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OCCUPATIONAL HEARING CONSERVATION

A series of articles on occupational hearing testing and conservation from leaders in the field

Maurice H. Miller, PhD, guest editor

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OCCUPATIONAL HEARING CONSERVATION

▶ **INTRODUCTION**

Occupational Hearing Conservation: Unique Challenges & Opportunities

By Maurice H. Miller, PhD, *guest editor*

This special issue of *The Hearing Review* features articles on the topic of occupational hearing testing and conservation, guest-edited by Maurice Miller, PhD. The following article introduces some of the most pressing issues in occupational hearing conservation and the unique opportunities the field holds for hearing care professionals.

Noise exposure, in and out of the workplace, accounts for more new cases of sensorineural hearing loss (SNHL) and tinnitus than all other etiologies combined. Of the over 30 million persons with hearing loss in the United States, noise exposure was the primary causative factor or, with age and ototoxic medications, a major contributing factor. Over 5 million workers in various manufacturing industries are exposed to average daily noise levels of 85 dBA or more, capable of producing significant and irreversible hearing loss in vulnerable, unprotected ears over a work lifetime. Another 5 million workers receive high levels of noise exposure in agriculture, mining, construction, the military and transportation. The Veterans Administration, H.U.D. and the Independent Agencies Appropriation Committee have expressed concern about 20 million people in the United States who are exposed on a regular basis to dangerous levels of noise in the workplace.[1]

Despite an avowed interest in noise abatement expressed by various federal agencies, it is now over 12 years since the Environmental Protection Agency's (EPA) Office of Noise Abatement and Control was closed and as of this date neither the Congress nor the EPA has yet designated any funds for the program. While the dangers of air and water pollution are widely recognized (and comparatively well financed), noise is an invisible and largely ignored destroyer of human auditory function and communication. Dr. Alice Suter, one of the nation's leading investigators in this area, reminds us that, while "noise often causes discomfort and sometimes pain, noise does not cause ears to bleed and noise-induced hearing loss usually takes years to develop" and "can indeed impair the quality of life, through a reduction in the ability to hear important sounds and to communicate with family and friends."[2]

While noise exposure from home appliances, personal stereo headsets, amplified guitars, power saws, noisy toys used by young children, and hunting and target shooting are documented causes of hearing loss, noise in the workplace is *by far* the most significant factor in causing massive hearing loss in the work population. The sound pressure level of the noise and duration of exposure over a work lifetime are predictable factors accounting for SNHL in the work population. The frequency spectrum of the noise and individual susceptibility account for Damage Risk Factors relating to the effects of noise exposure.

Control of noise in the workplace is a mandated responsibility of OSHA, a division of the Department of Labor. The Walsh-Healey noise standard[3] required employers to limit workers' exposures to daily average noise levels of 90 dBA for 8 hour exposures with a time-intensity trade-off of 5 dB. Feasible engineering or administrative controls were required to keep the employees' exposure to the specified levels. Congress passed the *Occupational Safety and Health Act of 1970* which delegated specific responsibilities to the

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Department of Heath and Human Services and a newly created organization called The National Institute for Occupational Safety and Health (NIOSH). A division of the Department of Labor called the Occupational Safety and Health Administration (OSHA) was assigned responsibility for regulating and enforcing measures relating to occupational health and safety programs. A "final" revised *Hearing Conservation Amendment* (HCA) was published in the Federal Registry on March 8, 1983.[4] The events preceding the passage of the final standard have been reviewed by Suter.[5]

The OSHA *Final Hearing Conservation Amendment* remains the standard which serves as the basis for *Occupational Hearing Conservation Programs* (OHCPs) throughout the nation. Individual companies have viewed the Amendment as a "starting point" and have incorporated procedures which exceed OSHA's requirements. Furthermore, on the basis of 16 years of real-world experience, significant weaknesses in the OSHA standard have been identified.

NIOSH in 1998 released a document titled "Criteria for a Recommended Standard: Occupational Noise Exposure"[6] to alert OSHA that the research and science in this area supports a *revision* of the existing standard. NIOSH states in connection with their new document that "Criteria documents provide the scientific basis for new occupational safety and health standards." Recommendations by NIOSH include changes in the *Recommended Exposure Limit* (REL), a new definition of the *Standard Threshold Shift* (STS), elimination of the currently optional presbycusic "correction," a revised method of derating the *Noise Reduction Ratio* (NRR) for different forms of personal hearing protection and methods of evaluating the effectiveness of the OHCP. OSHA is not compelled to take the advice offered by NIOSH, but OSHA is expected to address the issues raised by NIOSH and will probably adopt at least some of the recommendations in a forthcoming revision of the standard. "Behind the scenes" activity regarding potential legislative changes are discussed by John Franks following this article.

Regarding noise exposure, NIOSH has moved away from the current OSHA position of dual action and criterion levels to a single recommended exposure limit of 85 dBA. Currently, personal hearing protection must attenuate employee exposure to an eight hour *Time-Weighted Average* (TWA) of 90 dB. For employees who have experienced a standard threshold shift, hearing protectors must attenuate employee exposure to an 8 hour TWA of 85 dB or below. A single REL of 85 dBA will offer significantly greater protection to noise-exposed workers. NIOSH has concluded from review of extensive research that, at the 85 dBA level, there is an 8% excess risk of hearing loss. The risk rises to 25% at the 90 dBA exposure level. These risk estimates are based upon the occurrence of a *material* hearing impairment defined as the average hearing threshold levels for both ears of greater than 25 dB at 1000, 2000, and 3000 Hz over a 40-year work lifetime. NIOSH recommends exposure monitoring every two years and repeat monitoring within three months of the occurrence of a change in equipment, production processes or maintenance routines. Currently, OSHA requires monitoring once to determine risk and then only as conditions change for the worse.

A 3 dB time-intensity trade-off is recommended rather than the current 5 dB. The 3 dB exchange rate is based on the equal-energy exchange principle in which an increase of 3 dB doubles the acoustic energy. This principle considers equal amounts of noise energy to be equally hazardous. The 3 dB exchange rate is the method most firmly supported by scientific evidence and is in use by the EPA, the U.S. Department of Defense and worldwide by Canada, Australia, New Zealand, the People's Republic of China, the United Kingdom and many others.[6]

NIOSH has also addressed and made recommendations regarding the audiometric testing aspects of the standard. The current standard requires that pure-tone air-conduction audiograms be performed on all employees whose noise exposure reaches or exceeds the OSHA "action level" (i.e., 85 dB or more for a TWA of 85 dBA or more). The baseline audiogram must be performed within six months of the employee's first exposure to the action level or within one year when testing is performed on a mobile test van. The baseline audiogram must be preceded by at least 14 hours without exposure to workplace noise. *Personal hearing protective devices* (PHPD) are considered an acceptable substitute when workplace noise exposure cannot be avoided. Currently, the definition of a *standard threshold shift* (STS) is an *average* change of 10 dB or more in either ear at 2000, 3000 or 4000 Hz. A retest is allowed (not required) within 30 days and the retest threshold levels can be considered as the annual audiogram. A presbycusic correction based on the age correction values for males and females included in tables F-1 and F-2 of the Appendix to the Standard is allowed and can be applied to the annual audiogram. When an STS has occurred, the employee is informed in writing within 21 (calendar) days of the determination. When the STS reaches or exceeds 25 dB average, and is related to workplace noise exposure, the employer must enter this occurrence on OSHA Form 200, on which is recorded occupational injuries and illnesses.[7]

NIOSH has made significant recommendations for change in this area. Workers are not to be exposed to noise levels at or above 85 dBA for a mini-

> A "natural potentiation" between noise and industrial chemicals may occur. In a study of simultaneous exposures to noise and carbon monoxide on pure-tone thresholds and hair cell survival in rats, large threshold shifts at all frequencies were found.[12] A 1986 study found that 23% of a group of workers exposed to noise levels of 80-90 dBA and industrial solvents suffered "pronounced hearing loss" while 5-8% of workers exposed to higher noise levels (95-100 dB) in non-chemical environments had impaired hearing.

mum of 12 (not 14) hours before receiving a baseline audiometric test. PHPDs are not to be used in lieu of the required "quiet" period. It should be noted that the "quiet" period of non-noise exposure refers to occupational noise exposure. Recreational noise exposure (e.g., shooting, rock concerts, home shop tools, snowmobiles and aerobics classes) should be avoided and workers informed of these risks to their hearing and the need to avoid them prior to the audiometric test. While the "quiet" period refers to the baseline audiogram, a number of organizations have recommended that the annual test be performed during or after the work shift to assist in identifying workers who sustain the largest shifts in their hearing so that appropriate steps can be taken to prevent further hearing loss. Among the possible steps which can be taken with this group of susceptible workers are more frequent monitoring of hearing and meticulous supervised use of PHPDs. The use of otoacoustic emissions (OAE) promises to provide early evidence of outer hair cell damage from noise (and other factors) since abnormal OAE findings may precede pure-tone sensitivity changes.[8]

NIOSH, after review of various recommendations for change in the STS definition, has selected a definition of a shift for the worse of 15 dB at any test frequency confirmed to be persistent by an optional follow-up test conducted immediately after the annual test which they call the "monitoring audiogram." Thus, NIOSH advocates the elimination of frequency averaging in calculating the STS. NIOSH also favors the elimination of the age correction factor on the premise that adjusting hearing test results "masks" hearing loss until it is too late for effective intervention and prevention. NIOSH further recommends two—not one—hearing tests per year for workers exposed to a level of 95 dBA or greater.

The ambient noise level for areas in which audiometric testing is performed must currently conform to the ANSI S3.1-1960 (R 1971) levels. The more vigorous, stringent allowable noise levels incorporated in the ANSI S3.1-1991 Standard receive NIOSH's endorsement.[10] For example, with ears covered as is done in occupational audiometric tests, the noise level on the newer standard cannot exceed 14.5 dB in the frequency range where the center frequency is 500 Hz compared to 40 dB in the 1960 standard. The new standard specifies 21.5 at 1000 Hz; the old standard specifies 40 dB. Adoption of the 1991 requirement would necessitate major changes in the test environments (i.e., many currently used rooms will not conform to the 1991 standard).

Finally, NIOSH recommends an Exit Audiogram for workers leaving employment or whose jobs no longer involve exposure to hazardous noise. In performing the audiometric test, NIOSH recommends testing at 8000 Hz which can provide useful information about etiology. This author has advocated testing at 8000 Hz for many years and has reported the detection of a large acoustic tumor in a secretary employed at a major power generation plant; her tumor was initially signaled audiologically by reduced sensitivity at 8000 Hz in the affected ear.[11]

Hearing professionals should also be aware of the impact of environmental toxins in the workplace which can affect hearing in association with noise exposure or independent of such exposure. Chemicals such as the organic solvent toluene which is used in glues and latex-based paints, and styrene and xylene which are commercially used in plastics and to clean various types of industrial equipment such as printing presses and computer boards are ototoxic.[11] A "natural potentiation" between noise and industrial chemicals may occur.

In a study of simultaneous exposures to noise and carbon monoxide on pure-tone thresholds and hair cell survival in rats, Fechter, Young and

TERMS AND ABBREVIATIONS USED IN OCCUPATIONAL HEARING CONSERVATION

As with most specialties, the field of occupational hearing conservation and testing has a substantial number of unique abbreviations and terms. The following is a list of terms designed to help the reader when reading articles in this special edition of *The Hearing Review*.

%W_S: Percent worse sequential

%BW_S: Percent Better or Worse sequential

AAO-HNS: American Academy of Otolaryngology-Head & Neck Surgery

ACGIH: American Conference of Governmental Industrial Hygienists

ADBA: Audiometric data-base analysis

ANSI: American National Standards Institute

ARPTS: Age-related permanent threshold shift

ASA: Acoustical Society of America

ASHA: American Speech-Language-Hearing Assn.

CAOHC: Council for Accreditation in Occupational Hearing Conservation

CPL: A compliance directive

DRC: Damage risk criteria

EDM: Electronic data management

EPA: Environmental Protection Agency

HCA: Hearing Conservation Amendment

HCP: Hearing conservation program; same as OHCP.

HLs: Hearing levels

HML: High/medium/low levels

HPDs: Hearing protection devices

MSHA: Mine Safety and Health Administration

NIOSH: National Institute for Occupational Safety and Health

NIPTS: Noise-induced permanent threshold shift

NIHL: Noise-induced hearing loss

NHCA: National Hearing Conservation Assn. Also see CAOHC.

NRR: Noise Reduction Rating used to assess HPDs

NRR(SF): Noise Reduction Rating (Subject Fit)

OHCP: Occupational Hearing Conservation Program

OHC: Occupational hearing conservationist

OSHA: Occupational Safety and Health Administration, a division of the Dept. of Labor

PEL: Permissible exposure limit

PHPDs: Personal hearing protection devices

REL: Recommended exposure level

SNHL: Sensorineural hearing loss.

STS: Significant threshold shift

TWA: Time-weighted average

TWA8: Time-weighted average over an 8-hour period

Carlisle[12] found that large threshold shifts at all frequencies (but mainly at the higher frequencies) produced widespread hair cell loss over half of the basilar membrane. A 1986 study found that 23% of a group of workers exposed to noise levels of 80-90 dBA and industrial solvents suffered "pronounced hearing loss" while 5-8% of workers exposed to higher noise levels (95-100 dBA) in nonchemical environments had impaired hearing. In a study performed at the Univ. of Cincinnati, workers exposed simultaneously to noise and toluene faced a 24-fold greater risk of hearing loss than workers exposed to either noise or toluene separately. Synergistic interactive effects clearly occur with such dual exposures.[13] Synergistic interactive effects may also affect other dual exposures in the workplace (e.g., noise and aspirin, noise and other ototoxic medications such as cisplatinum and neomycin).

Personal Hearing Protective Devices (PHPDs)

NIOSH has made a number of important recommendations in the area of PHPDs which are considered in the article by Elliott Berger (pgs. 68-72). Currently, OSHA has a dual criterion for use of PHPD's. OSHA requires hearing protection for workers exposed to a 90 dBA or greater level. For workers exposed to 85 dBA who have experienced an STS, hearing protection is required, but not for those exposed to 85-89 dB who have not sustained an STS. This creates an unwieldy situation with morale problems in many operations: some workers do not have to use PHPDs while others who have not experienced an STS do. Those exposed to the OSHA "action level" are required to be enrolled in the OHCP, a major objective of which is to get the employee to use PHPDs. NIOSH has appropriately addressed this problem by its recommendation that hearing protection be required for *all* exposed workers at the 85 dBA level independent of whether an STS has been sustained.

NIOSH anticipates the eventual adoption of ANSI Standard S12.6-1997.[14] The object of this standard is to develop procedures to estimate the field performance of PHPDs. Methods currently in use overestimate the attenuation which employees experience in the workplace. The new standard uses a protocol designated as "Subject-Fit" which assesses subjects who are naive with respect to the use of hearing protection. Royster et al.[15] found results from the Subject-Fit method which corresponded more closely to real world data than other protocols which have been evaluated.

On an interim basis, NIOSH advocates a *variable* derating system to correct for the known differences between laboratory-derived attenuation values and the protection actually experienced by workers in the real world. This variable derating system is as follows: Earmuffs: subtract 25% from the manufacturer's labeled NRR; 50% for slow-recovery formable earplugs and 70% for all other earplugs. Berger also discusses the implications of these procedures in his article in this issue.

Evaluating the Effectiveness of the OHCP

NIOSH has proposed an annual review of hearing test data as the definitive measure of program effectiveness. The effectiveness of the program should be evaluated in terms of the hearing losses prevented for each worker and the overall rate of hearing loss in the population of workers. This evaluation should be performed on a continual basis. A method of evaluation is necessary that can monitor trends in the population of workers enrolled in the program and identify problems with the program before many STSs occur.

The first part of the evaluation examines the internal integrity of the audiometric data. A draft ANSI standard details a method for such an evaluation.[17] The second part of the evaluation involves a comparison of the rate of threshold shift among noise-exposed workers to that of persons not exposed to occupational noise. This can be done by comparing the percentage of workers showing STSs with a control group of non-noise-exposed workers within the same company. This system requires that all workers, whether or not they are noise-exposed, receive annual audiometric examinations. STS incidence rates of 3-6% are considered reasonable rates that can be met by effective programs. The Roysters do not consider STS as a valid means of evaluating the effectiveness of OHCPs. They address the topic of evaluating the effectiveness of OCHPs in their article (pgs. 28-34).

Conclusion

As demonstrated, the field of occupational hearing testing and conservation is diverse and dynamic. In addition to the topics and articles mentioned above, this special edition of *The Hearing Review* also features a review by John Earshen of procedures for noise exposure measurements (pgs. 37-40), while John Erdreich details engineering assessment methods and modifications that can help quiet noisy industrial machinery (pgs. 42-46). Allocation of hearing loss methods (e.g., noise-induced vs. age-related hearing loss) relative to litigation issues are discussed by David Lipscomb (pgs. 48, 61-64). Additionally, George Cook presents information on the necessity for and use of software-based occupational hearing conservation data (pgs. 74-78).

Few audiological subspecialties offer more promise than occupational hearing conservation in terms of future growth for the hearing care profession *and* for educating the working-age public on the value of better hearing, hearing conservation and available options in the event of hearing loss. ◆

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