

The Effects of Noise-Induced Hearing Loss on Children and Young Adults

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There are roughly 40 million individuals in the United States who have been identified as having a hearing loss, with 10 million of these hearing losses attributed to noise-induced hearing loss (NIHL; Dangerous Decibels, 2011). The American Academy of Audiology (AAA, 2008) estimates that one in eight children has sustained NIHL. Currently, it is estimated that 16% of teenagers have sustained NIHL (Kean, 2010). Another group of young adults who have sustained

NIHL is U.S. Army soldiers who served in the Gulf War. Of those who served, 21% were 18 to 24 years of age (House Committee on Veterans' Affairs Subcommittee on Economic Opportunity, 2010). Within this group, there was a high incidence of NIHL, frequently due to blast exposure (Helfer et al., 2011). Helfer et al. (2011) examined the inpatient and outpatient records of U.S. Army soldiers who served predominantly in Iraq and Afghanistan. Within this group, there was a conservative estimate of 27,427 soldiers who showed a significant threshold shift in hearing level. A standard threshold shift is a hearing level change, relative to the baseline audiogram, of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear (Washington Administrative Code, 2009). Chart reviews of soldiers who had sustained blast-related injuries in Iraq and Afghanistan also showed that 60% of the soldiers reported hearing loss, of which 50% were sensorineural (Cave, Cornish, & Chandler, 2007).

For young individuals, listening to music too loud over a lengthy period of time on personal listening devices (PLDs) such as CDs, iPods, and other MP3 players has been shown as a potential contributor to NIHL. Other potential sources of NIHL include various recreational activities and certain children's toys that emit sounds that exceed safe listening levels (Axelsson & Jerson, 1985; Nadler, 1995). An examination of 329 student musicians, ages 18 to 25 years, found that 45% had sustained NIHL, with 78% of this loss occurring at 6000 Hz (Phillips, Henrich, & Mace, 2010). NIHL

ABSTRACT: Purpose: This tutorial offers a review of the causes and effects of noise-induced hearing loss (NIHL) along with signs of hearing loss in children and young adults. NIHL has been ascribed to listening to sounds or music too loud over a lengthy period of time when using personal listening devices (PLDs) such as iPods and other devices. There are also unexpected sources of NIHL, such as children's toys. NIHL is insidious, with PLD users frequently unaware of the onset and progression of this type of hearing loss.

Method: A literature review, methods for identifying hearing loss, and strategies to prevent NIHL are provided.

Conclusion: Guidelines for preventing NIHL are needed because many PLD users are listening too loud and too long to their PLDs. In addition, many PLD users may be unaware of additional factors that can lead to NIHL.

KEY WORDS: noise-induced hearing loss (NIHL), language difficulties, children's toys, noise

is the most common form of hearing loss after hearing loss related to age (Rabinowitz, 2000). The National Institute on Deafness and Other Communication Disorders (NIDCD, 2007) stated that NIHL results from exposure to sounds that are excessively high, >85 dBA, along with lengthy exposure. The most significant aspect of NIHL is that it is insidious, with listeners frequently unaware that a hearing disorder is developing or is present (NIDCD, 2007).

The human ear is damaged as a function of sound level, exposure time, and frequency content of the sound. Sound intensity is measured in units of decibels (dB), which are expressed on a logarithmic scale. On the decibel scale, sound intensity increases tenfold for every additional 10 dB. Thus, an increase from 60 dB (conversation) to 90 dB (heavy traffic) is equivalent to a 1,000-fold increase in intensity. The ear is less sensitive to very low and very high frequency sounds, but rather sensitive to mid-frequency sounds. This sensitivity is captured by A-weighting, which is essentially a band pass filter emphasizing frequencies between 1000 Hz and 4000 Hz and de-emphasizing frequencies below and above this range. Decibels are a measure of sound intensity that can be expressed in terms of several reference levels; dBA is sound intensity with an “A” contour filter that adjusts the measurement to be less sensitive to very high and very low frequencies. Hence, noise exposure is described in A-weighted decibels (dBA).

Instrumentation for Measuring Sound Levels and Considering Risk for NIHL

There are generally two classes of devices that are used to measure exposure to sound that might be potentially hazardous: sound level meters (SLMs) and noise dosimeters. Generally, SLMs are handheld devices that use a microphone and signal processing hardware; they are calibrated to report the actual instantaneous sound level in the free-field. SLMs make use of *slow* versus *fast* integration of the level observed at the microphone and different filters (for instance, A-weighted vs. C-weighted filters). Slow-integration settings report the sound level observed by the microphone averaged across 1 s of time; fast-integration settings report the sound level observed averaged across 125 ms of time. Slow integration is better for reporting typical sound levels for the sake of long-term exposure, and fast integration gives a better approximation of the peak sound pressure level. Noise dosimeters are essentially identical in structure and function to SLMs, but instead of reporting instantaneous sound levels, they sample sound at regular time intervals and report average sound exposure over the course of hours (or longer).

The choice of which filter (A-weighted vs. C-weighted) to select on the SLM or dosimeter depends on the purpose of using the sound measuring device. The population risk for NIHL was determined using large samples of persons who were exposed to noise without hearing protection in the 1960s to 1970s (Prince, Stayner, Smith, & Gilbert, 1997). Researchers conducting these studies of population risk used SLMs and noise dosimeters set to A-weighting and slow integration and compared each person’s sound exposures to his or her pure-tone hearing thresholds. This provided

the scientific community with a dose–effect relationship for sound exposures and resultant risk for NIHL that is based explicitly on A-weighted sound levels. A-weighting was selected for these historic studies because the A-weighted filter approximates the mechanical properties of the human middle ear (eardrum and ossicles), where lower frequencies (<1000 Hz) are not transmitted from the ear canal to the inner ear (the cochlea) as efficiently as are mid-to-higher frequencies (1000–4000 Hz). Consequently, A-weighting reduces the contribution of low-frequency sound, relative to mid-to-higher frequency sound, in reporting the overall sound level. It is well known in the NIHL literature that the human ear is more susceptible to cochlear damage from sound in the 1000–4000 Hz range than from sound <1000 Hz due to the mechanical properties of the middle ear (Henderson, Subramaniam, & Boettcher, 1993).

As a result, most NIHL literature describes sound exposures based on sound pressure levels in A-weighted decibels. Decibels sound pressure level (abbreviated *dB SPL*, or often shortened to simply *dB*) are the typical unit of measure of sound, and A-weighted dB (abbreviated *dBA*) indicates that the sound was measured with an A-weighted filter applied. Controversy exists over whether or not it is in fact appropriate to apply A-weighting to measures of sound exposure over all intensities of sound capable of causing hearing damage; however, as the seminal research reported sound levels in dBA, and it is on these data that all subsequent studies considering “how loud is too loud” are based, arguments to the contrary are moot.

Noise Exposure and Dangerous Levels

In terms of noise exposure, the most dangerous intensity levels are found in jet aircraft takeoff (130 dBA), snowmobiles (120 dBA), and rock concerts (110 dBA). To understand *how loud is too loud*, the following A-weighted decibel levels are offered to describe noise exposure (NIDCD, 2012).

- 150: Fireworks
- 120: Ambulance siren
- 110: Chain saw and rock concert
- 105: Personal stereo system at maximum level
- 100: Wood shop and snowmobile
- 95: Motorcycle
- 90: Power mower
- 85: Heavy city traffic
- 60: Normal conversation
- 40: Refrigerator humming
- 30: Whispered voice

Safe listening levels (zero risk) depend on the the level (*how loud*) as well as the duration (*how long*) of exposure. However, due to known individual susceptibility to NIHL (Henderson et al., 1993), two individuals with identical noise exposure likely will not have the same resultant hearing damage. To guide public policy and the scientific community, the Occupational Safety and Health Administration (OSHA) requested input from organizational stakeholders to

analyze the historic NIHL dose–effect data and recommend maximum noise exposure levels. The resulting “damage risk criteria” (DRC) described the appropriate maximum sound levels and durations of exposure, with time–intensity trading ratios that would suggest equal risk for NIHL for different durations of exposure. For instance, the National Institute for Occupational Safety and Health (NIOSH, 1998) recommends a maximum exposure level of 85 dBA for an 8-hr exposure, with a time–intensity trading ratio (also known as *exchange rate*) of 3 dB.¹ Thus, a person who is exposed to 88 dBA for 4 hr carries equal risk for NIHL as someone who is exposed to 91 dBA for 2 hr or 100 dBA for 15 min or 103 dBA for 7.5 min. This NIOSH DRC (85 dBA for 8-hr exposure, 3-dB exchange rate) accepts that 8% of people who are exposed to noise at their recommended exposure level (REL) will still sustain significant NIHL with enough years of regular exposure. This is, however, a much more conservative DRC than is presently accepted by OSHA (1981), which follows a DRC of 90 dBA for an 8-hr exposure, with a 5-dB exchange rate. Thus, the OSHA permissible exposure level (PEL) allows 95 dBA for 4 hr and considers the NIHL risk to be equivalent to 100 dBA for 2 hr and 105 dBA for 1 hr. Contrast this with NIOSH’s more conservative REL, which allows only 15 min (not 2 hr) exposure at 100 dBA. OSHA’s DRC accepts that 25% of people who are exposed to noise at their PEL will sustain significant NIHL with enough years of regular exposure. For recreational sound exposures, then, it is more appropriate to follow the more conservative NIOSH guidelines than the OSHA guidelines, as the NIOSH standard is the more hearing-protective limit (Neitzel, 2008). Additional guidelines for dangerous noise levels and exposure can be found in the Appendix.

The Incidence of NIHL

One of the primary causes of NIHL among younger individuals is listening to recreational noise (Peng, Tao, & Huang, 2007; Weichbold & Zorowka, 2007). PLD users may be at risk for NIHL if they use these devices at high volumes for long periods of time (Fligor, 2006). As far back as 19 years ago, investigators found that the percentage of second graders with hearing loss had increased 2.8 times from measures that had been taken 10 years earlier (Montgomery & Fujikawa, 1992). Measures from 15 years ago found that 1% of the school-age population had some degree of hearing loss (Blair, Hardegree, & Benson, 1996), whereas figures from 2001 reported symptoms of NIHL in ~12% of children ages 6–19 years (Niskar et al., 2001).

A survey by Zogby (2006) examined the reported hearing status of 301 high school students and 1,000 adults and found that teens were more likely than adults to report three of the four symptoms of hearing loss: increasing the volume on their television or radio, saying *what* or *huh* during normal conversation, and reporting tinnitus or ringing in the ears (17% students vs. 12% adults). Portnuff,

Fligor, and Arehart (2011) also found that teenage males, 13 to 17 years of age, might be listening louder than their female peers. Teenagers frequently play their music at a louder intensity than other PLD users without perceiving the loudness of their devices (Portnuff et al., 2011). Portnuff et al. also found that teenagers are more likely than adults to increase the volume on their television or radio. Teens who reported that they could not enjoy their music as much on low volume tended to listen louder, even when indicating concern about hearing loss.

College-age PLD users have also been found to listen louder. Levey, Levey, and Fligor (2011) examined the volume listening levels of 189 college students on a New York City campus. Findings showed that the average participant had an estimated exposure of 88 dBA L_{eq} , indicating that the average participant was at risk for NIHL from PLD use alone. The average listening level was 92.3 dBA, with average hours of use per week at 18.3. With continued exposure to loud noises, children and teens are at risk for further hearing loss.

There is also a high incidence of hearing loss in individuals between 46 to 64 years of age, which is greater than the expected age-related loss for individuals >65 (Rosenbloom, 2007). This finding suggests that factors other than age are affecting adults’ hearing abilities. One study of 5,742 participants, 20 to 69 years of age, found that 8.9% of adults in this population had a unilateral hearing loss (Agrawal, Platz, & Niparko, 2008). Findings also showed that individuals with a high-frequency hearing loss were less likely to notice or to report this loss than those with a lower frequency hearing loss.

Social Factors Associated With PLDs

Although some PLD users may be aware of the effects of loud and long listening on their hearing, there are social factors that lead listeners to ignore the possibility of damage. With its unmistakable white headphones, the iPod, in particular, has become ubiquitous. For many, the iPod has become a symbol of a generation and a marker of social status. It has been called an urban Sherpa, meaning that people now rely on the iPod to navigate today’s urban world (Bull, 2007). Consequently, it has become almost a necessity of life. Owners of iPods are members of a private club with a membership in the millions (Jones, 2005). According to the Student Monitor, a market-research group, college students rated listening to their iPods as the coolest free time activity (Associated Press, 2006). Because of the prevalence of iPods, users must be made aware of the hazards associated with inappropriate use.

Unexpected Sources of Noise

One of the more disquieting sources of NIHL is found in children’s play with toys. Investigators have found that certain children’s toys may exceed safe listening levels, placing children at risk for NIHL (Axelsson & Jerson, 1985; Nadler, 1995). University of California–Irvine researchers (2007) found that many common children’s toys emit sounds at decibel levels that are high enough to cause

¹When comparing one A-weighted decibel level to another, the “A” is dropped and only “dB” is reported.

permanent hearing damage. A number of toys, for example, can reach levels ≥ 100 dBA, which is equivalent to the sound of a power saw, subway train, or power mower. An investigation of common toys used in play revealed the following volume levels (Cochary, 2009).

- Rattles and squeaky toys have been measured at sound levels as high as 110 dBA.
- Musical toys, drums, and horns can reach sound levels as loud as 120 dBA.
- Toy phones have been measured between 123 dBA and 129 dBA.
- Toys producing firearm sounds (e.g., toy guns) produce sounds as loud as 150 dBA, even if a child is standing a foot away from the source of the noise.

Axelsson and Jerson (1985) examined squeaky toys, moving toys, toy weapons, and firecrackers. Sound levels for squeaky toys were 78–109 dBA, with risk for NIHL if the toys are placed close to a child's ear for even minutes per day. Sound levels for moving toys, such as toy cars, were 82–100 dBA, with the prediction that exposure for several hours per day may cause NIHL. Measurement of stationary toys was 130–140 dBA, requiring that children be monitored for limited frequency and duration of use to prevent NIHL. The measurement of toy weapons revealed peak values of 143–153 dBA and of firecrackers of 125–156 dBA, indicating the need for ear protection to prevent NIHL when children are exposed to these events. The danger from noisy toys may be greater than the sound-level measurements indicate. For example, when a child holds a toy that emits 90 dBA at arm's length, the level is actually 120 dBA when the toy is held at the ear, which is equivalent to the takeoff of a jet (American Speech-Language-Hearing Association, 2011). In summary, NIHL can result from even innocent play.

The Effect of Excessive Noise on Hearing Abilities

To understand the effect of noise on hearing, it is important to understand the function of sensory cells in the inner ear (NIDCD, 2007). Sound waves enter the outer ear and travel through the ear canal to the eardrum. The eardrum vibrates from the incoming sound waves, and vibrations are sent to the middle ear. Here, bones (ossicles) in the middle ear (malleus, incus, and stapes) amplify these sounds. These vibrations are sent to the cochlea (inner ear). The cochlea is a fluid-filled organ with an elastic membrane called the basilar membrane. Sensory cells (outer and inner hair cells) sit on top of the basilar membrane. The vibrations sent to the inner ear lead to a traveling wave along the basilar membrane, resulting from the electromotility of the outer hair cells. This motion causes bristly structures (stereocilia) on top of the inner hair cells to bump up against an overlying membrane (tectorial membrane) and deflect. This causes the inner hair cells to depolarize and release neurotransmitters across the synapse between the inner hair cell and the auditory nerve fiber. Here, the sound waves are changed into electrical signals. These signals are carried by

the auditory nerve to the brain. In the brain, the signal is translated into sound perception.

NIHL develops when toxic noise exposure overworks the outer hair cells, causing them to exhaust their energy supply. Free radical molecules are overproduced as a result of this noise exposure, overwhelming the ear's antioxidant defense mechanisms against this metabolic overload. If the ear is not given a chance to rest and recover, cells go through a cascade of chemical events that leads to cell death. Although free radicals are typically present in cellular life processes, they damage cells when they are present in excess (Le Prell, Yamashita, Minami, Yamasoba, & Miller, 2007). Free radical molecules consist of reactive oxygen species (ROS) and other free radical molecules (Neukom, 2007). Free radicals have unpaired electrons, rendering them capable of altering the electron arrangements in stable molecules (Henderson, Bielefeld, Harris, & Hu, 2006). During noise exposure, the outer hair cells in the cochlea demand high levels of energy (Thalman, Myoshi, Kusakari, & Ise, 1975). The consumption of greater amounts of oxygen creates byproducts that react with other molecules to create high levels of ROS in the cochlea. The ROS acts to damage hair cell nuclei and cell wall membranes, resulting in cell death due to necrosis (tissue death) and apoptosis (a process of cell self-destruction; Henderson et al., 2006). When a hair cell dies, it fragments and is ejected from the basilar membrane and is consumed by macrophages. This cell is then replaced with local supporting cells that act as scar tissue. The scar tissue maintains the integrity of the membrane but cannot contribute to the active process of hearing as the hair cell did when it was alive and functioning (Henderson et al., 2006).

The integration of sound level over exposure time ultimately determines the relative risk for NIHL. Equivalent continuous sound level (L_{eq}) and time-weighted average (TWA) are two ways that level-over-time can be expressed. Safe PLD listening is placed at the 89 dBA level for no longer than 90 min at a time (Portnuff et al., 2011).

The Effect of NIHL on Communication

Research efforts have indicated that exposure to loud sounds over a long period of time may lead to difficulty understanding speech (NIDCD, 2007). The Centers for Disease Control and Prevention (CDC, 2011) reported that even a small degree of hearing loss can affect a person's speech, language comprehension, communication, classroom learning, and social interaction. In fact, as little as a 10-dB reduction from normal thresholds will reduce the subjective loudness sensation of a speech signal by half (Hearing Loss, 2001). Consequently, even a mild hearing loss may lead to an uncertain grasp of many of the grammatical aspects of spoken language, including weak consonants such as fricatives (*f*, *s*, *sh*, and *h*) and stops (*p*, *t*, and *k*), along with morphemes that mark verb tense, possessives, and plurals (*-ed*, *'s*, and *-s*). NIHL renders sounds as distorted or muffled and can cause tinnitus, which is heard as a ringing or buzzing in the head or ear (Daniel, 2007). Children and teens who have been exposed to even a single, very intense noise (such as an explosion or gun

shot blast) may experience both hearing loss and tinnitus, with symptoms lasting for at least a year or more (Holgers & Pettersson, 2005).

The early onset of NIHL can result in a minimal hearing impairment (MHI), although there are other causes for a mild or minimal hearing loss, such as otitis media (i.e., inflammation in the middle ear that is usually associated with fluid buildup). Even this minimal hearing loss places children at risk for academic difficulties (Goldberg & McCormick Richburg, 2004) due to effects on language and learning development (Bess, Dodd-Murphy, & Parker, 2004). Children with an MHI are also frequently unidentified as having a hearing loss, as MHI may not be as apparent as a more severe hearing loss (Goldberg & McCormick Richburg, 1998). These children's hearing losses may be missed even with hearing screening, given that hearing screenings are generally placed at 1000, 2000, and 4000 Hz. Consequently, screening may not identify an MHI secondary to NIHL, given that the onset of NIHL is prevalent at 6000 Hz (Holmes et al., 2007). This hypothesis was confirmed in an examination of the records of school-based pure-tone hearing screening protocols for adolescents across 46 state agencies (Meinke & Dice, 2007). Meinke and Dice (2007) found that screening protocols were not adequate for the early identification of NIHL. Consequently, better screening protocols and greater awareness of hearing difficulties are essential factors in supporting children's academic development.

Identification and Management for Children With Hearing Loss

Given the difficulties that children with hearing loss face in academic contexts, it is essential that these children be identified early and accurately. A hearing loss may be present if children frequently exhibit the following behaviors (Hall, Oyer, & Haas, 2001):

- Ask for repetition.
- Misunderstand what is said to them.
- Appear inattentive to tasks involving listening.
- Have problems with certain sounds (e.g., fricatives and stops).
- Watch other children to understand what they are saying or doing.
- Are fatigued at the end of the day.
- Withdraw from situations that require good listening skills.

DISCUSSION AND GUIDELINES TO PREVENT NIHL

The effects of NIHL on children's language and academic skills have been presented here in order to alert readers to the need to prevent NIHL and thereby support children's communication and academic skills. Guidelines have been developed to decrease the number of individuals who may experience NIHL (Fligor, 2006; Levey et al., 2011). For example, individuals should not listen to music for longer

than 1½ hr at 80% of the maximum volume control setting on their PLDs (Portnuff et al., 2011). The average user is able to listen to a player at ~70% of full volume for ~4½ hr without risk. There are also guidelines for the type of earphone that should be used to prevent NIHL (Fligor & Cox, 2004; Portnuff et al., 2011). Although the output of in-ear or ear bud-style headphones may be higher than over-the-ear or supra-aural headphones (Portnuff et al., 2011), people tend to use their headphones at the same level, depending on background noise (Fligor & Ives, 2006). However, the primary risk lies in listening to music in noisy environments, with headphone type a secondary concern (Fligor & Ives, 2006; Portnuff et al., 2011). Contrary to popular belief, using in-ear headphones that completely seal the ear allows the user to block out background noise, often causing the listener to choose to listen at lower levels, even with high background noise (Fligor & Ives, 2006; Portnuff et al., 2011). In summary, guidelines for (a) appropriate listening level and duration and (b) appropriate headphone type contribute to preventing NIHL.

Henderson et al. (1993) described that not everyone shares the same risk of hearing loss, given that some individuals have "tougher" ears and others have "tender ears." Currently, it is not possible to predict who is more at risk for NIHL. Consequently, it is best to exercise caution when using PLDs. The most significant problem is that hearing loss occurs slowly but is permanent. Parents or teachers may not notice this type of hearing loss until it is quite extensive. For this reason, early prevention is important to prevent communication and academic difficulties. The results of the current study suggest that PLDs produce high enough volume levels to pose a risk of hearing loss if they are used at high volumes for extended durations. Thus, PLD users must become aware of their listening levels and of the maximum amount of time they can listen at their chosen volume without risking hearing loss.

Strategies to Reduce Potential for NIHL

There are several strategies that can reduce the incidence of NIHL (CDC, 2011; Danielson, 2012; Fligor, 2011; World Health Organization, 1997).

- Education on the sources of toxic noise: jet engines, motorcycles, chainsaws, powerboats, personal stereos, wood working tools, gas powered lawnmowers, gun shots, concerts, tractors, snowmobiles, power tools, video games, and playing in a band.
- Education on the effects of hearing loss: communication difficulties, learning difficulties, pain or ringing in the ears (tinnitus), distorted or muffled hearing, and an inability to hear environmental sounds.
- Avoiding or limiting exposure and protecting ears when exposed to the sources of toxic sounds.
- Using hearing protection when unable to avoid noise exposure.
- Turning down the volume on PLDs, television, and car radios.
- Wearing ear protection when exposed to loud noise at clubs, sporting events, and workplaces.

- Increasing the distance from loud noise when attending events such as concerts or sporting events (i.e., do not stand next to speakers) to reduce the intensity of the sound and the potential for damage.
- Reducing the time spent at noisy events and in noisy environments.
- Expanding safe hearing education on NIHL to contact a wider number of individuals, such as through the use of social media (e.g., Facebook and Twitter).
- Legislation to control environmental noise at certain spectator events, such as movie theaters.
- Protecting the ears of children who are too young to protect their own.
- Making family, friends, and colleagues aware of the hazards of noise.

In addition, the AAA (2008) suggests that television should be used to educate children by presenting short, concise facts about PLDs and other devices that may affect their hearing. It is also important to find concrete methods to educate younger children. For example, young children can be taught that tinnitus signs can be an internal alarm to develop self-awareness of the effects of noise. Adults can also take on the role of powerful models by wearing hearing protection in the same manner they wear sunscreen and sunglasses. Educational programs are essential to provide information on the actions necessary to prevent NIHL. To this end, schools should establish a preventive program to target the inappropriate use of PLDs. In addition, early identification of children with NIHL is essential to provide them with the necessary supports for academic skills and to prevent greater loss of hearing abilities.

There are Smartphone applications (apps) available to measure the decibel level of sounds. These apps can be downloaded and used to determine the noise levels in clubs or shows. In this way, a method for preventing NIHL is available. The availability of these apps makes sound measurement much more possible, as dedicated research equipment is no longer necessary. However, due to the possibility of Smartphones' microphones "drifting" (that is, losing sensitivity due to wear and tear) and these apps assuming that the microphone performs according to original manufacturer specification, the reported dBA on the app might be in error (likely underestimating the actual dBA). Persons wishing to calibrate the accuracy of their Smartphone SLM or dosimeter app should consult an audiologist or acoustician who has the capacity to calibrate microphones to a known sound pressure level.

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APPENDIX. SOUND, SOUND INTENSITY, AND RECOMMENDED EXPOSURE LIMITS

<i>Sound level</i>	<i>Sound intensity</i>	<i>Recommended exposure limits^a</i>
Potentially hazardous		
School cafeteria	85 dB	8 hr
Band class	90 dB	2 hr
Wood or metal shop, power tools, snowmobile	100 dB	15 min
Hazardous		
Personal stereo at high volume	105 dB	5 min
Chainsaw, loud rock concert	110 dB	1.5 min
Ambulance siren	120 dB	9 s
Firecrackers, fire arms	140 dB–165 dB	Immediate hearing damage possible

^aNational Institute on Deafness and Other Communication Disorders' recommended exposure limits are based on repeated exposures occurring over a period of years.

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