not been presented here to warrant abandonment of these protocols. Figure 2, for example, indicates potential utility of the protocols in identifying protected (i.e., over 50%) versus unprotected (less than 50%) employees. Considerably more data will be necessary, however, to characterize interpretive limits on variability outcomes when pre-existing hearing loss is taken into account. The current public domain audiometric database may not be sufficiently large to accommodate the demographic parameters necessary for this task. Furthermore, retrospective analyses (as is the current investigation) will not sufficiently ensure integrity of the data upon which conclusions regarding reliability and validity of ANSI S12.13 protocols are based. The most recent audiograms from the samples in this investigation were taken in 1985. It was therefore impossible to characterize integrity of such important data as occupational noise exposures or reported use of HPDs. Longitudinal data will be necessary for more precise documentation of these critical variables.
In the interim, caution appears warranted when using ANSI S12.13 outcomes to judge overall HCP effectiveness. In particular, extreme caution appears warranted when using ANSI S12.13 outcomes in the formulation of hearing protection policies without careful consideration of pre-existing hearing loss in the populations under scrutiny.

CONCLUSIONS

1. Relationships between pre-existing hearing loss and ANSI S12.13 outcomes identified in this investigation generally do not support assumptions that audiometric variability is an indirect measure of TTS.

2. HCP managers should use extreme caution in interpreting ANSI S12.13 outcomes to rate overall program performance. In particular, HCP managers should not rely upon these outcomes for decisions regarding hearing protection policies without careful consideration of pre-existing hearing loss in the populations involved.


4. Future research efforts to characterize reliability and validity of HCP effectiveness measures should be longitudinal rather than retrospective.

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