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# Evaluation of Hearing Handicaps and Presbycusis Using World Wide Web-Based Calculators

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## Abstract

This article is a clinical report on the applicability of computer software in determining hearing handicaps and presbycusis. The software is now World Wide Web based and can be implemented in a clinical setting by using JavaScript calculators housed on the World Wide Web at <http://www.occupationalhearingloss.com>. Added features consist of calculating the maximum recommended allowable noise exposure using the National Institute of Occupational Safety and Health 1997 frequencies in handicap determination and the projection of future audiometric thresholds using the International Standards Organization 1999 compression factor. A review of the literature and the theoretical and clinical applications of these new features are discussed. A guide in the selection of Web-based development software is also presented in the hope of encouraging other researchers to develop Web-based versions of their software applications.

**Key Words:** Audiometry, case report, computer-assisted diagnosis, hearing tests/instrumentation, human, Internet, male, microcomputers, middle age, occupational exposure, presbycusis, prognosis, software design, World Wide Web

**Abbreviations:** AAO = American Academy of Otolaryngology; AAOO = American Academy of Ophthalmology and Otolaryngology; ASHA = American Speech-Language-Hearing Association; CHABA = Committee on Hearing, Bioacoustics, and Biomechanics for the National Academy of Sciences, National Research Council; HTL = hearing threshold level; IARL = initial age-related loss; IHT = initial hearing threshold; ISO = International Standards Organization; NIL = noise-induced loss; NIOSH = National Institute of Occupational Safety and Health; OSHA = Occupational Safety and Health Administration; PARL = projected age related loss

**T**his is a follow-up clinical report on the utility of using a computer program in determining hearing handicaps and projection of future hearing as described in Kavanagh (1992). The original software required a moderately complicated installation process, was not truly cross-platform, and required both time to distribute and support. In addition, it had significant limitations in its ability to project future hearing and did not support the new frequency combination from the National Institute of Occupational Safety and Health (NIOSH) 1997 equation (NIOSH, 1998).

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It was decided to completely rewrite the program, with added features, as a World Wide Web (WWW)-based calculator posted on [www.occupationalhearingloss.com](http://www.occupationalhearingloss.com). This will not be a software package that can be downloaded from the Web but a Web-based program for entering data and printing reports. When completed, the project will provide easy to use calculators that do not require installation or support and are readily available to anyone on the Web. Housing the program on the Web also allows one to incorporate multiple supporting documentation and linkages to related sites that provide supporting and related information.

Development software requirements were as follows:

- \* No user installation or downloading of plug-ins
- \* Easy to Use
- \* Cross-platform
- \* Low Cost

**Table 1: Hearing Handicap Equations**

<i>Equation</i>	<i>Frequencies (Hz)</i>	<i>Low Fence</i>	<i>High Fence</i>	<i>Better Ear Ratio</i>	<i>Reference</i>
AAO 1979*	500, 1000, 2000, 3000	25	92	5:1	AAO, 1979
AAOO 1959	500, 1000, 2000	25	92	5:1	AAOO 1959
NIOSH 1972	1000, 2000, 3000	25	92	5:1	NIOSH, 1972
NIOSH 1997	1000, 2000, 3000, 4000	25	92	5:1	NIOSH, 1998
Ireland	500, 1000, 2000, 4000	20	100	4:1	Hone, 2001
Wisconsin (CHABA)	1000, 2000, 3000	35	92	4:1	Sataloff, 1993
Oregon	500, 1000, 2000, 4000, 6000	25	92	5:1	Sataloff, 1993

\*Adopted by the American Medical Association for the calculation of hearing impairment.

CHABA = Committee on Hearing, Bioacoustics, and Biomechanics for the National Academy of Sciences, National Research Council.

The upgrades to software capabilities were as follows:

- \* Ability to calculate the maximum allowable noise exposure using National Institute of Occupational Safety and Health (NIOSH, 1998) and Occupational Safety and Health Administration (OSHA, 1983) criteria.
- \* Ability to use the NIOSH 1997 equation frequencies to determine a hearing handicap
- \* Expansion of the capabilities to project future hearing by using the International Standards Organization (ISO, 1999) compression factor for adding noise and presbycusis, to reduce the influence of the 1999 compression factor by 50 percent, and to project male audiometric data with female presbycusis data.

## METHOD

After studying the various options, JavaScript was chosen for program development since it was easy to use, required no user installation or plug-ins, had the highest cross-platform and browser compatibility, and was inexpensive. In fact, it was free, requiring only a browser and the software note pad to generate the program. Cost is a major factor because it is the author's intention to post these calculators on the Web, free of charge, for all to use. The only disadvantage was that the database storage function of the original calculation program was lost. Reports and audiometric data would have to be printed and stored on paper.

Eleven Web-based calculators were written in JavaScript using the program "Notepad" and were posted on the Web at <http://www.occupationalhearingloss.com> using *Microsoft FrontPage*. The calculators require *JavaScript 1.1*

for their operation and will operate on *Netscape 3.0* and *Explorer 4.0* or higher.

## Determination of the Recommended Maximum Level of Noise Exposure

The Web site also contains two calculators for determining OSHA and NIOSH recommended noise exposure levels. The formulas for these calculators are shown below:

$$\text{OSHA maximum noise exposure} = 16 / ((\text{dB}-85)^2/5) \quad (\text{OSHA, 1983a})$$

$$\text{NIOSH maximum noise exposure} = 16 / ((\text{dB}-82)^2/3) \quad (\text{NIOSH, 1998})$$

## Hearing Impairment Equations

All six of the original handicap equations are contained in the Web-based software, and one calculator using the NIOSH 1997-based frequencies (1000, 2000, 3000, and 4000 Hz) was added. The hearing handicap formulas supported by the Web-based program and the parameters used are shown in Table 1. Two calculators were written for determining maximum allowable noise exposure. Presbycusis is determined by Robinson and Sutton's (1979) (ISO 1999 Annex A) or Spoor's (1967) equations.

The master calculator contains all of the audiometric handicap and presbycusis evaluation formulas. There is also an added option of displaying the impairment results of all formulas for a single audiogram.

## Future Projection of Audiometric Thresholds

A major expansion of the program's capabilities was in the projection of audiometric data into the future using the ISO 1999 compression

factor. The ISO 1999 compression equation can now be used in adding presbycusis and non-presbycusis hearing loss for which the sum is greater than 20 dB. Use of this compression factor is optional in the master calculator but mandatory in all other projection calculators. The following steps were taken in the programming of this feature:

1. The noise component in the initial audiometric values is determined using the following equation:

$$\text{Hearing loss caused by noise} = (120 * (\text{IHT} - \text{IARL})) / (120 - \text{IARL})$$

where IHT is the initial hearing threshold and IARL is the initial age-related loss (determined by Robinson and Sutton's [1979] or Spoor's [1967] equations).

2. After the hearing loss caused by noise is calculated, the projected age-related loss (PARL) is determined by Robinson and Sutton's (ISO 1999) or Spoor's equations. The following formula is then applied to determine the projected threshold.

$$\text{Projected hearing threshold} = \text{PARL} + \text{NIL} - (\text{PARL} * \text{NIL}) / 120$$

where NIL = noise-induced loss.

3. All projected hearing thresholds and presbycusis levels are capped at 100 dB.

The master calculator also has the option of reducing the offset by 50 percent. This option changes the constant in the above equations from 120 to a value of 240.

## DISCUSSION

### Determination of the Recommended Maximum Level of Noise Exposure

Two different equations, one from NIOSH and one from OSHA, can be used to determine recommended maximum noise exposure levels in the workplace. The two methods give different results. It is amazing how two agencies of the same government can both develop recommendations on the prevention of occupational hearing loss but implement widely different standards.

The NIOSH recommendations are more restrictive. If followed, a person who works 40 hours per week for 40 years will have an 8 percent chance of developing a noise-related hearing loss. Following OSHA standards (NIOSH, Revised Criteria 1998), the worker would have

a 25 percent chance of developing a noise-related hearing loss. It should be remembered that there is a significant variation in the susceptibility to noise among individual workers (Chop, 1996). It can easily be argued that even the NIOSH recommendations, which are expected to produce an 8 percent incidence of hearing loss, are too lax.

Two Web-based calculators are offered on [www.occupationalhearingloss.com](http://www.occupationalhearingloss.com) for calculating the maximum recommended noise exposure under OSHA and NIOSH guidelines.

### Hearing Impairment Equations

The calculators on [www.occupationalhearingloss.com](http://www.occupationalhearingloss.com) offer a variety of hearing handicap equations (see Table 1). The most commonly used equations are from the American Academy of Otolaryngology (AAO 1979, using frequencies 0.5, 1, 2, and 3 kHz) and the American Academy of Ophthalmology and Otolaryngology (AAOO 1959, using frequencies 0.5, 1, and 2 kHz). A few states are still using the NIOSH 1972 handicap formula. In addition, the Committee on Hearing, Bioacoustics, and Biomechanics for the National Academy of Sciences, National Research Council (CHABA) recommended equation as used by the State of Wisconsin and the Ireland Equation (500, 1000, 2000, and 4000 Hz) and an equation that incorporates the frequencies that are used by the State of Oregon, which are also available on the Web-based master calculator.

### The NIOSH 1997 Formula

In 1981, the American Speech-Language-Hearing Association (ASHA) proposed a handicap formula using 1000, 2000, 3000, and 4000 Hz. In 1997, Prince et al used this definition and found it useful in the evaluation of the risk of developing a hearing loss or hearing handicap from noise trauma. Phaneuf et al (1985) also found that these frequencies provided "a superior prediction of hearing disability in terms of specificity, sensitivity, and overall accuracy." Based on this information, in 1997, NIOSH defined "material hearing impairment as an average of the HTLs [hearing threshold levels] for both ears that exceeds 25 dB at 1000, 2000, 3000, and 4000 Hz."

However, in 1998, Dobie pointed out that these frequencies never became ASHA policy and that they are not commonly used, if at all, in compensation. Dobie also pointed out that these frequencies are weighted toward the area

**Table 2 Hearing Handicaps as Determined Various Handicap Equations**

<i>Frequency (Hz)</i>	<i>Right Ear (dB)</i>	<i>Left Ear (dB)</i>
250	20	15
500	20	20
1000	25	30
2000	35	40
3000	50	55
4000	60	65
6000	55	60
<i>Handicap Equation</i>		<i>Handicap ( % )</i>
AAO 1979		12.2
AAOO 1959		3.3
NIOSH 1972		18.8
NIOSH 1997		27.5
Ireland		19.7
Wisconsin		4.7
Oregon		22.0

of maximum loss from noise exposure and away from the spectral "center of gravity" for speech at 1600 Hz. He stated that the best frequencies representing this band are 500, 1000, 2000, and 4000 Hz.

The author (Kavanagh, 1992) agrees with Dobie. It makes little sense to exclude the frequency of 500 Hz but include frequencies in half-octave intervals in the higher ranges. The frequencies of 1000, 2000, 3000, and 4000 Hz may be ideally suited for the monitoring and early detection of noise-induced hearing loss but should have limited application in the determination of compensation for occupational hearing loss. That being said, it should be noted that although the AAO 1979 formula is most commonly used, some compensation determinations by the federal government require only the frequencies of 1000, 2000, 3000, and 4000 Hz.

Because of the above, the master calculator also offers equations based on the NIOSH 1997 (1000, 2000, 3000, and 4000 Hz) and an equation based on the frequencies of 500, 1000, 2000, and 4000 Hz.

Table 2 presents a typical audiogram from noise-induced hearing loss and the hearing handicaps as determined by the various handicap equations. The calculated handicap varies from 3.3 (AAOO 1959) to 27.5 percent (NIOSH 1997), depending on the formula selected. Which equation is used is based on a combination of science and politics. Science chooses the frequencies in handicap equations based on the difficulty subjects have in using speech and language. Politics determines the law that can mandate equation use and is often based on the lobbying

influence of plaintiffs and defendants and the resultant economic impact of the calculated handicaps. Sometimes, the use of the appropriate equation needs to be argued in court.

### **Accounting for Presbycusis in Audiometric Data**

OSHA states that it is not mandatory to account for presbycusis in handicap determination (OSHA, 1983b), but it is often done in the legal setting, with several states allowing deductions for presbycusis (Sataloff and Sataloff, 1993).

In determining presbycusis, two equations are offered: Robinson and Sutton's (1979) and Spoor's (1967), both controlled for noise exposure in the tested subjects. Robinson and Sutton's data controlled for exposure to nosocosis (hearing loss caused by factors other than noise; Kryter, 1983) and intense noise, including gunfire. This data set is used for the determination of presbycusis in ISO 1999 Annex A. Unscreened subjects were used to determine thresholds in ISO 1999 Annex B. Kryter (1991) reported that the main difference between thresholds in ISO 1999 Annex A and those in the nonscreened male population Annex B is attributable to hearing loss from gunfire. An estimated 50 percent of the subjects in Annex B have been exposed to gun noise.

A third method to compensate for aging is used by OSHA. This method is not supported by the Web-based calculators but for comparison with values calculated from Robinson and Sutton's and Spoor's equations is shown in Table 3. In addition, there is no corresponding compression factor, as described in ISO 1999, when adding noise and presbycusis. Since there are no OSHA age correction values below 1000 Hz, they can be used only with the NIOSH and Wisconsin formulas.

The high incidence of sociocosis (non-workrelated noise-induced hearing loss, i.e., gunfire; Kryter, 1983) in the working population (Kryter, 1991), along with the frequency of inaccurate medical history (Cooper and Lightfoot, 2000), may lead the employer to argue for the use of OSHA standards. Hone et al (2001) found exaggerated thresholds in 25 percent of his subjects, and the Committee on Hearing Bioacoustics and Biomechanics (CHABA, 1963) reported exaggerated thresholds in 25 to 40 percent of studied subjects. It should be noted that the OSHA standards do not use a compression factor when adding presbycusis and noise-induced hearing loss,

**Table 3 Presbycusis Equations: Comparison of 60-Year-Old Males and Females (Thresholds in dB)**

<i>Frequency (Hz)</i>	<i>Robinson and Sutton's Equations ISO 1999 Annex A</i>		<i>Spoor's Equations</i>		<i>OSHA Standards 29 C.F.R. 1910.95 App F (After Subtracting Baseline at Age 20)</i>	
	<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>
250	5.3	5.3	6.9	7.3		
500	6.2	6.2	7.7	8.1		
1000	7.1	7.1	7.8	8.4	6	7
2000	13.4	10.6	14.9	12.3	10	8
3000	20.3	13.2	22.2	15.4	19	13
4000	28.2	15.9	28.4	18.8	28	14
6000	31.8	21.2	33.3	24.7	30	16
8000	38.8	26.5	35.2	25.3		

as is often used with Robinson and Sutton's equations (ISO 1999). If one compares the results using OSHA standards without a compression factor and Robinson and Sutton's equations with a compression factor, the OSHA standards will often predict a greater hearing loss.

**Future Projection of Audiometric Thresholds**

This feature has been significantly expanded and can be used to give guidance to the prediction of an exit audiogram based on pre-employment data. The question is often asked, Is the hearing loss on the employee's exit audiogram greater than the expected progression of the hearing impairment?

This projection is affected by the workers' exposure to nosocosis (hearing loss caused by factors other than noise; Kryter, 1983) and intense noise, including gunfire. Individuals exposed to gunfire are difficult to evaluate: "the hearing losses from the railroad noise in trainmen who had used guns are to a large extent masked by, or are not distinguishable from, the losses due to the gun noise, and vice versa" (Kryter, 1991). This is supported by Macrae (1971) and Passchier-Vermeer (1968), who reviewed several studies and reported that the maximum hearing loss from noise occurred during the first 10 years of exposure; after this, the hearing level followed the same course in four studies (Rosenwinkel and Stewart, 1957; Nixon and Glorig, 1961; Burns et al, 1964; Taylor et al, 1965) and even decreased in one study (Gallo and Glorig, 1964), as in the nonexposed group.

Another confounding factor in determining the impact of nosocosis and sociocosis (non-workrelated noise-induced hearing loss; Kryter, 1983)

in plaintiffs is the accuracy of the plaintiff's history. It has been shown in multiple reports that the history derived from the plaintiffs in a legal case is often not accurate (Cooper and Lightfoot, 2000), with up to 25 to 40 percent of subjects exaggerating their hearing losses reported in CHABA (1963).

Another use of the projection feature in the software is to give guidance to the prediction of the future hearing in a patient. Patients will often wonder what the chances are that they will have to wear a hearing aid in the future. This is a somewhat easier question to answer because a stipulation can be added to this prediction that the patient refrain from activities that are associated with an increased incidence of hearing loss. Risk factors that can be avoided or mitigated with proper medical treatment are ear infections, vertigo, diabetes, smoking and heart disease, and exposure to environmental noises such as gunfire, home stereos, rock concerts, and lawn equipment (Clark, 1992).

**Interaction of Noise-Induced Hearing Loss and Presbycusis**

The characteristics of presbycusis and how it progresses and interacts with noise-induced hearing loss is important in the prediction of future hearing. One of the first studies on the relationship between presbycusis and noise was by Macrae (1971), who found that in noiseexposed veterans, the progression of hearing loss at 1000 and 4000 Hz was predicted by Spoor's equations. In a review of several studies, Passchier-Vermeer (1968) concluded that after 10 years of exposure, the damage caused by noise exposure remains constant, and presbycusis progresses as predicted.

Table 4 Hearing Loss in Miners

Frequency (Hz)	Observed Hearing Loss (dB) Mean Age 49.5	Expected Hearing Loss (dB) Age 49.5	Observed Hearing Loss (dB) Mean Age 56.5	Expected Loss RS (Difference) Age 56.5	Expected Loss RS + CF (Difference) Age 56.5
2000	42	35.0	46	45.50 (-0.5)	44.36 (-1.6)
3000	54	42.6	57	59.64 (-2.6)	57.43 (+0.4)
4000	60	44.1	65	67.87 (-2.9)	64.52 (+0.5)
6000	56	38.1	61	64.82 (-3.8)	61.53 (+0.5)
8000	58	36.2	64	68.78 (-4.8)	64.81 (+0.8)

Modified from Rosler (1994). The second column is the mean hearing loss at age 49.5 of 45 subjects; the third column is the expected hearing loss after subtraction of presbycusis thresholds derived from Robinson and Sutton's equations (used to derive the data for ISO 1999 Annex A); the fourth column is the mean hearing loss at age 59 of 59 subjects; the fifth column is the expected hearing loss after adding presbycusis thresholds derived from Robinson and Sutton's equations (used to derive the data for ISO 1999 Annex A) for age 56.6 to the third column, the difference between the expected threshold and the observed threshold is shown in parentheses; the sixth column is the expected loss after applying Robinson and Sutton's equations and the ISO 1999 compression factor (Mills, 1998) to the data in column two and projecting the data to age 56.5 The difference between the expected threshold and the observed threshold is shown in parentheses.

RS = Robinson and Sutton; CF = compression factor.

However, there was one exception, a study by Gallo and Glorig (1964) that found that when the average presbycusis levels are subtracted from the total threshold, the component from noise-induced hearing loss decreases with age. Welleschik and Raber (1978) also found slightly less effect of noise exposure in the oldest workers. Rosler (1994) observed that in higher ages and in hearing losses above 45 to 50 dB, presbycusis and noise-induced hearing loss were not purely additive. Many of Rosler's subject groups were small, and his study assumes that each subject group was exposed to the same noise exposure level, at the same ages, over decades of working. More importantly, in Rosler's calculations, he simply added or subtracted the thresholds for presbycusis as described in ISO 1999 and did not apply the ISO 1999 compression factor as described by Macrae (1991) and Miles (1999). Reanalysis of Rosler's data for his largest subject group with known mean ages using the ISO 1999 compression factor is shown in Table 4. Applying the compression factor results in a more accurate projection.

In projecting audiometric data, the Web-based calculators first determine the noise-induced hearing loss component in the audiometric test data that is to be projected. This is not done simply by subtracting the ISO 1999 Annex A presbycusis values but also by accounting for the additivity of hearing loss from noise and presbycusis using the ISO compression factor.

Other formulas have been proposed for calculating the relationship of noise-induced hearing loss and presbycusis. Bies and Hansen

(1990) proposed an equation that added the two on an antilogarithm basis. However, Macrae (1991) applied the two formulas to audiograms from aging war veterans with noise-induced hearing loss and found a better prediction using the ISO 1999 formula. However, he also found that the ISO 1999 formula underestimated the hearing loss progression and recommended doubling the compression constant value from 120 to 240 (this results in the reduction of the offset factor by 50%). In addition, he proposed that the constant may change as a function of frequency. Further research in this area is needed.

### ***Gender and Presbycusis***

Several studies have looked at primitive cultures that were not subjected to occupational noise (Rosen et al, 1962; Goycoolea et al, 1986). These studies found aging effects in the studied population, but there were no differences between men and women (Rosen et al, 1962; Goycoolea et al, 1986). In addition, animal studies have found no gender difference (Hunter and Willot, 1987). Thus, it has been postulated that the gender difference, which causes males to have worse hearing, is attributable to differences in environmental factors, primarily caused by noise (Kryter, 1983). Of interest is that Goycoolea et al (1986) found in the Easter Island population hearing loss caused by presbycusis equal in both males and females. Those males who left the Island and lived in an industrial society had higher levels of hearing loss. Those male natives who stayed on the Island had presbycusis levels

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similar to the females of the industrial society of the United States.

Other factors should also be considered with giving an opinion regarding hearing loss and projecting data. Mills (1998) reported that projecting audiometric data may overestimate the hearing loss in individuals exposed to intense, short-duration noise. Rosenhall et al (1990) presented data indicating that with advanced age (i.e., above age 79), the difference in hearing acuity between individuals exposed to and not exposed to noise is "no longer significant."

The Web-based calculators also offer several projection options. They are as follows:

- \* Robinson and Sutton's equations (1979)
- \* Spoor's equations (1967)
- \* Thresholds can be projected with or without the ISO 1999 compression factor
- \* Option to double the constant in the compression factor (reduces the threshold offset by 50%)
- \* Male data can be projected with female presbycusis data (for those who feel strongly that the difference between male and female presbycusis can be accounted for by nosocosis and sociocosis)

### A Caveat About the Prediction of Future Hearing Thresholds

When using the calculators to project future hearing from audiometric data, one must remember that the legal judgment of "what is more likely than not" is being made to obtain a settlement of a legal action. Medical causation is not sought. In any individual, the evaluation will probably be inaccurate. What is sought is a medical-legal opinion (legal causation), which has an equal chance of underestimating as it does of overestimating the conclusion.

Thus, one should *not* use this technique, or account for presbycusis, when determining the existence or progression of occupational hearing loss for medical purposes. If an employee has even a small chance that his or her hearing loss is caused by noise exposure, aggressive intervention should be taken that is aimed at preventing further progression.

NIOSH (1998) does *not* recommend accounting for presbycusis when looking for medical causation of a progressive hearing loss:

NIOSH does not recommend that age correction be applied to an individual's audiogram for significant threshold shift

calculations. Although many people experience some decrease in hearing sensitivity with age, some do not. It is not possible to know who will and who will not have an age related hearing loss. Thus, applying age corrections to a person's hearing thresholds for calculation of significant threshold shift will overestimate the expected hearing loss for some and underestimate it for others, because the median hearing loss attributable to presbycusis for a given age group will not be generalized to that experienced by an individual in that age group.

However, this recommendation does not apply when determining legal causation.

### Determining the Percentage of Handicap Attributable to Presbycusis

The addition of the ISO 1999 compression factor created a dilemma in how to calculate the percentage of presbycusis in the final projected audiogram. As stated above, there is growing evidence that as the hearing loss from noise exposure increases, the amount of presbycusis and/or noise-induced hearing loss decreases by a compression factor. One may argue that presbycusis may make the damage from noise exposure less or that the noise exposure lessens the development of presbycusis. Medically, this may be an important distinction, but, medicolegally, it is not. Either the noise damage was lessened and the actual amount of presbycusis was the same, or the noise trauma caused a portion of the presbycusis not to develop, in which case, this portion of the noise trauma did no harm. In either case, this portion of the hearing loss should not be compensatable. Thus, the calculators report the "percentage of the handicap expected from presbycusis" and not the "percentage of the handicap caused by presbycusis."

Thus, all Web-based calculators report presbycusis thresholds as defined by either Robinson and Sutton's or Spoor's equations. These values are not "compressed" or adjusted for the coexistence of noise-induced hearing loss.

### Sample Case Report

A 64-year-old male is leaving employment at an industrial tool shop. He has a history of hunting and "usually" wears earplugs. He does not wear ear protection when operating lawn equipment.



**Table 5 Pre-employment Audiogram of a 25-Year-Old Subject**

Frequency(Hz)	Right Ear (dB)	Left Ear (dB)
500	20	15
1000	25	20
2000	30	30
3000	35	40
4000	50	55
6000	45	50

AAO 1979 handicap of 2.19%.

His pre-employment audiogram is shown in Table 5. The subject's age is 25.

His exit employment audiogram is shown in Table 6. The subject's age is 64.

Should the employer be responsible for the increase in the employee's hearing handicap? The author's answer would be "No." The progression of this subject's hearing loss is what is expected using Robinson and Sutton's equations with the ISO 1999 compression factor. In addition, the subject had a history of noise exposure outside the workplace that would further reduce the employer's liability in this case.

**CONCLUSION**

This article describes several Web-based calculators to aid the practitioner in the evaluation of occupational hearing loss. The calculators can determine the NIOSH and OSHA maximum recommended noise exposure levels and expected threshold shifts from presbycusis and evaluate hearing handicaps using eight equations. The literature is reviewed on several methods of predicting future hearing losses in subjects. The calculators support presbycusis measurements using Robinson and Sutton's and Spoor's equations and use the ISO 1999 compression factor for adding the effects of

**Table 6 Exit Employment Audiogram of a 64-Year-Old Subject**

Frequency (Hz)	Right Ear (dB)	Left Ear (dB)
500	25	20
1000	30	25
2000	40	40
3000	50	55
4000	70	75
6000	70	76

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