Perceived Effects of High Frequency Hearing Loss in a Farming Population

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Abstract

Previous research has suggested that farmers are at increased risk for noise-induced hearing loss (NIHL) due to excessive amounts of loud noise exposure from farming equipment. This study was conducted to determine the perceived effects of hearing loss in a small farming population. Ninety-three subjects, ranging in age from 18 to 75 years and actively engaged in the farming industry, were asked to complete a case history form regarding noise exposure and demographic information. Hearing sensitivity was assessed by obtaining air conduction thresholds at audiometric test frequencies 500-8000 Hz bilaterally. Subjects completed the Self Assessment of Communication (SAC) hearing handicap scale if any threshold in either ear was poorer than 25 dB HL. Study results revealed that the presence of high-frequency hearing loss and perceived hearing handicap increased with age, with the largest effects seen in those over 50 years of age. The relationship between SAC scores and four hearing handicap formulae utilizing different pure-tone averages was also investigated. The highest correlation coefficients occurred for formulae employing higher frequencies and excluding 500 Hz in the calculation. Implications of this study are that audiologists should be aware of the potential hearing handicap associated with high-frequency hearing loss in the farming population and educational programs concerning the dangers of noise and ways to prevent NIHL should be developed for those in farming occupations.

Key Words: hearing handicap, farming population, noise-induced hearing loss, high-frequency hearing loss, pure-tone average.


Sumario:

Investigaciones previas han sugerido que los agricultores tienen un mayor riesgo para desarrollar una hipoacusia inducida por ruido (NIHL), debido a la exposición a cantidades excesivas de ruido intenso generado por el equipo agrícola. Este estudio se condujo para determinar la percepción de los efectos de tal pérdida auditiva en una pequeña población de agricultores. Se le pidió a noventa y tres sujetos, con edades entre los 18 y los 75 años y activamente involucrados en la industria agrícola, que completaran una fórmula de historia de caso, con datos de exposición a ruido e información demográfica. Se evaluó la sensibilidad auditiva obteniendo umbrales bilaterales de conducción aérea en las frecuencias de 5000 a 8000 Hz. Los sujetos completaron la escala de impedimento auditivo conocida como Auto Evaluación de la Comunicación (SAC), si cualquier de los umbrales en cualquier oído era menor de 25 dB HL. Los resultados de estudio mostraron que la presencia...
The farming profession is one that is associated with many risks and health hazards. According to Ehlers et al. (1993), agriculture is one of the three most dangerous occupations. Potential health hazards include exposure to pesticides and vibrations from farm machinery and equipment (Ehlers, Connan, Themann, Myers, & Ballard, 1993; Karlovich, Wiley, Tweed, & Jensen, 1988; May, Marvel, Regan, Marvel, & Pratt, 1990; McJilton & Aherin, 1982; Weston, 1963). Additionally, it is widely accepted that farmers risk noise-induced hearing loss (NIHL) due to excessive occupational noise exposure (Broste, Hansen, Strand, & Stueland, 1989; Crutchfield & Sparks, 1991; Plakke & Dare, 1992). In fact, a survey of farm operators showed that more that 50% acknowledged a health risk associated with their work, with exposure to loud noise being the condition reported most frequently (Crutchfield & Sparks, 1991).

Of the many potential sources of noise exposure in farming, the most common is from tractors, with additional noise sources including grain dryers, bush hogs, chainsaws, combines, power tools and other types of equipment (Holt, Broste, & Hansen, 1993; Kristensen & Gimsing, 1988; Plakke & Dare, 1992; Thelin, Joseph, Davis, Baker, & Hosokawa, 1983). Several studies have determined that noise produced by tractors and other equipment to be potentially damaging to hearing when compared to current standards employed in many industries (Broste et al., 1989; Hessel, Heck, & McJilton, 1982; Holt et al., 1993; Jones & Oser, 1968; Plakke, 1990; Weston, 1963). Karlovich et al. (1985) and Crutchfield and Sparks (1991) found that male farmers were exposed to noise that closely approximated an 8-hour time-weighted average of 95 dBA sound level in a number of agricultural operations and practices. Other studies recorded decibel readings in excess of 90 dBA for tractors without cabs (Hessel et al., 1982; Holt et al., 1993; Jones and Oser, 1968; Plakke, 1990; Weston, 1963), while Plakke (1990) reported that the combined noise of tractors and farming implements can exceed 110 dBA.

Given the dangerously high levels of noise that farmers may be exposed to while farming, it is not surprising that studies have shown that they may be at increased risk NIHL compared to non-farmers (Thelin et al., 1992; Ehlers et al., 1993). The risk may even occur at an early age (Broste et al., 1989; Karlovich et al., 1988). Plakke and Dare (1992) reported a tendency for NIHL to be established as early as the third or fourth decade of life, and become increasingly worse. Clinical audiologists should be aware that farmers are at an increased risk for NIHL and target this population for clinical assessment and prevention education.

While NIHL in the farming population may be easily measured and classified using pure-tone audiometry, its potential handicapping effect on affected individuals is harder to determine. There are several pure-tone formulae that can be used to calculate the amount of hearing handicap...
resulting from a given hearing loss (AAOO, 1959; AAO-HNS, 1979; NIOSH, 1972; ASHA, 1981). The formulae use different frequency combinations for calculating their respective pure-tone averages. Three of the four use a 25 dB fence with 1.5% handicap given for each decibel of hearing loss (average of three or four frequencies) over the fence, and a 5:1 weighting for the better ear. The ASHA formula also uses a 25 dB fence and a 5:1 weighting for the better ear, but applies a 2% handicap for every dB over the fence. Another formula, the Binaural NIOSH (1997) formula, uses a 25 dB fence also, but does not weight the better ear or employ any handicap assessment for each decibel over the fence. It is used to merely identify the percentage of a particular population that has a binaurally averaged pure-tone average (1-4KHz) over a 25 dB hearing level fence.

Although pure-tone formulae can be used to objectively estimate the degree of hearing handicap caused by a particular hearing loss, the actual hearing handicap experienced by the affected individual may not be well predicted by audiometric test results (Ventry & Weinstein, 1982). There are several self-assessment scales available to quantify the perceived hearing handicap reported by the person with hearing impairment. Some of these scales assess the ability to hear speech in specific listening situations, some assess the psychosocial impact of hearing loss, and still others assess both the situational and the psychosocial effects of hearing loss (Ventry & Weinstein, 1982). Nerbonne, Stewart, and Stewart (1998) used the Self-Assessment of Communication (SAC) to assess perceived handicap in a clinical population exhibiting high frequency hearing loss and found it sensitive to the difficulties perceived by individuals with precipitously dropping audiograms. This type of audiometric configuration is similar to those frequently encountered in the farming population. Stewart, Pankiw, Lehman, and Simpson (2002) administered the Hearing Handicap Inventory for Adults – Screening Version (HHIA-S) to 232 recreational firearm users for whom they had also obtained pure-tone air audiometry at audiometric test frequencies of 500 – 6000 Hz. The HHIA-S scores varied directly with high frequency (1000 - 4000 Hz) hearing thresholds. In addition, these investigators found that the HHIA-S correlated more highly with pure-tone formulae that did not employ 500 Hz in the calculation. Finally, Gomez, Hwang, Sobotova, Stark, and May (2001) found that agreement between self-reported hearing loss and audiometry was greatest for a mid-frequency average (1000, 2000, 3000, and 4000 Hz) compared to low-frequency (500, 1000, and 2000 Hz) and high-frequency (3000, 4000, 6000, and 8000 Hz) averages.

Since farmers are at increased risk for NIHL and associated hearing handicap, it is important for audiologists to know and understand the work environment and types of exposure farmers face on a daily basis. To obtain a greater understanding of the hearing loss in this population, more information is needed including demographic data, noise exposure habits, hearing protective device (HPD) use, audiometric status, and perceived hearing handicap status. This information will be useful in preventing and treating hearing loss in this population. Specifically, the purposes of this study were to determine: (1) the reported typical daily durations of loud occupational noise exposure in this population and the consistency of HPD use, (2) other sources of non-farming noise to which farmers are exposed, (3) the effect of age and farming employment status on hearing thresholds and perceived hearing handicap scores, and (4) the relationship between hearing handicap calculated using different pure-tone formulae and self-reported SAC scores for farmers with hearing loss.

**METHOD**

**Subjects**

Ninety-three males who identified themselves as actively engaged in the farming industry were subjects in this study. The subjects were attending a recent annual conference of the Michigan vegetable growers and were recruited according to availability. Subjects ranged in age from 18 to 75 years.

**Experimental Procedures**

Each participant was required to complete a case history form. Information obtained included date of birth, county of residence, years in the farming profession, average number of hours of loud farm noise exposure per day, percentage of time hearing protection was utilized, and participation in non-occupational activities involving noise
exposure (including hunting with firearms, riding snowmobiles, motorcycling, and exposure to other forms of occupational noise outside the farm industry). The examiner reviewed the case history information with each subject, asking follow-up questions where necessary.

Outer and middle ear status was assessed via otoscopic examination and tympanometric testing. Pure-tone air conduction thresholds were collected at audiometric frequencies of 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz for each ear using a Maico MA-41 microprocessor audiometer with TDH-39 supra-aural earphones. All audiometric testing was completed in an IAC model 250 single-walled sound booth housed in a custom-made mobile hearing testing unit. Acceptable ambient noise levels were verified in the booth prior to the start of each testing shift using a Quest Model 2700 sound level meter per OSHA (1983) specifications. The subjects were counseled, provided literature on hearing loss associated with farm noise and given a sample pair of foam plug HPDs.

Following audiometric testing, the SAC was administered to subjects who exhibited a hearing threshold poorer than 25 dB HL at any test frequency for either ear. The SAC is a 10-item questionnaire consisting of six items related to communication situations and four items related to the social-emotional aspects of hearing loss. Answers for the SAC are close ended with each item being rated on a five-point continuum (a response of “almost never” receives a rating of 1, an “occasionally” response a rating of 2, an “about half the time” response a rating of 3, a “frequently” response a rating of 4, and a “practically always” response a rating of 5). There are a total of 50 possible points. The raw scores are classified as follows: a score of 10 – 18 would indicate no hearing handicap, 19-26 a slight hearing handicap, 27-38 a mild to moderate hearing handicap, and 39 – 50 a severe hearing handicap.

RESULTS

Demographic information

Table 1 depicts the results of the hearing health case history form and demographic information completed by the farmers. Overall, the average age of the 93 participants was 46 years (sd = 14). The average age of the full-time farmers was 46.9 years and 41.5 years for part-time farmers. The breakdown of subjects by age was as follows: 12 subjects in the 18-30 year age group, 22 subjects in the 30-40 year age group, 27 subjects in the 40-50 year age group, 13 subjects in the 50-60 year age group, 13 subjects in the 60-70 year age group.

<table>
<thead>
<tr>
<th>Group Sizes</th>
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<tbody>
<tr>
<td>All</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>Part-time</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Fruit/Vegetable</td>
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<td></td>
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<tr>
<td>Livestock/Fruit/Vegetable</td>
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<td></td>
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<tr>
<td>Mean Age (in years)</td>
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<td></td>
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<tr>
<td>All</td>
<td>46.0</td>
<td></td>
</tr>
<tr>
<td>Full-time</td>
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</tr>
<tr>
<td>Part-time</td>
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<tr>
<td>Full-time</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Part-time</td>
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<td></td>
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<tr>
<td>Farm Noise Exposure (Hours/Day)</td>
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<td></td>
</tr>
<tr>
<td>Part-time</td>
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<td></td>
</tr>
<tr>
<td>Hearing Protection Device use</td>
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</tr>
<tr>
<td>Number Using</td>
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</tr>
<tr>
<td>Percentage of Use</td>
<td>34.5</td>
<td></td>
</tr>
<tr>
<td>Number of subjects reporting additional noise exposure by type</td>
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<td></td>
</tr>
<tr>
<td>Firearm noise</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Other occupational noise</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Noisy hobbies</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Music</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Results of selected items on the case history questionnaire (N=93)

Table 2. Reported Loud farm noise exposure, HPD use, and number of subjects reporting exposure to non-farm noise (N=93)
group, and six subjects in the 70-80 year age group. These groups were utilized to analyze the effects of age on audiometric status. Seventy-eight of the 93 subjects reported farming as a full time occupation, while the remaining 15 subjects reported part-time farming. The average number of years farming for the entire subject population was 29 years (sd = 16) with the average years farming for the full-time group being 31 years (sd = 16), and 20 years (sd = 13) for the part-time population. Seventy-five of the subjects reported working on fruit and vegetable farms, while 17 subjects reported livestock, fruit, and vegetable farming.

Reported noise exposure and HPD use

Table 2 shows the reported daily exposure durations to loud farm noise for the past year, HPD use habits, and number of subjects reporting additional non-farm noise exposure. Full-time farmers reported being exposed to loud farm noise an average of 6.8 hours/day (sd=3.5), while part time farmers reported 4.9 hours/day (sd=4.6). Approximately 60% of the subjects reported using hearing protection at "some time" during their farming career for an average of 34.5% of the time while exposed to loud noise. All subjects were asked if they were exposed to any additional types of non-farm noise exposure. Figure 1 reveals that 12 subjects (12.9%) reported no additional noise exposures other than farm noise, thirty-two subjects (34.4%) reported one additional noise exposure, 33 subjects (35.4%) reported two additional noise exposures, 12 subjects (13%) reported three additional noise exposures, and four subjects (4.3%) reported four additional noise exposures in addition to farm noise. The categories of noise exposure included shooting firearms, non-farm occupational noise, noisy hobbies, and music. Sixty-seven of the subjects (72%) reported shooting firearms as an additional noise exposure with 56 reporting shooting right-handed and 11 reporting shooting left-handed. Thirty of the subjects (32.2%) reported regular exposure to other occupational noise such as factory work. Thirty-three of the subjects (35.4%) reported noisy hobbies such as snowmobiles, fireworks, etc. and twenty of the subjects (21.5%) reported exposure to loud music.

Audiometric Status

A four-way (age x full-time farming status x ear x high frequency average) analysis of variance (ANOVA) with ‘ear’ and ‘high frequency average (2-8KHz)’ treated as repeat-
ed measures variables was conducted on these data. Hearing level (dB HL) was the dependent variable. The main and interaction effects are described below.

**Frequency**

Figure 2 displays the mean binaural air conduction thresholds for all subjects across the frequency range. When averaging thresholds obtained for all subjects at each frequency, regardless of age group, it is evident that hearing loss increases significantly as frequency increases. This figure also reveals that hearing loss is the greatest at 6000 Hz, with thresholds slightly improving at 8000 Hz. Analysis of variance found a significant main effect for high frequency (2-8KHz) thresholds ($F^4_{4,328} = 55.1, p < .001$). Post hoc multiple comparisons using the Least Significant Difference method revealed that all comparisons were significant with the exception of the 4000 Hz – 8000 Hz comparison.

**Age Group**

Figure 3 displays mean binaural 2-8KHz pure-tone averages for the different age groups. Analysis of variance found a significant main effect for age group ($F^5_{5,82} = 14.5, p < .001$). Post hoc multiple comparisons using the Least Significant Difference method revealed that the 18-30, 31-40 and 41-50 groups were not different from each other in high frequency thresholds, but were different from the other three older age groups. Similarly, the 51-60, 61-70, and 71-80 groups were not significantly different from each other but were significantly different from the other three younger age groups. These data suggest that high-frequency hearing in this sample of farmers became significantly poorer by age 50.

**Ear**

ANOVA found the left ear high frequency average was significantly worse than the right ear average ($F^1_{1,82} = 6.7, p < .05$). The mean threshold across frequencies 2-8KHz for the right ear was 27.7 dB HL while the left ear value 29.2 dB HL. Poorer left ear hearing may have been due to the large number of right-handed firearm users in

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**Table 4.** Spearman rank correlation coefficients between SAC scores and four different pure tone hearing handicap calculations for all subjects who received the SAC (N=79) and for only subjects with hearing handicap scores over the fence of the respective formulae. Also shown is the number of subjects identified as being hearing handicapped for all four formulae.

<table>
<thead>
<tr>
<th></th>
<th>ASHA</th>
<th>AAO059</th>
<th>NIOSH72</th>
<th>AAO079</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAC</td>
<td>0.411*</td>
<td>0.353*</td>
<td>0.359*</td>
<td>0.392*</td>
</tr>
<tr>
<td>N</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td>Subjects Exceeding Formula Fence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAC</td>
<td>0.420*</td>
<td>0.176</td>
<td>0.395</td>
<td>0.344</td>
</tr>
<tr>
<td>N</td>
<td>35</td>
<td>9</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>

*Significant at $p < 0.05$
High-frequency hearing acuity tended to be worse for the part-time farmers although no statistically significant difference was observed in mean hearing thresholds (2-8KHz) as a function of full-time versus part-time farming status (F1,82 = 3.6, p = .062). The mean high frequency average for the full-time farmers was 27.9 dB HL and 31.2 dB HL for the part-time farmers.

**Interactions**

Although most interactions were not statistically significant, two were. These included frequency x age group and frequency x full-time/part-time status. Figure 4 reveals the 61-70 age group had a poorer mean threshold at 3KHz, but better mean thresholds at 2KHz, 4KHz, and 6KHz compared to the 41-50 and 71-80 age groups. Figure 5 shows part-time farmers had a better mean threshold at 2 KHz but significantly poorer mean thresholds at 3-8KHz compared to the full-time farmers. Given the small number of subjects in each group and the relatively small threshold differences observed, these data may not have much practical relevance.

**Perceived hearing handicap**

Table 3 shows SAC scores as a function of age and farming status. An ANOVA revealed that the mean total SAC scores were not significantly different across age groups of farmers with hearing loss, although there was a trend for older hearing-impaired farmers to report more hearing handicap than younger hearing-impaired farmers (F5,73 = 2.22, p = .062). Similar results were obtained when SAC scores were examined as a function of full-time farming status, with no significant differences observed (F1,77 = .016, p = .901).

Total SAC scores were utilized to create the following three SAC categories: No hearing handicap, slight hearing handicap, and mild-to-moderate hearing handicap. Figure 6 shows the mean binaural air conduction thresholds at each frequency for each of the SAC categories. Analysis of variance found significant differences existed in mean binaural 2-8KHz averages as a function of SAC category (F2,89 = 7.3, p < .01) with multiple comparisons using the Scheffe method revealing that the no hearing handicap group had a lower mean high frequency average than both the mild and mild-to-moderate hearing handicap groups.

**Relationship between formula-based and perceived hearing handicap**

Table 4 shows the Spearman rank correlation coefficients between SAC total scores and the percent hearing handicap determined by the AAOO, AAO-HNS, NIOSH and ASHA hearing handicap formulae. The first calculation included all subjects who completed the SAC (N=79). Correlation coefficients were highest for the formulae that did not include 500 Hz, but included 4000 Hz in the calculations. The lowest correlation occurred with the AAOO (1959) formula, but significant correlations were obtained for every formula when all subjects who competed the SAC were included in the calculation.

Secondly, shown in Table 4 are correlation coefficients calculated between the SAC scores and percent hearing handicap determined by the various formulae for subjects whose scores exceeded the hearing impairment fence for a particular formula. These correlation coefficients were calculated in this way to determine relationships between variables without including subjects who did not have hearing handicap according to the particular formula. When eliminating subjects according to the particular requirements of the formula, the correlations tended to be lower because many subjects with
no hearing loss and no reported hearing handicap were excluded from the calculation. While SAC scores ranged from 11 to 40 regardless of the hearing handicap formula utilized, the range of formula scores (percent hearing handicap) was more variable (ASHA formula: range = .004 - 954; AAO059 formula: range = .004 - .283; NIOSH72 formula: range = .004 - .583; AAO079 formula: range = .003 - .456). The only significant correlation found with this method was with the ASHA formula. The ASHA formula identified the largest number of subjects (35) as being hearing handicapped while the AAO059 formula identified the smallest number of subjects (9).

DISCUSSION

The results of this study suggest that farm noise exposure, in addition to exposure to other occupational and recreational noise, may put farmers at risk for NIHL and subsequent hearing handicap. Farmers in this study reported sporadic use of HPDs when exposed to loud farm noise while approximately 90% of the subjects also reported additional non-farm noise exposure. Subjects over fifty years of age exhibited significantly more high frequency hearing loss than younger subjects. Although the difference in high frequency hearing thresholds as a function of age is expected, the trend for part-time farmers to have poorer high frequency hearing than full-time farmers cannot be explained on the basis of age since both groups were similar in that respect. Part-time farmers may have had greater exposure to other types occupational noise (i.e. factory work) and thus incurred more NIHL. It is also possible that the part-time farmers may have had more NIHL than the full-time farmers because they farm with older, noisier equipment such as tractors without cabs. Audiologists should complete thorough noise exposure histories when evaluating farmers audiologically and provide appropriate intervention when appropriate.

SAC performance for the subjects in the study differentiated individuals who had normal hearing from those with varying degrees of high-frequency hearing loss in many cases. Subjects with greater high-frequency hearing loss tended to report more hearing handicap on the SAC. Based upon these results, it appears that the SAC may be useful in this population and other populations where high frequency hearing loss is prevalent. The SAC may also be useful as a tool to counsel individuals with high-frequency hearing loss and to assess the benefits of intervention strategies for this population.

Interestingly, correlation coefficients between perceived hearing handicap and pure-tone thresholds obtained in this study follow a similar pattern to those reported by Stewart et al. (2002) with firearm users. That study utilized the HHIA-S, which differs from the SAC in that all ten items assess purely social-emotional aspects of hearing handicap without concern for communication situations. Moreover, Gomez et al (2001) reported that even a simple self-assessment questionnaire asking farmers to describe their hearing status provided better agreement with hearing loss in the 1000-4000 Hz frequency range than lower (500-2000 Hz) or higher (3000-8000 Hz) ranges. Collectively, these studies show the clinical utility of using even relatively short hearing handicap instruments as screening tools to aid in the identification of high frequency hearing loss.

The pure-tone average formulae used in this study were chosen to represent the spectrum of hearing handicap formulae that use different pure-tone frequencies in calculating the degree of hearing handicap. The results of this study support the use of formulae that use higher frequency pure-tone averages in the formulae and exclude 500 Hz when assessing hearing handicap in populations where high-frequency hearing loss is prevalent. The two formulae in this study identifying the largest number of subjects as being “hearing handicapped” based on their audiometric results were the ASHA and Binaural NIOSH formulae. The formula showing the highest correlation with self-reported hearing handicap was the ASHA formula (which uses the highest pure-tone frequencies in its average with the weighting factors mentioned previously). Because the Binaural NIOSH formula does not assign a percent handicap to a particular hearing loss, the correlation between formula-based hearing handicap and self-reported hearing handicap could not be calculated using this formula. These results are in agreement with Stewart et al (2002), even though they used a different hearing handi-
cap scale and population, and further support the notion that pure-tone formulae using higher frequencies more closely correlate with self-reported hearing handicap than those employing lower frequencies, at least for populations where the hearing loss is predominantly high frequency. Audiologists and hearing conservationist using formulae that include higher frequencies to calculate hearing handicap in populations at risk for NIHL may be able to intervene earlier and prevent further hearing loss.

Many subjects in this study indicated they do not routinely, if ever, utilize hearing protection on the job. This is a sign that they are unaware of the danger to their hearing posed by exposure to loud sound. Education is needed to encourage consistent HPD use in industrial farming environments. Additionally, comprehensive hearing conservation programs for farmers should include sound level monitoring, annual audiometry, and record keeping in accordance with OSHA (1983) standards. If farmers do not receive hearing conservation services similar to those received by individuals employed in other noisy industries, they will certainly be at increased risk for occupationally-related NIHL.

REFERENCES


