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# Hearing Loss and Hearing Handicap in Users of Recreational Firearms

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**Abstract**

This investigation sought to establish the prevalence of hearing loss and hearing handicap in a population of 232 recreational firearm users. Hearing handicap was calculated based on four methods using pure-tone threshold data from the American Academy of Ophthalmology and Otolaryngology, American Academy of Otolaryngology-Head and Neck Surgery, National Institute of Occupational Safety and Health, and American Speech-Language and Hearing Association in addition to the self-report Hearing Handicap Inventory for Adults-Screener (HHIA-S). Subjects (45 female and 187 male) ranging in age from 13 to 77 years (mean = 40 years, SD = 15.1) completed a short questionnaire regarding demographics and shooting practices followed by pure-tone air audiometry at Occupational Safety and Health Administration test frequencies of 500 to 6000 Hz. A total of 177 who exhibited varying degrees of hearing loss also received a face-to-face administration of the HHIA-S. Audiometric and HHIA-S results revealed that both high-frequency hearing loss and hearing handicap varied significantly as functions of age and occupation. Significant gender effects were observed audiometrically but not as a function of hearing handicap. HHIA-S scores varied significantly as a function of high-frequency (1000–4000 Hz) hearing loss. Correlation coefficients between the four different pure-tone methods of calculating hearing handicap and the self-reported HHIA-S were highest for pure-tone methods that do not employ 500 Hz in the calculation.

**Key Words:** Firearm users, gender, hearing handicap, high-frequency hearing loss, noise-induced hearing loss, pure-tone average

**Abbreviations:** AAO-HNS = American Academy of Otolaryngology-Head and Neck Surgery; AAOO = American Academy of Ophthalmology and Otolaryngology; ANOVA = analysis of variance; ASHA = American Speech-Language and Hearing Association; HHIA-S = Hearing Handicap Inventory for Adults-Screener; HPD = hearing protective device; NIHL = noise-induced hearing loss; NIOSH = National Institute of Occupational Safety and Health; SAC = Self-Assessment of Communication

**Sumario**

Esta investigación buscó establecer la prevalencia de alteraciones auditivas y de discapacidad auditiva en una población de 237 usuarios de armas de fuego para recreación. El grado de discapacidad auditiva fue calculado con base en cuatro métodos que utilizan información de tonos puros de acuerdo a la Academia Americana de Oftalmología y Otolaringología, a la Academia Americana de Otolaringología y Cirugía de Cabeza y Cuello, al Instituto Nacional de Seguridad y Salud Ocupacional y a la Asociación Americana de Habla, Lenguaje y Audición, además de un auto-reporte utilizando el Inventario de Discapacidad Auditiva para Adultos (HHIA-S). Los sujetos (45 mujeres y 187 hombres) con edad de 13 a 77 años (media de 40 años, DS = 15.1) completaron un corto cuestionario relacionado con aspectos demográficos y de las prácticas de tiro, seguido de un audiometría de tonos puros por vía aérea en las frecuencias recomendadas por la Administración de Seguridad y Salud Ocupacional (500 a 6000 Hz). Un total de 177 sujetos quienes exhibieron grados variables de hipoacusia también se sometieron a la administración cara a cara de la prueba HHIA-S. Los resultados audiométricos y de la prueba HHIA-S demostraron que tanto la hipoacusia para altas frecuencias como la discapacidad auditiva variaban significa-

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tivamente como una función de la edad y la ocupación. Se observaron efectos significativos del género en la audiometría pero no en función de la discapacidad auditiva. Los puntajes en la prueba HHIA-S variaron significativamente en función de la hipoacusia para alta frecuencias (1000–4000 Hz). Los coeficientes de correlación entre los cuatro diferentes métodos de tonos puros para calcular la discapacidad auditiva y los resultados de la prueba de auto-reporte HHIA-S fueron mayores para los métodos tonales que no utilizaban 500 Hz en el cálculo.

**Palabras Clave:** Usuarios de armas de fuego, género, discapacidad auditiva, hipoacusia para alta frecuencias, hipoacusia inducida por el ruido, promedio tonal puro.

**Abreviaturas:** AAO-HNS = Academia Americana de Otolaringología y Cirugía de Cabeza y Cuello; AAOO = Academia Americana de Oftalmología y Otolaringología; ANOVA = análisis de variancia; ASHA = Asociación Americana de Habla, Lenguaje y Audición; HHIA-S = Inventario de Discapacidad Auditiva para Adultos-Tamizador; HPD = dispositivo de protección auditiva; NIHL = hipoacusia inducida por el ruido; NIOSH = Instituto Nacional de Seguridad y Salud Ocupacional; SAC = Auto-evaluación de la Comunicación

From a clinical viewpoint, it is apparent that firearm noise exposure is one of the leading causes of noise-induced hearing loss (NIHL) in the United States today. As the shooting sports continue to increase in popularity, audiologists are seeing more patients who have suffered acute acoustic trauma or gradual sensorineural hearing loss secondary to excessive firearm noise exposure. Sudden hearing loss can result from high sound pressure levels of impulse noise that exceed a critical level (Ward et al, 1961) for a given individual by causing instantaneous mechanical and metabolic damage to inner ear structures (Luz and Hodge, 1971). Gradual hearing loss results from years of exposure to levels of firearm impulse noise that are not high enough to cause acoustic trauma yet have an accumulative damaging effect on inner ear structures. Some of these patients seek audiologic services because they are having difficulty understanding speech (especially in noise), whereas others are annoyed by a constant or intermittent tinnitus.

Several studies (Taylor and Williams, 1966; Johnson and Riffle, 1982; Prosser et al, 1988; Updike and Kramer, 1990; Kryter, 1991; Stewart et al, 2001) have found that recreational firearm noise exposure can contribute to high-frequency sensorineural hearing loss. The audiometric configuration of the NIHL caused by exposure to loud firearm impulse noise is often characterized by normal or near-normal hearing in the lower frequencies, with a precipitous drop-off in the higher frequencies bilaterally. The result is a loss of high-frequency consonant perception with little loss of lower-frequency vowel perception. The steep slope of the audiometric configuration in the high-frequency range coupled with normal or near-normal hearing at 2000 Hz often makes remediation of the loss with amplification difficult. Because the ear contralateral to the shoulder supporting a rifle in a firing position is closer to the source of the sound (gun bore) and the ipsilateral ear is slightly protected by head shadow, asymmetry in high-frequency hearing may occur, with the contralateral ear being worse. Also, the directionality of the noise causes the level of the impulse noise to be reduced to the ipsilateral ear (Cox and Ford, 1995).

Although the impairment of high-frequency hearing seen in the firearm user population is easily measured and classified, its potential handicapping effect on afflicted individuals is often difficult to establish. In the medicolegal model, determining the degree of hearing handicap for compensatory purposes usually involves a straightforward assessment of hearing thresholds at specific frequencies and perhaps a particular fence at which hearing handicap begins (Matthews et al, 1990). Several different methods of this type of determination of hearing handicap are presently being used (AAOO, 1959; NIOSH, 1972; AAO-HNS, 1979; ASHA, 1981). The American Academy of Ophthalmology and Otolaryngology (AAOO) formula uses a three-frequency binaural average consisting of 500, 1000, and 2000 Hz; the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) employs the binaural average at 500, 1000, 2000, and 3000 Hz; the National Institute of Occupational Safety and Health (NIOSH) formula uses the binaural average at 1000, 2000, and 3000 Hz; and the American Speech-Language and Hearing Association's (ASHA) formula averages binaural thresholds at 1000, 2000, 3000, and 4000 Hz. All methods employ a 25-dB fence and a weighting factor for the better ear (5:1). The first three assign a 1.5 percent handicap for each decibel over the fence, whereas ASHA assigns 2 percent per decibel. According to Dobie (2000), the 1972 AAO-HNS pure-tone formula is currently the most widely used in the United States.

Although the formulae provide an objective means of computing hearing handicap, the actual hearing handicap experienced by a hearing-impaired individual may not be well predicted by audiometric results because of the complexity of factors that affect how a given individual will respond to a given hearing impairment (Ventry and Weinstein, 1982). There are several self-assessment scales of hearing handicap that can be used to quantify the amount of perceived hearing handicap reported by individuals with hearing loss (Matthews et al, 1990). Some of these scales assess a person's ability to understand speech in specific listening conditions, others assess the psychosocial impact of the hearing loss, and still others assess both the situational and the psychosocial effects of hearing loss (Ventry and Weinstein, 1982).

The relationship between the audiometric methods and self-assessment methods of quantifying hearing handicap is an area of research that has received considerable attention in the past several years. According to literature reviews by Giolas (1982) and Erdman (1994), several studies generally found only mild or moderate correlations between audiometric results of hearing loss and self-assessment of hearing handicap. One study by Newman and colleagues (1990) revealed correlations between both speech frequency (500, 1000, and 2000 Hz) and high-frequency (1000, 2000, and 4000 Hz) pure-tone averages and results on the Hearing Handicap Inventory for Adults (HHIA) to be weak (yet statistically significant) at 0.34 and 0.33, respectively. This study employed subjects with hearing ranging from normal unilaterally to moderately to severely impaired bilaterally.

Recently, Nerbonne and colleagues (1998) studied self-reported hearing handicap using the Self-Assessment of Communication (SAC) scale with individuals exhibiting precipitous high-frequency sensorineural hearing loss presumably caused by excessive noise exposure. The SAC is a 10-item questionnaire that has six items relating to difficulty hearing in adverse environments and four items relating to the social-emotional consequences of the hearing loss. These authors found that subjects with normal hearing through 1000 Hz reported more difficulties hearing in various listening environments and experienced greater social-emotional problems than subjects with normal hearing through 2000 Hz.

The extent to which self-assessment of hearing handicap is related to pure-tone audiometric results for individuals with precipitous high-frequency sensorineural hearing loss needs more study. Also of interest is whether hearing loss and hearing handicap are different for various subgroups within the shooting population. A final point of interest is which of the pure-tone methods of calculating hearing handicap are more highly correlated with self-reported hearing handicap. Therefore, the purposes of this study were to (1) determine hearing loss for different subpopulations of shooters, (2) determine the amount of hearing handicap reported by different shooter subpopulations, (3) investigate the relationship between self-reported hearing handicap scores and high-frequency hearing acuity, and (4) determine the relationship between different methods of calculating hearing handicap using pure-tone test results and the actual handicap reported by hearing-impaired shooters. The pure-tone formulae used in this study were the four discussed above and the simple binaural average of 1, 2, 3, and 4 KHz (B1–4). Also, the subjects provided information regarding demographics (age, gender, and occupation), knowledge and the use of hearing protective devices (HPDs), firearm safety training, and shooting habits.

## METHOD

### Subjects

A total of 232 shooters ranging in age from 13 to 77 years with a mean age of 40 years (SD = 15.1 years) participated in the study. There were 187 males and 45 females. All subjects reported that they had shot firearms during the previous year. The hearing acuity of the subjects ranged from bilaterally normal across the frequency range to a severe to profound high-frequency hearing loss bilaterally. All subjects reported a negative otologic history for middle ear disorders.

### Equipment and Procedures

The subjects were approached as they entered a large northern Michigan sporting goods store the weekend before the past deer hunting season and were asked to participate in the study. Each participant received payment of a $5 gift certificate valid toward the purchase of any item in the store. All subjects completed a short questionnaire relating to demographic information, knowledge and use of HPDs, firearm safety training, and shooting habits. Following an otoscopic examination, hearing thresholds were obtained bilaterally for each subject at audiometric test frequencies of 500, 1000, 2000, 3000, 4000, and 6000 Hz using Micro-Audiometrics microprocessor audiometers calibrated according to American National Standards Institute (1989) specifications. All audiometric testing was completed in Industrial Acoustics Corporation model 250 industrial soundbooths housed in a custom-made mobile hearing test unit.

The screening version of the Hearing Handicap Inventory for Adults (HHIA-S) was administered to subjects with hearing thresholds ≥ 25 dB at any frequency in either ear to determine the degree of self-perceived hearing handicap resulting from their hearing losses (N = 177). The HHIA-S is a 10-item scale of hearing handicap consisting of two subscales, each of which contains five items. One subscale measures the social impact of hearing loss, whereas the other measures the emotional. The respondent is asked to answer "yes," "sometimes," or "no" to each of the 10 items. A "yes" response is worth 4 points, a "sometimes" is given 2 points, and a "no" is not awarded any points. Scores can range from 0 to 40. According to Newman and colleagues (1991a), scores of 10 or more suggest a substantial self-perceived hearing handicap, whereas scores ≥18 are predictors of successful hearing aid use. The HHIA has been used to measure self-perceived hearing handicap in populations with varying degrees of hearing loss (Newman et al, 1990, 1997). The HHIA-S has been found to have high test–retest reliability (Newman et al, 1991b).

## RESULTS

Table 1 depicts the results of the questionnaire the shooters completed. The average age of female shooters (n = 45) was 39.1 years (SD = 14.0), whereas the average age of males (n = 187) was 40.2 years (SD = 15.4). The mean ages of blue collar (n = 86) and white collar workers (n = 52) were 41.8 (SD = 11.1) and 39.0 (SD = 11.3) years, respectively. Occupational groups that were not classified as blue collar or white collar (i.e., military, retired, student, agricultural, etc.) are listed as others (n = 94; mean age of 38.8, SD = 19.5). The shooters reported

**Table 1 Results of Selected Items on Shooter Questionnaire (N = 232)**

| | |
|---|---|
| Mean age of females | 39.1 yr |
| Mean age of males | 40.2 yr |
| Mean age of blue collars | 41.8 yr |
| Mean age of white collars | 39.0 yr |
| Mean age of others | 38.8 yr |
| Mean no. of years shooting | 23 |
| Hunter safety course | 65% |
| HPD component | 49% of those taking the course |
| Mean no. of unprotected shots in past year | 241 |

HPD = hearing protective device.

shooting an average of approximately 23 years (SD = 14.2). Sixty-five percent of the shooters reported receiving a formal hunting safety course, yet only 49 percent of those who had a course said that it included a component on proper HPD use while shooting. The average shooter reported being exposed to 241 unprotected shots (SD = 187, range = 1–5000) in the previous year; however, the variability expressed by the standard deviation and range values is so large that the shooting habits of the average shooter are difficult to describe. The data on the number of unprotected shots are similar to those found by Stewart and colleagues (1998) and suggest that some shooters are at considerable risk for NIHL based on the large number of unprotected exposures to firearm noise they reported.

Figure 1 shows the mean binaural hearing level as a function of age. As is evident in the figure, hearing loss increased at all frequencies tested with increasing age. A series of one-way analyses of variance (ANOVAs) was calculated, with age group as the independent variable

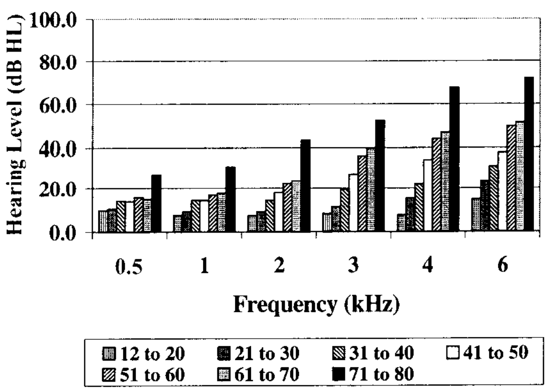


**Figure 1** Mean binaural air-conduction thresholds as a function of age (in years).

**Table 2 Summary of the Results of Pairwise (Scheffé) Comparisons between the Age Groups at Each of the Tested Frequency Levels**

| | *Age Group (yr)* | | | | | | |
|---|---|---|---|---|---|---|---|
| *Age Group* | *12–20* | *20–30* | *30–40* | *40–50* | *50–60* | *60–70* | *70–80* |
| 500 Hz | | | | | | | |
| 12–20 | — | NS | NS | NS | NS | NS | * |
| 20–30 | | — | NS | NS | NS | NS | * |
| 30–40 | | | — | NS | NS | NS | NS |
| 40–50 | | | | — | NS | NS | NS |
| 50–60 | | | | | — | NS | NS |
| 60–70 | | | | | | — | NS |
| 1000 Hz | | | | | | | |
| 12–20 | — | NS | NS | NS | * | * | * |
| 20–30 | | — | NS | NS | * | NS | * |
| 30–40 | | | — | NS | NS | NS | NS |
| 40–50 | | | | — | NS | NS | NS |
| 50–60 | | | | | — | NS | NS |
| 60–70 | | | | | | — | NS |
| 2000 Hz | | | | | | | |
| 12–20 | — | NS | NS | NS | * | * | * |
| 20–30 | | — | NS | NS | * | * | * |
| 30–40 | | | — | NS | NS | NS | * |
| 40–50 | | | | — | NS | NS | NS |
| 50–60 | | | | | — | NS | NS |
| 60–70 | | | | | | — | NS |
| 3000 Hz | | | | | | | |
| 12–20 | — | NS | NS | * | * | * | * |
| 20–30 | | — | NS | * | * | * | * |
| 30–40 | | | — | NS | NS | * | * |
| 40–50 | | | | — | NS | NS | NS |
| 50–60 | | | | | — | NS | NS |
| 60–70 | | | | | | — | NS |
| 4000 Hz | | | | | | | |
| 12–20 | — | NS | NS | * | * | * | * |
| 20–30 | | — | NS | * | * | * | * |
| 30–40 | | | — | NS | * | * | * |
| 40–50 | | | | — | NS | NS | NS |
| 50–60 | | | | | — | NS | NS |
| 60–70 | | | | | | — | NS |
| 6000 Hz | | | | | | | |
| 12–20 | — | NS | NS | * | * | * | * |
| 20–30 | | — | NS | * | * | * | * |
| 30–40 | | | — | NS | * | NS | * |
| 40–50 | | | | — | NS | NS | NS |
| 50–60 | | | | | — | NS | NS |
| 60–70 | | | | | | — | NS |

*Significant at p < .05.

and each of the tested frequencies as dependent variables. Significant differences were obtained for each frequency (500 Hz: $F = 4.971$, $df = 6, 225$, $p < .05$; 1000 Hz: $F = 7.397$, $df = 6, 225$, $p < .05$; 2000 Hz: $F = 10.010$, $df = 6, 225$, $p < .05$; 3000 Hz: $F = 19.091$, $df = 6, 225$, $p < .05$; 4000 Hz: $F = 21.857$, $df = 6, 225$, $p < .05$; 6000 Hz: $F = 17.394$, $df = 6, 225$, $p < .05$). Post hoc analyses using the Scheffé test were conducted for each frequency level. These comparisons are summarized in Table 2. In general, higher frequencies are characterized by a greater number of significant differences, with the older group having a significantly higher threshold than the younger in each case. At 500 Hz, the only significant differences were between the 70- to 80-year group and the 12- to 20- and 20- to 30-year groups. However, at 4000 and 6000 Hz, elevated hearing thresholds are observed in the groups above 40 years of age, whereas the hearing thresholds for groups below 40 years are not significantly different.

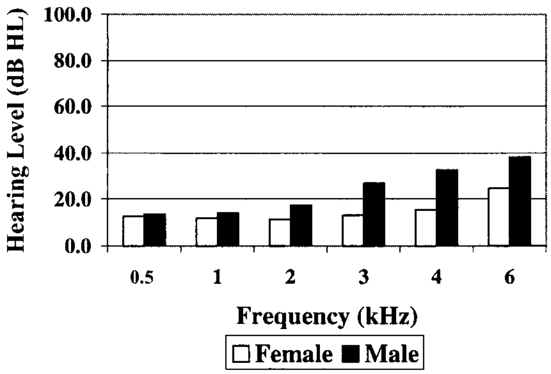


**Figure 2** Mean binaural air-conduction thresholds as a function of gender.

Gender differences in hearing levels are displayed in Figure 2. One-way ANOVAs calculated for each frequency level indicated that significant gender differences exist at frequencies of 2000 Hz and above (2000 Hz: $F = 7.256$, $df = 1, 230$, $p < .05$; 3000 Hz: $F = 19.244$, $df = 1, 230$, $p < .05$; 4000 Hz: $F = 22.792$, $df = 1, 230$, $p < .05$; 6000 Hz: $F = 14.493$, $df = 1, 230$, $p < .05$). In each case, hearing thresholds for males are poorer than those of females.

Hearing levels as a function of occupational setting (blue and white collar) are observed in Figure 3. ANOVA indicates that significant differences exist at all frequency levels (500 Hz: $F = 14.048$, $df = 1, 136$, $p < .05$; 1000 Hz: $F = 15.876$, $df = 1, 136$, $p < .05$; 2000 Hz: $F = 16.251$, $df = 1, 136$, $p < .05$; 3000 Hz: $F = 16.056$, $df = 1, 136$, $p < .05$; 4000 Hz: $F = 14.214$, $df = 1, 136$, $p < .05$; 6000 Hz: $F = 9.427$, $df = 1, 136$, $p < .05$), with blue collar workers exhibiting significantly poorer thresholds than the white collar workers.

Table 3 reveals the mean total (social plus emotional) HHIA-S scores as a function of age, gender, and occupation. As expected, total HHIA-S scores increased significantly with age just as

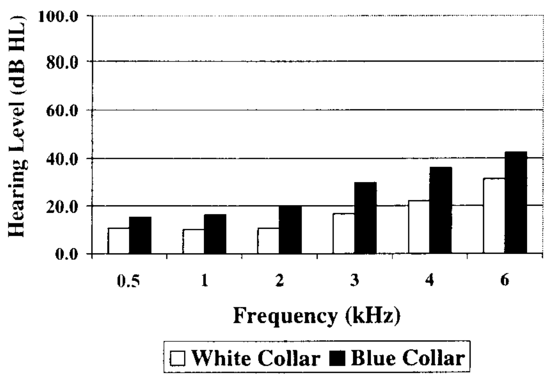


**Figure 3** Mean binaural air-conduction thresholds as a function of occupation type.

hearing loss did (F = 5.450, df = 6, 169, p < .05). Post hoc analyses using the Scheffé test revealed that the comparisons between the 20- to 30-year group and the 40- to 50- and 60- to 70-year groups were significant. Moreover, the small numbers associated with the 12- to 20- and 70- to 80-year groups probably contributed to the lack of significant differences with the other age groups. The average shooter over 40 years of age reported a substantial self-perceived hearing handicap according to a criterion (i.e., scores ≥ 10) established by Newman et al (1991a). Table 3 also shows that males reported a hearing handicap more than 50 percent greater than females, although this difference was not significant. Blue collar workers reported a significantly higher degree of hearing handicap than white collar workers (F = 5.192, df = 1, 110, p < .05). These results are most likely linked with hearing status of the respective demographic groups but may also be associated with other factors such as lifestyle and listening needs. Interestingly, HHIA-S scores for average male and blue collar shooters are at the threshold of being a substantial self-perceived hearing handicap (i.e., scores over 10). The variability of HHIA-S scores for all demographic groups was high, with standard deviations equal to or slightly larger than respective mean values. These data suggest that individuals within the various demographic subgroups are heterogeneous with respect to self-perceived hearing handicap.

To examine the relationship between HHIA-S scores and high-frequency hearing loss, the HHIA-S scores were recoded to create four HHIA-S score categories (0, 1–10, 11–20, >20). The binaural high-frequency hearing thresholds (average at 1–4 kHz) for each of these categories is shown in Figure 4. A one-way ANOVA

**Table 3 Mean Total HHIA-S Scores for Various Demographic Groups**

| | *n* | *Mean* | *SD* |
|---|---|---|---|
| Age group | | | |
| 10–20 | 7 | 1.4 | 3.8 |
| 20–30 | 28 | 2.9 | 4.6 |
| 30–40 | 30 | 7.1 | 7.3 |
| 40–50 | 48 | 10.4 | 10.7 |
| 50–60 | 42 | 12.3 | 8.8 |
| 60–70 | 18 | 8.7 | 7.9 |
| 70–80 | 3 | 17.3 | 8.3 |
| Gender | | | |
| Male | 154 | 9.1 | 9.2 |
| Female | 22 | 5.7 | 7.1 |
| Occupation | | | |
| Blue collar | 77 | 10.6 | 10.1 |
| White collar | 35 | 6.2 | 8.0 |

HHIA-S = Hearing Handicap Inventory for Adults-Screener.

found a significant difference in high-frequency hearing thresholds as a function of HHIA-S categories (F = 53.411, df = 3, 172, p < .05). Post hoc analyses using the Scheffé test revealed that all paired comparisons were significant except for the difference between the 1 to 10 and 11 to 20 HHIA-S categories. Individuals in HHIA-S category 0 exhibited mean high-frequency hearing well within normal limits. Individuals in HHIA-S categories 1 to 10 and 11 to 20 had mean high-frequency hearing thresholds of approximately 25 dB and 30 dB, respectively. Individuals in HHIA-S category >20 exhibited average high-

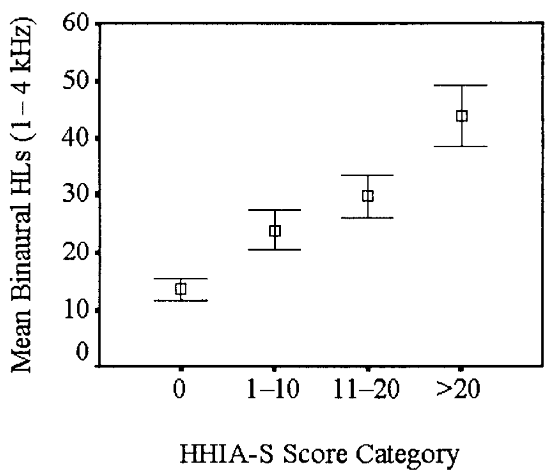


**Figure 4** Mean binaural hearing thresholds as a function of four categories of Hearing Handicap Inventory for Adults-Screener (HHIA-S) scores (0, 1–10, 11–20, ≥21). Ninety-five percent confidence intervals are also shown.

**Table 4 Pearson Product-Moment Correlation Coefficients Describing Relationships between HHIA-S Scores and Four Different Pure-Tone Hearing Handicap Calculations for All Subjects Administered the HHIA-S (n = 176) and for Subjects with Hearing Handicap Scores above the Threshold for Each Scale**

| | *AAOO* | *AAO–HNS* | *NIOSH* | *ASHA* | *Binaural Average 1–4 kHz* |
|---|---|---|---|---|---|
| HHIA-S | 0.550* | 0.641* | 0.655* | 0.661* | 0.678* |
| HHIA-S† | 0.465* | 0.495* | 0.450* | 0.593* | 0.604* |
| n | 40 | 59 | 62 | 87 | 73 |

*Significant at p ≤ .01. †Subjects with hearing handicap scores above the threshold for each scale.

HHIA-S = Hearing Handicap Inventory for Adults-Screener; AAOO = American Academy of Ophthalmology and Otolaryngology; AAO-HNS = American Academy of Otolaryngology-Head and Neck Surgery; NIOSH = National Institute of Occupational Safety and Health; ASHA = American Speech-Language and Hearing Association.

frequency hearing thresholds of approximately 45 dB. Clinically, these data suggest that individuals with mild to moderate high-frequency hearing loss may report a substantial hearing handicap (HHIA-S scores ≥ 10), whereas individuals with greater degrees of high-frequency hearing loss may be candidates for amplification (HHIA-S scores ≥ 18).

Table 4 shows the Pearson product-moment correlation coefficients between each of the five pure-tone methods of calculating hearing handicap and self-reported hearing handicap calculated two different ways. The first calculation included all subjects with any degree of hearing loss (n = 176), whereas the second calculation included only the subjects whose hearing thresholds were over the hearing handicap fence for a particular formula. Correlations were highest for the formulae that do not include 500 Hz in their calculations. The lowest correlation occurred between the AAOO speech frequency formula and self-reported hearing handicap scores. Comparison of the correlation coefficients yielded by each type of calculation procedure reveals that slightly higher values were obtained when all subjects were included. The number of subjects showing any degree of hearing handicap was variable across the pure-tone formulae. The AAOO formula identified the smallest number of subjects (31), whereas both the ASHA and B1–4 formulae identified the largest number of subjects (73).

Also shown in Table 4 are correlation coefficients calculated between HHIA-S scores and the various formulae for subjects whose score on the formulae exceeded the 0 percent threshold of hearing handicap. These correlation coefficients were calculated to determine the relationships between these variables without the inclusion of subjects with no hearing handicap. Inclusion of these subjects may have artificially elevated the correlation coefficients since their scores on the hearing handicap formula are zero and are presumably low on the HHIA-S. Indeed, eliminating these subjects from the calculation of the correlation lowered the coefficient in all cases. The ASHA and the B1–4 formulae, which are the only formulae that include 4000 Hz, had the highest correlation with the HHIA-S.

Examination of the data in Figure 5 reveals the better predictive ability of a higher-frequency formula (ASHA) over a lower-frequency formula (AAOO) and explains the higher correlation values when all subjects (some with normal pure-tone averages) are considered in the Pearson product-moment calculations. The scatter plot shows that the AAOO method underestimated

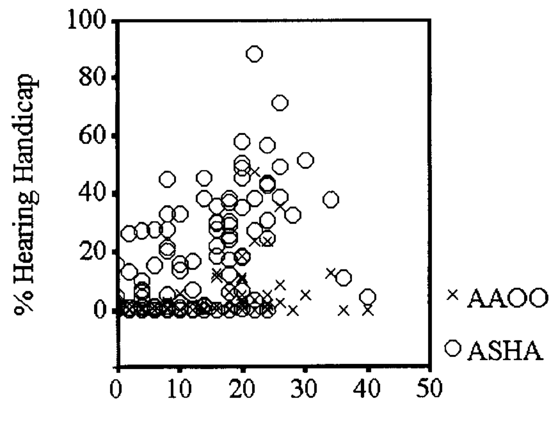


**Figure 5** Scatter plot characterizing formula-based hearing handicap as a function of Hearing Handicap Inventory for Adults-Screener (HHIA-S) score. Two methods of calculating impairment are shown: (1) American Academy of Ophthalmology and Otolaryngology (AAOO), depicted by "X," and (2) American Speech-Language and Hearing Association (ASHA), depicted by "O." This figure demonstrates a greater relationship between HHIA-S and ASHA than between HHIA-S and AAOO.

self-reported hearing handicap in the majority of cases, even for individuals who reported a high degree of hearing handicap. The figure also shows that many more X scores (ASHA) are in the linear portion of the function than O scores (AAOO). The inclusion of 500 Hz in the pure-tone formula serves to reduce the calculated hearing handicap in a population in which the 500-Hz hearing thresholds are usually normal but the higher frequencies may be significantly impaired. Finally, Figure 5 reveals that many subjects with minimal hearing loss according to either formula reported low hearing handicap scores, which served to increase the overall correlation coefficients.

## DISCUSSION

The results of this study revealed that many of the subjects who reported shooting firearms for sport purposes exhibited varying degrees of high-frequency hearing loss and associated self-reported hearing handicap. Certain demographic groups of the recreational firearm users, including males, older individuals, and blue collar workers, exhibited more high-frequency hearing loss and reported more hearing handicap than their demographic counterparts. Increasing hearing loss with age is expected; however, the difference between males and females cannot be explained on the basis of age because both groups were similar in that respect. Likewise, the difference between high-frequency hearing of blue collar and white collar workers cannot be explained by age because both groups were nearly identical in mean age. The most probable explanations are shooting habits and other types of noise exposure. Stewart and colleagues (1998) found that males reported over 2 times more yearly unprotected firearm noise exposures than females, whereas blue collar workers reported 1.65 times more unprotected shots in a 12-month period than their white collar cohorts. Males and blue collar workers also tended to shoot more powerful (louder) guns than their demographic counterparts. Of course, blue collar workers may also be exposed to industrial noise.

Performance on the HHIA-S for this sample of firearm users differentiated individuals with normal hearing from those with varying degrees of high-frequency hearing loss in many cases. Individuals with more significant high-frequency hearing loss tended to report more hearing handicap. Based on these results, it appears that the HHIA-S may be useful as a screening tool in populations in which NIHL is prevalent such as shooters and industrial workers. It may also be useful as an aid to counseling individuals with high-frequency hearing loss and to assess the benefits of intervention strategies by comparing pre- and postintervention scores.

The five pure-tone average formulae used in this study were chosen to represent the spectrum from low-frequency to high-frequency biased methods of calculating hearing handicap. The results of this study support the use of high-frequency pure-tone average formulae rather than pure-tone average formulae that include 500 Hz when attempting to predict self-perceived hearing handicap in individuals with high-frequency hearing loss. The two formulae that are most sensitive to high-frequency impairment (ASHA and B1–4) correlated higher with self-reported hearing handicap and, more significantly, identified a much higher percentage of the subjects as having a hearing handicap based on their audiometric results than the other formulae. The number of individuals deemed hearing handicapped using either the ASHA or B1–4 formula was more than double that of the more conservative AAOO formula, which certainly has implications for clinical audiologists and managers of industrial hearing conservation programs. Clinical audiologists using high-frequency pure-tone average formulae to identify patients who may be hearing handicapped are more likely to intervene earlier in populations with high-frequency hearing loss through the use of amplification or other audiologic rehabilitation procedures than those using formulae that employ 500 Hz. Likewise, managers of industrial hearing conservation programs who aggressively intervene at the first signs of high-frequency hearing loss in their employees enrolled in hearing conservation programs may do a better job of preventing hearing handicap later. However, industrial hearing conservation managers may be reluctant to use a high-frequency formula to calculate hearing handicap for their employees because a much larger percentage of their current work force would be classified as having some degree of hearing handicap.

It is interesting that the simple binaural average of 1, 2, 3, and 4 kHz with no weighting for the better ear correlated higher with self-reported hearing handicap than any of the other four formulae in this study. Dobie (2000) stated that using a simple binaural average without better ear weighting makes no sense because a case in which there is total deafness in only one ear would cause only a mild handicap, certainly not equivalent to one half of one caused by bilateral deafness. On the other hand, many subjects in the present study who had bilateral asymmetric high-frequency hearing loss of sufficient magnitude to be classified as being hearing aid candidates, and who reported significant social-emotional problems secondary to their hearing losses, were classified as having little or no hearing handicap because of the 5:1 better ear weighting. This was especially true for the AAOO and AAO-HNS formulae. In cases in which there is binaural high-frequency hearing loss with asymmetry, the rather arbitrary 5:1 weighting of the better ear may serve to significantly underestimate an individual's perceived hearing handicap, especially if low-frequency hearing thresholds are also included in the calculation.

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