Musicians and the Prevention of Hearing Loss

Les musiciens et la prévention de la surdité

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Abstract

Professional and amateur musicians pose a unique challenge for the audiologist. The musician is similar to an industrial worker in many ways, although a wholesale adoption of an industrial hearing conservation model may be simplistic. An assessment and treatment model is described, which takes into account what is known about the auditory perception of musicians as well as the various spectra which they are exposed to. An in situ real ear measurement technique is described which is clinically efficient and takes into account the musician's own playing style and instrument. Recommendations for ear protection and environmental changes are delineated, which will ensure that music/noise exposure is minimized while maintaining the ability of the musician to play and enjoy the music. Many of these recommendations are those which form the basis for the world's first safety guidelines for the live performance industry, recently established by the Ontario Ministry of Labour.

Abrégé

Les musiciens professionnels et amateurs présentent un défi particulier pour l'audiologiste. En effet, à de nombreux égards, le musicien ressemble à un travailleur de l'industrie, mais l'application du modèle de conservation de l'ouïe applicable à l'industrie paraît d'emblée simpliste. Suit la description d'un modèle d'évaluation et de traitement tenant compte de nos connaissances actuelles sur les perceptions auditives des musiciens et le spectre acoustique auquel ils sont exposés. Il est ici question d'une technique de mesure de l'audition in situ dont l'efficacité clinique a été prouvée et qui tient compte du style d'interprétation du musicien ainsi que de l'instrument dont il joue. Les recommandations relatives à la protection de l'ouïe et la description des changements à l'environnement ont pour but de minimiser l'exposition à la musique et au bruit, sans empêcher pour autant le musicien de pratiquer son art et de jouir de la musique. Bon nombre de ces recommandations sont à la base des premières lignes directrices mondiales sur la sécurité dans l'industrie du spectacle récemment élaborées par le ministère du Travail de l'Ontario.

There have been several attempts over the past decade to determine the extent to which intense music will damage hearing. Using dosimetry in a classical orchestra, Jansson and Karlsson (1983) found that depending on the seating position within the orchestra, musicians achieved their maximum safe weekly dose of exposure after only 10-25 hours of playing. Chasin and Chong (1991) found levels in excess of 100 dBA during a relatively quiet Étude at Canada's National Ballet, with a peak value of 126 dBA measured on the flute player's right shoulder. At the position of the teacher/conductor, levels of 110 dBA have been reported in high school band classes.

Interestingly, Lindgren and Axelsson (1983) found that 6 out of 10 subjects studied had greater temporary threshold shift (TTS) if exposed to noise than to music of equal energy. This finding of a lower susceptibility for music exposure was also found by Royster, Royster and Killion (1991). There are several potential reasons for this apparent difference in susceptibility between noise and music exposure. One reason is that industrial noise tends to be more steady-state than music, taking into account that all of the quieter portions would allow the auditory system to rest. While the research is not yet definitive on this subject, Ward (1991) states it best: "If it is possible to venture any general conclusion [it is that] intermittence does reduce hazard".

A second reason may be related to the brass and woodwind musicians constantly blowing against a resistance, which in turn creates a slight positive middle ear pressure (Valsalva maneuver). This slight middle ear dysfunction can amount to the equivalence of a 2-4 dBA reduction in noise exposure for bassoon and oboe players (double reeded instruments) and a 1-2 dBA reduction for clarinets and saxophone players (single reeded instruments) and brass players. Non-blowing musicians and industrial workers would not have this potential benefit (Chasin, 1989).

On the other hand, music has a different spectral characteristic despite having grossly equal energy to an "equivalent" noise spectrum. The crest factor (difference between the peak and the root mean square [RMS]) for music is in the order of 18-20 dB, while those of most industrial noises are approximately 10-12 dB.

Another factor is how the noise exposure is measured. Music, unlike industrial noise, has a significant amount of high frequency harmonic energy whereas most forms of industrial noise possess mostly low frequency energy components. Subsequently, the sound field to eardrum transfer function for industrial noise is negligible; that is, the outer ear is transparent for the lower frequencies. However, there can be a 15-20 dB high frequency boost due to the pinna and ear canal resonance which would affect the higher frequency harmonic energy of the music. The end result is that at the ear drum there may be significantly more energy from the music than from an industrial noise source, despite having equal energy in the sound field.

As can be observed, 2 of the 4 reasons mentioned above would decrease the propensity for hearing loss of a musician over that of an industrial worker (intermittent character and Valsalva), and two would increase the musician's propensity (crest factor and sound field to ear drum transfer function). The end result is undoubtedly a complex interaction of these factors as well as other phenomena which we are just becoming aware of, such as the possible effects of the efferent neurological pathways as well as auditory toughening. Nevertheless, musicians do suffer hearing loss albeit possibly to a slightly lesser extent than their industrial colleagues. Of the last 400 professional musicians seen at the Centre for Human Performance and Health Promotion (also known as the Musician's Clinic), 90% of them possessed a high frequency audiometric notch in their audiogram. Only seventeen of these musicians were referred for a primary problem of hearing loss or tinnitus.

This article will delineate some strategies and environmental modifications to prevent permanent hearing loss among those in the performing arts. Specially tuned ear protection based on the measured spectra of the generated music will be specified which both allows the musician to hear the music and to prevent further hearing loss.

General principles and approaches

Following are some general guiding principles and approaches to ensure that future music related hearing loss is minimized.

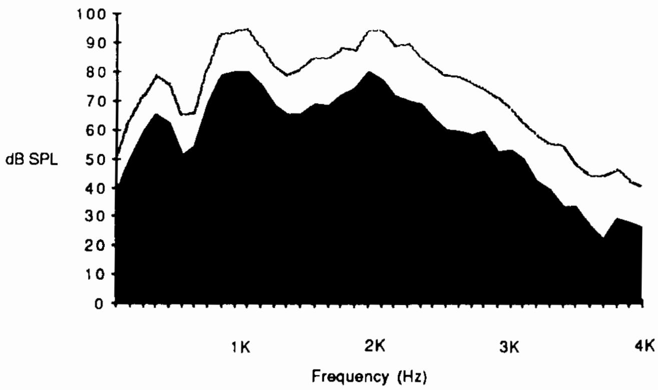
Education is the cornerstone of intervention. Hearing loss is gradual and often goes unnoticed as evidenced by the fact that 90% of patients who were referred to the clinic for non-hearing related problems, had the beginnings of hearing loss. Patients are provided with lay articles explaining the potential problem and given strategies to maintain their hearing. Patients are informed of some psychophysical results, such as intermittency probably reducing music/noise exposure and the related need for quiet breaks. Equal loudness contours are explained to put their hearing loss in perspective; despite having an audiometric notch at threshold, their equal loudness contours are most likely normal at a more intense level. The advantages of wearing long hair over their ears (especially in a Rock environment) are explained. Although this varies widely, relatively thick hair over the ears can reduce music/noise exposure by 3-5 dB in the mid-frequencies, thus doubling the amount of time they can be exposed before damage can occur. (Chasin & Chong, 1992). Although the exact degree of protection is not known, elicitation of the stapedial reflex by humming just before a loud noise will afford some ear protection. Most drummers do this naturally without having to be told.

Custom ear protection. These alternatives fall into two general types: uniform attenuator plugs from Etymotic Research (ER-15® and ER-25®) and vented/tuned earplugs. A full description of the ER-series technology can be found in Killion, DeVilbiss, and Stewart (1988).

The ER-series of ear protection utilizes an attenuator button which plugs into a custom canal tip or semi-shell earmold. The ER attenuator element, along with the volume of air in the bore of the custom mold, serves to enhance the higher frequencies such that the net effect at the eardrum is a flat response. The attenuation can be approximately 15 dB (ER-15®) or 25 dB (ER-25®). Modifications can be made on both the diameter of the bore of the mold, as well as to the length of the bore to obtain a flat response in an ear canal which possesses a non-normal resonance. A uniform attenuator earplug is ideal for many musicians since it treats the fundamental and harmonic energy identically. Figure 1 shows the spectrum of a violin with and without the ER-15® in place. Note that the relative balance of low frequency energy to higher frequency energy is maintained. The ER-series of earplugs is useful for broadband instruments such as the violin, where the magnitude of the higher frequency harmonics are important. Because of the higher spectral energies of drummers caused by the various cymbals and other percussive elements, more attenuation is required than the ER-15®. The ER-25® was subsequently developed.

The vented/tuned earplug is based on a different principle. There are some instruments who either do not have a significant amount of high frequency energy, such as some bass instruments, or the high frequency energy is not musically meaningful, such as with the clarinets and other reeded woodwinds. These woodwind instrumentalists need to hear the interresonant breathiness rather than the magnitude of the higher harmonics per se, so attenuating the high frequency energy will have no noticeable effect other than to lessen the potential damage and annoyance from other instruments in the musician's location.

Figure 1. The spectrum of a violin with (bottom/black) and without (top) the ER-15® in place playing A (440 Hz).



The vented/tuned earplug is simply a custom canal tip or semi-shell mold, with a select-a-vent (SAV) drilled down the main bore. In its most open position (3 mm), the earplug is acoustically transparent below 2000 Hz with a high frequency cut above this point. The air in the sound bore possesses a mass related inertance which resonates at about 500 Hz. This small resonance can serve a beneficial purpose by making the musician more aware of their instrument or voice.

Ear protection requirements. Table I shows the optimal forms of ear protection for the various musician types. These specifications are based on the spectral content of the instrument in question as well as those around them. For example, a solo cellist does not require ear protection, but one in an orchestral environment does because of the presence of the trumpet section to their rear. In some cases more than one type of ear protection is possible. For example, a clarinet player may only require a vented/tuned plug in an orchestral environment; however, this same clarinet player may require the broadband uniform ER-15® attenuator while playing in a jazz or blues band. Non-classical bands usually have speakers close to the clarinet/woodwind player, and the ER-15® attenuator would provide the added protection from this source.

Figure 2. The attenuation pattern of four forms of earplugs are shown - ER-15®, ER-25®, vented/tuned and an industrial foam plug.

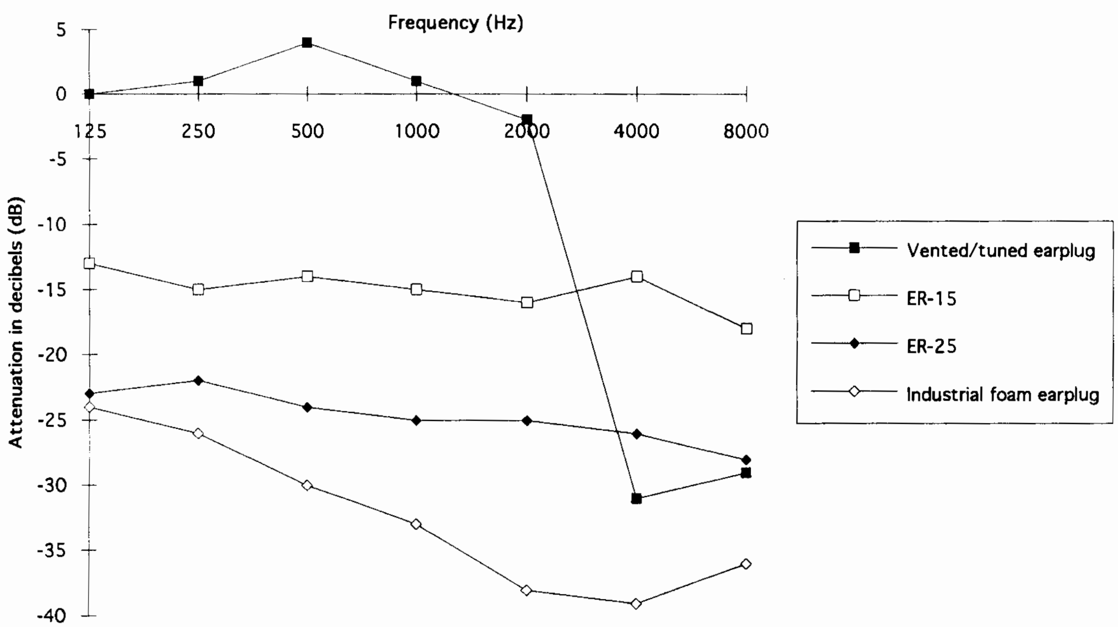


Table I. The optimal forms of ear protection for the various musician types. These specifications are based on the spectral content of the instrument in question as well as those around them.

Instrument	Auditory Damage	Earplugs
Reeded woodwinds	Brass section to rear	ER-15 (Vented/tuned)
Flutes	Flutes (> 105 dB SPL)	ER-15 (Vented/tuned)
Small strings	Small strings (> 110dB SPL)	ER-15
Large strings	Brass section	Vented/tuned
Brass	Brass section	Vented/tuned
Percussion	Percussion (high hats)	ER-20/HI-FI
Vocalists		
Solo	Soprano (> 115 dB SPL)	Vented/tuned
Non-solo	Other instruments	ER-15
Amplified instruments	Amplifiers	ER-15

Environmental strategies. Ontario is the first jurisdiction to pass guidelines for the live performance industry via Ontario's Department of Labour in 1993. The Centre for Human Performance and Health Promotion was instrumental in advising on these guidelines and the rationales have grown out of our experience with musicians in various performing venues. These guidelines are summarized here:

1. Hearing Protection: The uniform and vented/tuned plugs are referred to with the suggestion that audiological input be sought.

2. Speakers: These should have minimal floor contact so that lower frequencies will be transduced to the audience. The sound engineer will not need to have the level as intense in order to obtain the same sense of loudness.

3. Risers: These should be used for the trumpet section as these instruments are highly directional for the higher frequencies only. It is the high frequency energy which is the most damaging, so the risers will protect those who are downwind.

4. Spacing: Whenever possible, 2-3 meters of reflective floor surface should be left unoccupied at the front of the performing group in order to generate high frequency reflections for the audience without the performers being subject to it.

5. Isolation of impulse sounds: Impulse sound sources such as drummers should be at least 2 meters from non-percussive performers or else sound barriers should be utilized.

6. Sound baffles and acoustic shields: These can be used, but only give significant protection (up to 17 dB) if within 18 cm of the musician's head (Camp & Horstman, 1992).

The assessment

Other than simple audiometry, which includes air conduction thresholds in the inter-octave frequencies of 3000 Hz and 6000 Hz, the emphasis should be on the spectral assessment (incorporating the musicians technique, reed, and bow) and the forensic determination of the various sound spectra which the musician is confronted with.

Any real ear measurement (REM) system can be used which has the capability of disabling the reference microphone. Different manufacturers have different nomenclature for this but such a disabling can be accomplished by selecting "substitution" (vs. pressure), or "reference mic. off" (vs. reference mic. on). The REM device should first be calibrated in the normal fashion. Following this the speaker should be disabled (unplugging the speaker is usually sufficient) and the reference microphone is then disabled. We now have an in situ sound level meter which can perform spectral analyses at the ear drum or at any other point in space.

Playing and sustaining a musical note while the REM device performs a filtered sweep or an FFT (Fast Fourier Transform) will yield the in situ spectrum. Playing notes of different intensities and of different fundamental frequencies will delineate the range of the instrument. From a forensic point of view, the audiologist should determine which instruments are to the front, rear and sides of the musician in question, in order that music/noise exposure information from other sources can be obtained.

Two examples

(1) Violins are capable of generating wide band spectra which can be in the order of 110 dBA, as measured at the left eardrum of the musician. This value would be greater than that measured in the sound field or even at the meatal opening of the left ear, because the high frequency harmonic energy is enhanced due to the outer ear resonant effects. Clearly the violin can generate levels in excess of a damaging dose in short order. Indeed, an asymmetry is found usually at 6000 Hz in the left ear because of the close proximity of the violin to that ear. Similar results are also found with the slightly larger viola. Because of the intense music/noise exposure, the violinist requires some protection. A violinist needs to hear the relative magnitude of the higher frequency harmonics and as such requires a broad band uniform attenuator with about 15 decibels of attenuation.

Subsequently, the ER-15® ear plugs were recommended. This is the ear protection of choice for the violinist, and many professional violinists use them quite successfully. In some orchestras, part of the trumpet section is placed to the rear of the violin section. Elevating the trumpets on risers allows potentially damaging energy to literally go over the heads of the violinists downwind. Finally, a violinist should not be placed under an overhang in an orchestral pit, as this structure tends to absorb the higher frequency harmonics of the violin. Placing a violinist in this position may cause them to overplay (in order to re-establish the high frequency harmonic energy) with ensuing arm or wrist damage.

(2) A percussionist is found playing almost every type of music, be it classical, pop, rock, jazz, or cultural. A typical example is that of a rock drummer who is referred for wrist or arm damage. When questioned, he reported starting to wear industrial strength foam earplugs approximately 6-8 months previously. When the noise level from his drum strokes was assessed using a practice pad, levels of 111 dBA were obtained with the foam plugs in place. Without the foam plugs, the level dropped to 102 dBA. The drummer was fitted with a pair of ER-25® earplugs and his playing level was measured to be 103 dBA. With the foam earplugs, the drummer was overhitting the drums, causing wrist strain. When the ER-25® earplugs were made, his wrist problems abated, and associated electro-physiological measures of muscle strain such as EMG returned to a more normal level with the ER-25® earplugs in place. In addition, because of the use of the ER-25® earplugs, the noise levels from his drum set are no longer damaging. He was also encouraged to move his drum set as far away from the other musicians as the venue would allow, specifically to ensure that the high hats (typically on the left side of a right handed drummer) were as far as possible from the nearest musician. Audiometrically, there was a left ear asymmetry caused by the presence of the high hats on the left side. If this drummer had been playing more jazz than rock, there probably would not have been an audiometric asymmetry because these drummers play harder on the ride cymbal which is not as damaging.

Conclusion

We are not at the stage where we can make definitive comments about the damage risk criteria for musicians, nor to determine whether they are as prone to music exposure as are their industrial colleagues. Preliminary research indicates that indeed they are slightly less prone, but given the wide range of playing styles and resulting spectra, such a general statement must be offered only very tentatively. We do know that musicians receive a damaging dose because they are subjected to music/noise doses which exceed even the most conservative regulations by several orders of magnitude. In addition, audiometric notches are found in the vast majority of professional (and most amateur) musicians. Therefore, the most ethical clinical approach would be one of prevention.

A musician's playing style and equipment (reed, bow, instrument) all can significantly effect the music/noise level which reaches the eardrum. These levels can be assessed individually and expeditiously, typically within a half-hour session. The recommended ear protection can also be specified and verified with the same in situ technique, using the modified real ear measurement device.

The results of work such as this can and should be expanded to cover the typical work environments of school band teachers, aerobics instuctors, and dance teachers. Although there is minimal concern for the students in aerobics and dance classes, the teachers are frequently in high music/noise levels for 30-50 hour work weeks. People in the performing arts are at risk for long-term hearing loss. They currently fall in between the legislative cracks of most jurisdictions, although some provinces do cover school music teachers under the Worker's Compensation Board Act. Performing arts guidelines such as those recently implemented in Ontario are an important first step, but much work still needs to be done before these ideas can be enshrined in a legislative framework.

Author notes

Figure 1 and Table I were reprinted with permission from Chasin and Chong (1992) *Medical Problems of Performing Artists.*

To obtain a copy of the "Safety Guidelines for the Live Performance Industry in Ontario - 1st edition, December 1993", write to: Ontario Ministry of Labour, Information and Administrative Services, Operations Division, 400 University Ave., 9th Floor, Toronto, ON M7A 1T7.

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