

WORKPLACE SOLUTIONS

From the National Institute for Occupational Safety and Health

Using Total Worker Health[®] Concepts to Address Hearing Health

Summary

Exposure to hazardous types and levels of noise is common both at work and in daily life. Therefore, while protecting workers on the job is very important, it is also important to raise awareness and encourage protective behavior outside of work. In addition, other risk factors—both on and off the job—can interact with noise to increase or decrease risk. Through its *Total Worker Health*[®] (TWH) Program, the National Institute for Occupational Safety and Health (NIOSH) recommends an integrated approach to address the hearing health of workers. An integrated approach is a comprehensive consideration of risk factors intended to protect workers from work-related injury and illness and help them advance their overall health and well-being, on and off the job. The approach includes addressing exposures at work, environmental factors, and personal factors [NIOSH 2018c]. This Workplace Solutions document focuses on the application of TWH concepts to promote better hearing health and reduce the risks associated with noise exposure.

Description of Noise Exposure

Hearing health is important in all stages of life, and many factors influence hearing health. Each individual is on a personal “hearing health trajectory” – a lifelong path in which genetic, biological, behavioral, environmental, and social factors over time contribute to hearing ability as life progresses [Davis et al. 2016]. This trajectory begins at conception and is influenced by health, socio-economic factors, disease, genetics, injury, access to health care, lifestyle choices (e.g., smoking, diet), recreational activities (e.g., motorcycling, concerts, loud sports), environmental conditions, and occupational exposures [Davis et al. 2016]. These elements interact to influence how well one will be able to hear as he or she ages. Although some of the factors are difficult (if not impossible) to control (like ageing itself), many can be modified to reduce the risk of hearing loss. These include disease prevention, good nutrition and physical fitness, limiting exposures to hazards, and participating in hearing loss prevention programs at work. A comprehensive, integrated approach to health is needed to effectively prevent or reduce the risk of auditory disorders

such as hearing loss, tinnitus (ringing in the ears), and hyperacusis (abnormal sensitivity to sound).

Among the risk factors we can control, the single most important is exposure to loud noise. Exposures are not restricted to the workplace; exposures occur throughout our lifetime in our communities and home environment.

Health Effects of Noise Exposure

In addition to hearing loss, overexposure to noise can cause tinnitus and hyperacusis. Noise is a nonspecific biological stressor; as such, it can cause reactions in other bodily system as well. Exposure to high noise levels can cause adverse changes in blood pressure and chemistry [Themann et al. 2013a]. Noise and hearing loss have been associated with a wide variety of health problems, ranging from stress and hypertension to depression. Symptoms such as headaches, irritability, increased tension, fatigue, sleep disorders, and cardiovascular disease have also been described. Noise can sometimes lead to performance decrements (especially for complex or simultaneous tasks) and has been associated with increased accident risk and absen-



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teeism [NIOSH 2011; Themann et al. 2013a]. Implementing strategies that minimize noise exposure could have positive health effects beyond hearing health.

Exposure Limits

In the United States, occupational regulations and standards were established to protect workers against the health effects of exposure to hazardous substances and agents when certain values (or limits) are reached. Note that the exposure limits for noise have been established to prevent hearing loss caused by repeated exposure to excessive noise. Other health effects (e.g., stress, cardiovascular disease) may occur at lower levels, and other risk factors (e.g., ototoxic exposures, overall physical health) may alter one's personal hearing loss risk.

OSHA Permissible Exposure Limit

The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for noise is 90 dBA, and the action level (AL) is 85 dBA, both as an 8-hour TWA using a 5-dB exchange rate [Occupational Noise Exposure 29 CFR 1910.95]. This means that hearing protection, administrative controls, and annual monitoring are required when exposures exceed the AL, and engineering controls are required when exposures exceed the PEL. The OSHA occupational noise standard also mandates that exposures to impact or impulsive noise not exceed 140 dB peak sound pressure level.^{*}

^{*}The MSHA rule (30 CFR Part 62) is similar to OSHA's.

NIOSH Recommended Exposure Limit

NIOSH establishes recommended exposure limits (RELs) for various hazards on the basis of the best available science and practice. The NIOSH REL for noise is 85 decibels, using the A-weighted frequency response (often written as dB(A) or dBA) averaged over an 8-hour workday—usually referred to as the time-weighted average (TWA). The A-weighting of noise levels is used to provide a rating that indicates the injurious effects of noise on human hearing. Exposures at or above the REL are considered hazardous [NIOSH 1998].

NIOSH recommends a 3 dB exchange rate, or time-intensity trade-off, for occupational noise exposure. This means that for every 3 dB increase in exposure level, the allowable exposure time is halved; for example, when the noise level increases from 85 dBA to 88 dBA, the allowable exposure time decreases from 8 hours to 4 hours. The 3 dB exchange rate is based on the equal energy principle: with every 3 dB increase in noise level, the energy is doubled and therefore the exposure time is halved. Table 1 shows allowable exposure times for various noise levels under the NIOSH REL.

Exposure limits are not always set at levels that will protect the entire exposed population. In setting the REL for noise, NIOSH acknowledged that 8% of the noise-exposed population could still develop a hearing loss if exposed over a 40-year working lifetime to average daily noise levels of 85 dBA. Because individual susceptibility to noise exposure varies, NIOSH recommends the use of hearing protection whenever noise levels exceed 85 dBA—regardless of exposure duration.

Table 1. Allowable exposure times under the NIOSH REL

Exposure level	Time to reach maximum daily allowable noise dose (per NIOSH REL)
85 dBA	8 hours
88 dBA	4 hours
91 dBA	2 hours
94 dBA	60 minutes
97 dBA	30 minutes
100 dBA	15 minutes

EPA

The United States Environmental Protection Agency (EPA) recommends maintaining environmental noises below 70 dBA (averaged over 24 hours) to prevent hearing loss in the general population [EPA 1974]. This recommendation is based on evidence available at the time; EPA used the same scientific evidence and the same equal-energy rule that NIOSH used in setting its REL. Also like the NIOSH REL, the EPA assumed 40-year lifetime exposures in making its recommendations.

The difference between the NIOSH REL and the EPA recommendation for environmental noise exposures is due to several key factors. The NIOSH REL assumes an 8-hour exposure (during the workshift) with time for the ear to recover before the next exposure; the EPA limit is averaged over 24 hours with no time between exposures. In addition, the NIOSH limit is based on exposure for 250 *working* days a year, whereas the EPA limit is based on exposures for 365 days a year. Finally, the NIOSH REL is set at a level that will protect 92% of workers, whereas the EPA limit is set at a level that will protect 96% of the population [NIOSH 2016b].

WHO

The World Health Organization [WHO] also recommends that noise levels be maintained below 70 dBA for 24-hour exposures [WHO 1999] in order to prevent hearing impairment. Like NIOSH and EPA, the WHO recommendation incorporates a 3 dB equal energy time-intensity trade-off.

Research on Noise Exposure: Occupational Factors

Much of our understanding of noise-induced hearing loss comes from studies on the effects of noise at work, considering a working lifetime of up to 40 years [NIOSH 1998;

ANSI/ASA 2013]. Occupational hearing loss is one of the most common work-related illnesses in the United States. According to the National Health Interview Survey, 24% of cases of hearing difficulty among the working population are attributable to workplace exposures [Tak and Calvert 2008].

Hearing loss is prevalent in many industries—both those traditionally associated with noise exposure (such as manufacturing, construction, and mining) as well as industries generally assumed to have minimal risk of noise exposure (such as real estate and health care) [Masterson et al. 2013, 2015].

Many workers do not use hearing protection because they think it interferes with communication or warning signals. Other workers may adopt a fatalistic attitude and believe that hearing loss is inevitable or that management is not concerned about their hearing health [Morata et al. 2005].

Research on Noise Exposure: Environmental/Non-work Factors

Noise levels during some daily activities (for example, mowing the lawn or waiting for an approaching subway) and some recreational activities (such as motorcycling or listening to a personal music player) can exceed 70 or even 85 dBA. Some hobbies (such as hunting, target shooting, concerts, or setting off fireworks) can exceed 140 dB and are loud enough to trigger immediate auditory disorders. The NIOSH Hearing Loss and Prevention Topic Page [NIOSH 2018b] shows the decibel levels from various daily activities and other noise sources. CDC Vital Signs and the CDC National Center for Environmental Health [CDC 2017, 2019] also have information about decibel levels and sources of potential hearing loss.

Studies of populations who are not exposed to noise at work show a much lower risk of hearing difficulties than populations exposed at work [Masterson et al. 2016], and some studies show no group effects for those exposed to recreational noise or music [Neitzel et al. 2004; Dehnert et al. 2015; Williams et al. 2015]. However, certain individuals can still experience adverse hearing effects from recreational noise exposure [Flamme et al. 2012; Kardous and Morata 2010]. Susceptibility is determined by each person’s “hearing health trajectory” and by how loud and how often a person is exposed to hearing hazards. Moreover, since the duration of noise exposure influences risk, total noise exposure (including both work and non-work exposures) must be considered in efforts to prevent negative effects from noise. Since identifying those who are more susceptible is not possible, it is important to understand and manage risks.

What is Total Hearing Health?

Expanding occupational hearing conservation initiatives beyond the workplace would help prevent the adverse effects of noise; this includes integrating hearing loss prevention activities into clinical practice and community outreach programs. Regardless of occupation, nearly everyone will encounter hazardous noise throughout their lifetime. Raising awareness of noise levels outside of work will help ensure that overall daily noise exposures (not just daily workplace exposures) are safe. In addition, noise can interact with other risk factors to affect overall hearing health. For example, early noise exposures may affect quality of life as a person ages, while age may exacerbate the effect of workplace exposures.

Therefore, the scope of efforts to address exposure should be broadened to include multiple sources of noise. In addition, hearing difficulties are not the only health outcomes of noise exposure. Reducing the prevalence of hearing loss requires a comprehensive approach. Addressing exposures to noise could have benefits to health, safety, and wellbeing that go beyond the prevention of hearing loss, tinnitus, and hyperacusis.

Prevention efforts – both at and away from work – should address possible barriers. Adopting Total Hearing Health concepts conveys a strong message to workers that management is committed to promoting better hearing health and reducing adverse health risks from noise both at work and in everyday life.

Total Worker Health®: An Integrated Approach

Total Hearing Health is based on *Total Worker Health*®. *Total Worker Health* approaches are defined as policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts in order to advance employee well-being. Comprehensive practices and policies that take into account the work environment (both physical and organizational), while also addressing personal health risk factors, are more effective in preventing disease and promoting safety and health than each approach taken separately [NIOSH 2018c; Sorensen et al. 2013].

Controlling exposures to occupational hazards is the responsibility of employers and is the fundamental method of protecting workers' health. To protect workers' hearing health means to reduce noise at its source to the extent possible through methods such as engineering controls and Buy Quiet programs [NIOSH 2014, 2018a]. However, while employers are required to protect workers from harmful

working conditions, the *Total Worker Health*® approach encourages organizations to advance worker well-being more broadly. *Total Worker Health* strategies emphasize organization-level interventions over individual controls and strategies (including PPE), concentrating on workplace policies, programs, and practices that address the job design and workplace conditions (such as workload, management practices, and work schedules and shifts that could all play a part in reducing exposure to hazards.)

The following case studies illustrate how Total Hearing Health concepts are being applied in workplaces and communities.

Case Study 1

24-Hour Protection

The 3M manufacturing plant in Hutchinson, Minnesota addresses non-occupational noise exposures encountered by their workforce by promoting “24-Hour Protection” [NIOSH 2015c]. In their region, hunting is a favorite sport, and exposure to recreational firearm impulse noise is common among their workforce. In view of this, 3M Hutchinson:

- Incorporates information about the unique auditory risks of firearm noise and hearing protectors specially designed for shooting sports in their annual hearing conservation training programs.
- Stocks earplugs specifically designed for shooting sports in the employee store at minimal cost to workers and their family members.
- Promotes awareness campaigns reminding workers and their families to use hearing protection each fall and spring when hunting season opens.

Buy Quiet

To reduce workplace noise exposures, 3M implemented Buy Quiet [NIOSH 2014] principles, noise exposure assessments, and noise-reduction projects. As a result, noise exposures were so successfully reduced (12–14 dBA across 24 different areas and departments), that 199 of 203 employees were no longer required to be included in the 3M Alexandria Hearing Conservation Program. Both the Hutchinson and Alexandria 3M facilities received the Safe-in-Sound Award for Excellence in Hearing Loss Prevention in the Manufacturing Sector [CDC et al. 2018].

Case Study 2

Using participatory *Total Worker Health*® methods and tools, the Center for the Promotion of Health in the New England Workforce is developing a hearing health promotion

intervention for transportation workers that promotes active worker participation in its development, implementation, and maintenance [Cavallari et al. 2017]. As a first step, transportation workers participated in a survey about hearing health, overall workplace safety and health climate, and the use of hearing protection at home. Of 271 participants, only 94 (35%) had been tested within the last 2 years. Hearing loss diagnosis was reported by 32 (13%) participants; 148 (56%) report ringing in ears and/or muffled hearing following loud noise exposure. For the next phase of the project, workers and a steering committee (with management and union representation) will design and implement noise and hearing interventions tailored to their needs. These interventions include a safety leadership training for supervisors, a noise hazard scheme that allows worker to easily assess the noise level of a task/equipment and choose the right hearing protection device, and a video training for workers emphasizing the OSHA Hearing Conservation Program required elements as well as the noise hazard scheme and how to provide coworker support for the use of hearing protectors.

Recommendations for Employers: Incorporating Total Hearing Health Concepts into Workplace Safety and Health Programs [NIOSH 2014, 2015a,b; 2016a,b, 2018a,b,c, 2019; Schulte et al. 2012, 2015; Sorensen et al. 2013].

- Follow the hierarchy of controls to reduce noise exposure. Eliminate or substitute the noise source if possible, or use engineering controls to reduce the noise level.
- Implement a Buy Quiet program to move toward eliminating or substituting sources of hazardous noise. Establish design specifications regarding noise levels to be followed when purchasing equipment, and include equipment noise specifications in procurement documents.
- Encourage workers to get to know their noise exposures both on and off the job. Advances in technology have made it possible for anyone to monitor their own noise exposures using inexpensive sound level meters or smart phone apps (e.g., the NIOSH sound level meter app. The topic page includes information about how to interpret results). Discuss sound measurement apps at safety meetings or loan out inexpensive sound level meters to raise awareness about hazardous noise.
- When noise level measuring equipment or apps are not available, train workers to identify hazardous noise levels by using the following rule: if you have to raise your voice to be heard by someone three feet (an arm's length)

away, the level is probably loud enough to put your hearing at risk.

- Ensure that programs promoting hearing health and hearing loss prevention have the commitment of organizational leadership, support from all levels of management, and worker participation and input. Establishing a noise control program can be a good demonstration of organizational commitment to safer noise levels.
- Involve workers and labor representatives in designing and implementing procedures and practices to reduce noise exposure and promote better hearing health practices.
- Include health education about the effects of noise exposure and ways to prevent any negative effects. In addition to disseminating written information, host regular awareness sessions on hearing health.
- Promote the importance of healthful living and overall hearing health, and let workers know what resources are available to help them.
- Counsel workers about hearing risks among their family members. Establishing safe listening habits in youth can carry over into safe work habits when the children reach working age.
- Train workers in the proper use of hearing protectors.
- Make hearing protectors available during workshifts and also for off-the-job noise exposures. Educate workers about non-occupational exposures and encourage them to use hearing protection when they are exposed to noise away from work.
- Supply hearing protection for community events that may involve loud noise or loud music exposures or other risks to hearing. Supporting hearing loss prevention efforts in the community reinforces hearing loss prevention messages at work.
- Ensure that the program includes regular audiometric testing.
- Routinely evaluate the program and make adjustments as needed.

Recommendations for Workers: Protecting Hearing Health on and off the Job [NIOSH 1996, 2015a,b, 2019]

- Know your exposure. Overexposure to excessively loud noises can cause irreversible damage to your hearing. Use an inexpensive sound level meter or a sound measuring app (such as the NIOSH sound level meter app) to check noise levels.

- At work, take training on protecting your hearing and on wearing hearing protectors when needed, both during the workshift and for off-the-job noise exposures.
- Consult with event organizers or use crowd-sourcing apps or Internet searches to find information about noise levels associated with places you go or activities you do. Monitor how much time you devote to these activities.
- When using headphones, WHO [1999] recommends limiting exposure to 1 hour per day at 85 dB.
- Remember the following rule for identifying hazardous noise levels when a sound measuring device or app is not available: if you have to raise your voice to be heard by someone three feet (an arm's length) away), the noise level is too loud.
- Move around venues to find quieter spots. Locations that are farther away from the noise source and reflective surfaces such as walls may be quieter.
- Consider noise levels when buying tools, appliances, and other items for your home or hobbies. Noise levels may be provided on the product packaging or in online specifications. Consumer organizations also publish noise ratings for some types of products.
- Exposure time also contributes to risk. Take breaks in quieter areas. Limit your time in noise (from sports, transportation, firearms, etc.). It all adds up.
- Wear a hearing protector that you find comfortable each and every time you are around loud noise. Check the fit by cupping your hands over your ears; if you hear changes in sound with your hands over the protectors, the hearing protectors may not be fit properly.
- Have your hearing tested regularly. If you experience any auditory symptoms (such as ringing in your ears, a feeling that your ears are “full,” or “muffling” of sounds) for more than 24 hours, have your hearing checked as soon as possible. Tinnitus and temporary changes in hearing might be an early sign of permanent damage.
- Practice healthful lifestyle choices, such as good nutrition and exercise. Your general health can affect your hearing health.

Recommendations for Hearing Health Clinicians: Incorporating Total Hearing Health into Clinical Practice [NIOSH 2015a,b; 2016c; 2018a,b,c].

- Obtain hearing risk histories and counsel patients about prevention. Include questions about exposures to noise

and ototoxic agents (drugs, chemicals) both at work and away from work as a routine part of patient hearing history. Ask specific questions about hobbies and other recreational activities that may increase hearing risk.[†]

- Expand the test battery for at-risk patients to look for evidence of early hearing changes. Otoacoustic emissions, extended high frequency audiometry, speech in noise testing, and some parameters of acoustic reflex and auditory brainstem response tests may sometimes provide evidence of early hearing changes before they are evident on the pure tone audiogram [Themann et al. 2013b].
- Encourage patients to know their noise exposure levels – for example, by using sound measurement tools (such as the NIOSH sound level meter app) or checking apps or other resources that report noise levels for specific places or activities.
- Counsel patients to adopt strategies that protect hearing health, including avoiding exposures, reducing exposure times, and using hearing protection.
- Provide hearing protector selection and fitting services. Inform your patients about all types of hearing protection devices and keep a varied supply in stock. Help noise-exposed patients select appropriate hearing protection, in view of their noise exposures as well as comfort and communication needs. Hearing protector fit-testing systems are readily available and suitable for clinical use and ensure that patients are fitting the device properly and receiving sufficient noise reduction.
- Create, support, or participate in campaigns that promote hearing health. Conduct hearing screenings at health fairs, visit schools to discuss hearing health, and measure output levels of personal listening devices. Many organizations have materials that can help raise awareness about the importance of preserving hearing:
 - National Institute on Deafness and Other Communication Disorders (NIDCD, NIH). It's a Noisy Planet campaign: <https://www.noisyplanet.nidcd.nih.gov/>
 - Department of Defense Hearing Center of Excellence: <https://hearing.health.mil/Resources/Audio-and-Print-Materials>

[†]For guidelines about questions, consult the following:

Johnson TA, Cooper S, Stamper GC, Chertoff M [2017]. Noise exposure questionnaire: A tool for quantifying annual noise exposure. *J Am Acad Audiol* 28(1):14-35. doi: 10.3766/jaaa.15070

Morata TC, Little MB [2002]. Suggested guidelines for studying the combined effects of occupational exposure to noise and chemicals on hearing. *Noise Health* 4(14):73-87

The American Speech Language Hearing Association has recommendations for collecting a hearing history.

- Dangerous Decibels. Though originally designed for children, these materials have been adapted for adults and been translated into several languages: <http://dangerousdecibels.org/>
- American Speech Language Hearing Association. Listen to Your Buds campaign: <https://www.asha.org/buds/>
- Sight and Hearing Association: <http://www.sight-andhearing.org/Services/NoisyToysList.aspx>

Acknowledgments

This document was prepared by Christa L. Themann and Thais Morata of the Division of Field Studies and Engineering (DFSE), and Susan Afanuh of the Division of Science Integration, National Institute for Occupational Safety and Health. Subject matter expert review was provided by the DFSE Audiology Branch, the NIOSH Total Worker Health® team, and the National Center for Environmental Health of the Centers for Disease Control and Prevention.

Suggested Citation

NIOSH [2019]. Using *Total Worker Health*® concepts to address hearing health. By Themann CL, Morata T, Afanuh S. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2019-155, <https://doi.org/10.26616/NIOSH/PUB2019155>

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For More Information

More information about the NIOSH *Total Worker Health*[®] program can be found at <https://www.cdc.gov/niosh/twh/letsgetstarted.html>

More information about noise and hearing loss prevention can be found at <https://www.cdc.gov/niosh/topics/noise/>

Find NIOSH products and get answers to workplace safety and health questions:

1-800-CDC-INFO (1-800-232-4636)

TTY: 1-888-232-6348

CDC/NIOSH INFO: [cdc.gov/info](https://www.cdc.gov/info) | [cdc.gov/niosh](https://www.cdc.gov/niosh)

Monthly *NIOSH eNews*: <https://www.cdc.gov/niosh/enews/>

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DOI: <https://doi.org/10.26616/NIOSH PUB2019155>
DHHS (NIOSH) Publication No. 2019-155

September 2019