The Musician and Occupational Sound Hazards

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Incidence of Hearing Loss

Hearing loss is a "hidden disease." An individual's hearing loss is not immediately obvious to others because no visible physical abnormality exists. However, a hearing loss, when sufficient to interfere with communication, is both noticeable and handicapping. Approximately 21 million Americans suffer from hearing impairment. Over 2 million have total or profound hearing loss. More than one out of every four people over 65 years of age has a hearing disorder.[1]

Long-term exposure to industrial noise is recognized as a major cause of adult-onset sensory hearing loss.[2] Factors that cause occupational hearing loss in musicians have been receiving increased attention over the past 20 years.

The Ear and Noise Damage

The ear is commonly divided into three parts: the outer, middle, and inner ear. Hearing loss due to disease of the outer (pinna and ear canal) and middle (ear drum and ossicles) ear is termed conductive; inner ear (cochlea) losses are known as sensory. Hearing losses due to disturbance of the auditory nerve and its central connections are called neural. Associated conductive and sensory losses in the same ear are described as mixed; sensory and neural combinations are designated sensorineural or neurosensory hearing losses.

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Anatomically, the main focus of ear damage resulting from excessive sound levels is in the cochlea. The cochlear region, which corresponds to hearing perception in the 4000 Hz range, is uniquely vulnerable to acoustic trauma. In addition to hair cell damage within the hearing organ, intense sounds can alter cochlear blood supply. Thus, the typical degeneration of inner blood flow may be accelerated by adverse noise conditions.[3]

Noise trauma may produce the symptoms of tinnitus (ringing in the ears) and hearing loss. Tinnitus usually precedes subjective hearing loss because the initial hearing loss is frequently at 4000 Hz, just above the frequency range necessary for hearing speech. If noise exposure continues and hearing loss progresses, the hair cell damage includes frequencies below 4000 Hz into the speech range; communicative difficulties increase and the patient (and others) becomes aware of the hearing loss.

Individual susceptibility to noise-induced hearing loss (NIHL) varies widely. There are fragile ("tin") ears and "super" ears. Unfortunately, there is no way to distinguish between the two in advance. Hood[4] has suggested that individuals with hearing thresholds much better than average may be less susceptible to NIHL.

Intense sound levels produce temporary loss of hearing (temporary threshold shift, TTS) or permanent hearing loss (permanent threshold shift, PTS). A given individual may suffer TTS without PTS (Fig. 1).

In addition to tinnitus and hearing loss, noise-induced cochlear damage may result in increased loudness growth (recruitment), disturbed pitch discrimination (diplacusis), an upward shift in pitch (a given pitch sounds like a higher pitch), and speech discrimination difficulties in the presence of noise.[5]

There may also be nonauditory effects of exposure to intense sound levels. Abnormal blood pressure regulation, typically hypertension, is the most well-documented nonauditory ailment related to noise exposure.[6] In addition to cardiovascular distress, various studies also attempt to relate peripheral circulation, equilibrium, and gastrointestinal, respiratory, and musculoskeletal disturbances to high noise levels.[7] These problems must be addressed by well-defined and adequately-controlled studies before definite conclusions can be drawn.

Mental health may be compromised by prolonged noise exposure as well. Complaints of irritability, fatigue, and maladjustment are frequent among industrial workers.[7] In a recent survey of orchestral musicians, emotional repercussions of intense sound levels were also reported.[8]

Sound Levels and Environment

The Occupational Safety and Health Administration (OSHA) provides noise-exposure standards for industry. Permissible exposure levels are calculated using a time weighted average (TWA). A hearing conservation program must be available to workers if sound levels equal or exceed an 8-hour TWA of 85 decibels average (dBA), also referred to as a 50% noise dose.

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Presented in part at the Fourth Annual Symposium on Medical Problems of Musicians and Dancers, August 1986, Aspen, Colorado.

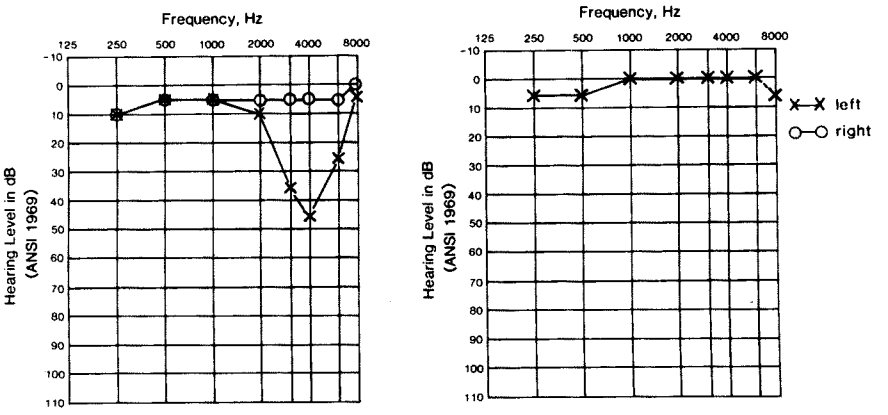

FIGURE 1. Temporary threshold shift (TTS). *Left*, A classic "noise-induced" notch is seen for the left ear less than 24 hours after attendance at a rock concert, approximately 10 feet from a speaker. *Right*, Hearing returned to normal within five days of exposure.

For every 5 dB increase in sound level, the permissible time is halved. OSHA has dictated that a conservation program must include sound level monitoring, audiometric testing, hearing protection, training, and record keeping.[9] Clearly, music sound levels do not rival daily exposure to industrial noise, and standardized hearing conservation programs have not been yet implemented in the music industry. This does not imply that hearing conservation is not necessary for musicians but rather that the current OSHA standard is not applicable in this context.

Hearing loss is detrimental to any individual at any age. A loss of hearing is particularly deleterious to a musician as it may affect both livelihood as well as the quality of life. A number of factors combine to create a potential risk to hearing for musicians and aficionados of live performance music: the intensity of the sound, rest intervals for the ear, reverberation time of the environment, distance from the sound source, and dynamic range of the music.

Investigators generally agree that rock/pop music reaches at least 105 dB to 115 dB sound pressure level (SPL). However, amplification may bring sound levels up to 120 to 130 dB only three feet from the loud speakers. The acoustic spectrum is fairly flat, with greatest intensity in the frequencies below 2000 Hz.[10–12] One investigator noted sound levels peaking above 150 dB SPL.[13]

Rock musicians are usually quite close to the sound source. Typically, loudspeakers are stacked on either side of the stage. The musicians use monitor speakers immediately behind them and sometimes in front in order to hear what they are playing.

A risk to the listener exists although to a lesser degree. In addition to being at a greater distance from the sound source, human bodies and clothes absorb sound. Sound levels in the sixth row have been measured to be approximately 15 to 20 dB less than on stage.[13]

The dynamic range of the music is another risk determinant. Rock music reaches a maximum intensity level quickly and generally remains within plus or minus 10 dB throughout the piece. There is little rest for the ear at exposure levels at or above 100 dB. A long reverberation time (the time it takes for the sound to "die away") creates a poor acoustic environment. Basement clubs without acoustic treatment tend to have reverberation times of about four seconds. Small rooms with long reverberation times cause greater sound reflection and increase the overall sound level.

Classical music has a greater dynamic range than does pop music, and concert halls are acoustically treated, allowing for a less hostile environment to the ear. However, recorded sound levels on stage still indicate a threat to hearing. Sound levels measured during classical performances are often quite high. Various studies indicate that intensity levels of 85–95 dB are not uncommon.[10,14–16] Sound levels beyond 120 dBA have been measured repeatedly. One bass clarinetist, sitting close to the bass drum, snare drum and tympani, was found to be exposed to levels in excess of 137 dBA.[15]

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Hearing and Musicians

Estimates of hearing loss for rock/pop musicians range from 13 to 30%.[11,12,14] The incidence of hearing loss in classical musicians has been reported to be between 4 and 43%.[12,15,17] The incidence of hearing loss depends upon the exact criteria used to define it. The criteria vary from any threshold worse than 20 dB to the detection of a minimal dip at 4000 Hz (Fig. 2). With few exceptions, hearing losses were slight and no permanent disability was reported. One investigator concluded that orchestral musicians do not face an increased risk of hearing damage;[18] however, hearing can be affected by loud music (Fig. 3).

A recent survey of 900 musicians reported in *Senza Sordino* indicated that classical musicians perceive high sound levels as a problem. Greater than 50% of respondents feared sustaining a hearing loss and felt that the high sound levels adversely affected their performance, concentration, and morale.[8]

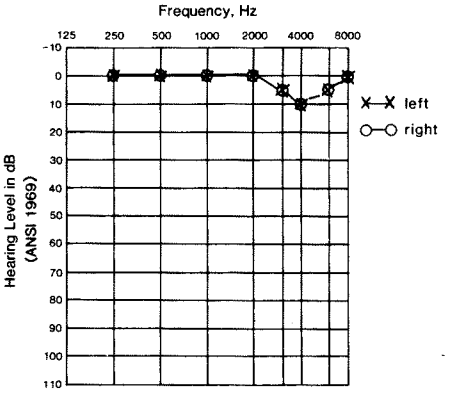

FIGURE 2. This audiogram depicts an idealized bilateral 10 dB noise-induced hearing loss (NIHL). Although the 4000 Hz dip may be clinically significant, thresholds are well within the normal range of hearing.

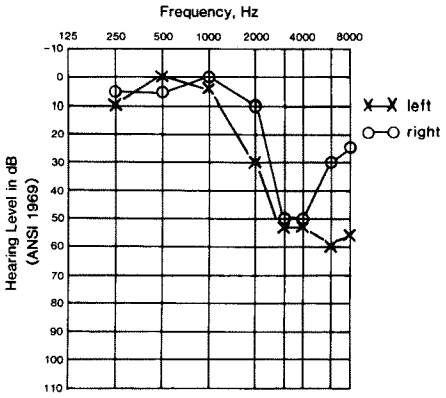

FIGURE 3. Audiogram of a 58-year-old male musician with over 40 years' exposure to rock and classical music. Right ear shows characteristic 4000 Hz notch while the left shows a sharply sloping impairment. Asymmetry may be related to 12 years of playing the trombone.

Sound levels for selected instruments are given in Table 1. Additionally, the piano played fortissimo can reach 92 to 95 dB. In one study, brass musicians and certain woodwind instrumentalists exhibited the greatest hearing loss.[14] In particular, those who played the french horn, trumpet, trombone, and bassoon showed an increased risk of sensorineural hearing loss.

Hearing loss is seen more often in musicians who are older, report long weekly exposure times, and have a history of military service.[14,15] Males appear to be affected more frequently than females. Also, asymmetric hearing loss is not uncommon. Violinists show greater hearing loss in the left ear because they hold their instruments on the left side, whereas flute players may have greater hearing loss in the right ear.

TABLE 1. **Sound Levels of Various Instruments***

Violin	84–103 dB A
Cello	84– 92 dB A
Bass	75– 83 dB A
Piccolo	95–112 dB A
Flute	85–111 dB A
Clarinet	92–103 dB A
French horn	90–106 dB A
Oboe	80– 94 dB A
Trombone	85–114 dB A
Xylophone	90– 92 dB A

*From Folprechtova and Miksovska, 1976,[18] with permission.

Medical Evaluation

Satisfactory evaluation of hearing problems in musicians is accomplished primarily on an individual basis. Not all otologists and audiologists are familiar with the problems specific to this population. The use of a comprehensive questionnaire is highly recommended to help isolate information that defines hearing and related problems. In addition to hearing loss, tinnitus, ear fullness, and dizziness are important symptoms to investigate. The onset, duration, and fluctuations of all symptoms must be questioned. A history of exposure to noise from gunfire (military, sport), an occupation, hobbies (power tools, chain saws, snowmobiles, motorcycles), stereophonic earphones and speakers must also be considered in establishing the cause of hearing loss.

Questions about music experience should include the number of years playing, types of instruments, present and past location in the orchestra or band, and the environment in which the musician performs (stage, pit, outdoors, small club, etc.).

There are a number of possible causes of hearing loss; therefore a complete medical history is essential. In particular, a patient or family history of diabetes, hypertension, renal disease, or heart or cerebrovascular disease should be documented and appropriate referrals made. The use of ototoxic drugs including nicotine or caffeine should be ascertained. Of course, a previous history of ear disease, including remedial surgery, must be investigated.

Audiologic Evaluation

In addition to a complete history, hearing tests are essential to help determine any causal relationship between music and hearing loss. At the very least, testing should include bilateral air and bone conduction thresholds. The presence of a notch centered at 4000 Hz, or even a sharply sloping loss, may implicate acoustic trauma. A hearing test immediately following exposure and then again some days later can determine whether a temporary threshold shift has occurred. Annual audiograms allow the measurement of the cumulative effect of exposure and may determine whether or not hearing loss is progressing.

Additional audiologic tests include the assessment of speech discrimination, i.e., the measurement of the communicative impact of a hearing loss. Objective measures of middle ear function (acoustic impedance audiometry) also provide important information regarding auditory status.

Treatment

With the exception of TTS, once the damage is done it is irreversible. All we can do is to deal with the consequences. Aural rehabilitation includes the use of hearing aids, hearing assistive devices, and optimal listening strategies, such as avoidance of noisy environments and the use of speech reading.

Tinnitus may be alleviated to some degree by avoiding totally quiet environments. For example, playing a radio when going to sleep may be helpful. Excessive emotional stress should be reduced as much as possible; psychiatric counseling and biofeedback may be beneficial. Hearing aids and, sometimes, noise maskers may reduce perceived tinnitus. Unfortunately, at this time, there appear to be no specific drugs that can ameliorate tinnitus without undesirable effects, which tend to preclude their use.

Prevention and Conservation

Most musicians agree that intense sound levels present a problem in the workplace. Orchestras and musicians have been combating this problem largely on an individual basis. Large numbers of musicians have independently investigated the use of hearing protective devices (HPDs), primarily ear plugs or ear muffs, the disadvantages of which are widely recognized. When effective enough to reduce sound levels, HPDs muffle the music the user wishes to hear; some are uncomfortable and require two hands to insert; and some performers feel they are obvious to the audience. Despite their drawbacks, ear plugs are the most frequently used hearing conservation method. Unfortunately, some players do not have the option of using an HPD. For example, the sound from the clarinet is directly transmitted to the inner ear via bone conduction through the upper teeth. If the ears are plugged, the clarinetist hears an annoying buzz, which restricts adequate self-monitoring by air conduction.

A number of orchestras have altered the environment in an attempt to re-

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duce sound levels on stage. Plexiglas shields or baffles have been placed in various "noisy" spots within the orchestra area; orchestra pits have been treated with acoustic panelling; percussion and/or brass instruments have been placed on risers so that the music flows over the musicians' heads rather than directly into the ears of the other performers; and, if space allows, the distance between musicians is increased.

Discussion

High sound levels, which may result in sensory, noise-induced hearing loss as well as other physical and emotional problems, are a significant concern in the community of musicians. To date, conservation efforts have fallen primarily upon the individual musician or orchestra and great success has not been reported. Attempts are being made to design hearing protective devices that are more suitable for the musician. One company, Sensaphonics, Inc., distributes a custom-fit ear mold. Tiny holes in the mold allow air to flow through the mold to alleviate pressure and to reduce heat buildup for increased comfort. High frequency sound enters unaffected through the ear mold, while the more damaging low-frequency sounds are attenuated up to 20 dB. Musicians who have worn the device report improvement in sound quality compared with other such devices. Of course, custom made hearing protective devices, costing approximately seventy dollars a pair, are substantially more expensive than the conventional plugs.

Information regarding the success of orchestras with different methods of sound reduction must be gathered and reviewed. The use of noise-control engineers to study the issue systematically should make solutions available. As in industry, a well-defined and standardized hearing conservation program is needed for concert musicians. The program must determine if sound levels are hazardous and, if so, provide a means to reduce the danger, whether through engineering techniques, hearing protective devices, or both. Serial audiograms and case histories are necessary to identify individuals who have sustained hearing loss from loud music or other causes. This is a difficult problem in that musicians may be reluctant to participate in such a program for fear that documentation of hearing loss may jeopardize their careers. However, a comprehensive and well-administered hearing conservation program can maintain hearing and reduce stress factors associated with exposure to intense levels. In so doing, musicians' professional capabilities will be preserved and their professional lives will be more productive.

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