Noise and Hearing Loss in Musicians

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Safety and Health in Arts Production and Entertainment (SHAPE)
Suite 280 - 1385 West 8th Avenue
Vancouver, BC
V6H 3V9

Prepared by:

Cheryl Peters,
Jadine Thom, Elaina McIntyre, Meghan Winters,
Kay Teschke, Hugh Davies*

School of Occupational and Environmental Hygiene
2206 East Mall
Vancouver, BC
V6T 1Z3

*Corresponding author

Executive Summary

This literature review was produced at the request of SHAPE, the association for Safety and Health in Arts Production and Entertainment.

SHAPE was concerned about noise exposure among arts and entertainment employees. An excellent lay publication *Listen While you Work*[1] had been previously completed and so SHAPE asked us for a rigorous systematic review of the scientific literature for specific questions such as "*To how much noise are musicians exposed? Is there a hearing loss problem for musicians? What do we recommend that musicians and other entertainment professionals do to protect their hearing?*"

We conducted a systematic and comprehensive review of the peer-reviewed scientific literature with respect to hearing loss among musicians, exposure to noise, determinants of noise exposure, and methods for controlling those exposures. Details of the literature search are given in an appendix.

We found that both classical and rock musicians are at increased risk of developing noise-induced hearing loss and an associated disease, tinnitus, as a result of their exposure to music.

Musicians – even classical musicians and choral singers – can be exposed to very high, damaging levels of sound. Average levels between 80 and 100 dBA have been recorded for classical musicians, and 90-105 dBA for rock musicians. Peak levels can be higher still. Non-musicians who work in entertainment venues are also at increased risk.

Factors contributing to hearing damage include playing a "loud" instrument; many wind instruments, including trombone, flute, piccolo French horn and clarinet are capable of producing sound over 100 dBA. Also, there is risk associated with sitting near loud instruments (especially in front of other loud instruments). Electronically amplified music can be much louder again. The risk of hearing loss increases with increasing duration of exposure, which includes not only performance, but also practice, and attending concerts (which may or may not be occupationally-related). Poor acoustical design of some venues may also result in increased noise exposure.

Despite these hazards, there are techniques that can be used to control exposure and help to prevent hearing loss. These may be behavioural (such as resting ones ears by avoiding loud noises outside of work), engineering-based (such as modifying the seating positions of loud instruments, or elevating speakers off of the floor), or various techniques (devices?) for ear protection, including many new models designed to reduce sound level without altering original sound quality. Certain barriers to implementing control measures are somewhat specific to musicians: the ability to retain sound quality while reducing sound level is paramount; there is a psychological aspect of not wanting to be

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[1] *Listen While you Work: Hearing Conservation for the Arts. Produced by Safety and Health in Arts Production and Entertainment, Vancouver, B.C. 2001*

seen to have “weak” hearing in business that is all about subtlety and nuance; and the risk of increasing risk of one hazard while reducing another, such as ergonomic strain from adjusting playing techniques.

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Why did we do this review?

SHAPE (an organization created to address Safety and Health in Arts, Production, and Entertainment) asked the University of British Columbia to help investigate several questions related to the noise-related health and safety of musicians and other workers potentially exposed to loud music that fall under their mandate. These questions were:

1. How much noise are musicians exposed to?
    a. How do we define noise?
    b. What kinds of regulations are there for the noise at music venues?
    c. How loud are music venues?
2. Hearing loss in musicians: Is there a problem?
    a. How well do classical musicians hear?
    b. What about rock musicians?
    c. What about other people who work around music, like bar and club staff?
    d. What factors can increase the risk of noise-induced hearing loss in musicians?
3. What do we recommend that musicians and other entertainment professionals do to protect their hearing?
    a. Changes to the environment or behaviours
    b. Hearing protection devices

A comprehensive literature search was performed using several scientific literature databases, and the references of gathered articles were also searched by hand for completeness. Please refer to Appendix 1 for further details about the search methodology. Appendix 2 contains tabular information on all of the papers that were reviewed, and includes Table 1 (Epidemiology), Table 2 (Exposure Assessment), Table 3 (Disorders Other Than Noise-Induced Hearing Loss), Table 4 (Controls and Preventive Measures), and Table 5 (Papers not used for this review, but may be of interest to the reader).

How much noise are musicians exposed to?

There are several unique reasons to be concerned about sound exposure and its effect on musicians' hearing. First of all, musicians' working hours are usually quite varied as compared to most employees, especially during performance weeks. Also, musicians spend a varied amount of time practicing, playing solo and as a member of different groups, and enjoying the music of others. One review article suggested that classical musicians play an average of 25 hours per week (Palin 1994), but this could vary widely from week to week, and from person to person.

How do we define noise?

As you probably know, sound has both pitch (frequency; which we quantify in units called Hertz) and loudness (amplitude; which we quantify in units called decibels, abbreviated dB). Sound is *produced* by sources and we experience *noise* at our ear, if the sound is undesirable.

Throughout this review, the *loudness* component of sound will be expressed in either decibels (dB) or A-weighted decibels (dBA). For reference, some common events with their corresponding sound levels are presented in Table 1.

"A-weighting" filters out some of the low-pitched sounds, because these do not contribute much to hearing loss. Therefore, exposures measured in dB will be somewhat higher than exposures measured in dBA, especially where there is a great deal of low-pitched sound.

Table 1: The sound pressure levels associated with different events (*adapted from "Listen While You Work", by Kevin Sallows for SHAPE, 2001*):

Approximate sound level (dBA)	Sound source
45-55	Normal conversation at arm's length
60-70	Piano played at moderate levels
75-85	Chamber music in a small auditorium
80	Telephone dial tone
90	Train whistle at 150 meters away
92-95	Piano played loudly
95	Subway train at 60 meters away
105-120	Amplified rock music at 1-2 meters away
120-137	Symphonic music peak
140	Jet engine at 30 meters away
150	Rock music peak

You may also recall that the scale that sound levels are measured on is logarithmic, such that for each increase of 3 dBA, the sound level is actually *doubling,* so 88 dBA is twice as loud as 85 dBA.

What kinds of regulations are there for the noise at music venues?

The regulatory limit for noise exposure in BC is 85 dBA, and this is set and enforced by the WCB (Workers' Compensation Board). This number is based on an 8-hour work day for which the average noise level is less than 85 dBA. **If either the total duration of noise exposure *or* the level of noise exposure increases the other must decrease to prevent permanent hearing loss**. The following table (Table 2) shows the maximum exposure times for different sound pressure levels:

Table 2: Maximum exposure times for different sound pressure levels

Sound level (dBA)	Maximum Exposure Time
82	16 hours
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes
103	7.5 minutes

How loud are music venues?

As you might imagine, the sound levels in a venue depend on a number of factors, such as the type of music being played, the number of musicians, types of instruments, amplification, and the design of the venue. The first detailed measurements of sound levels produced by musical instruments were reported in the early 1930's (Lebo and Oliphant 1968). Review articles on the subject of sound measurements report varied levels, but one result is clear: rock, pop, jazz, and symphonic music ***ALL*** have the potential to produce sound levels well above the WCB 8-hour limit of 85 dBA.

In a study by Westmore & Eversden, sound levels reached 104 dBA, resulting in perceptible pain for some of the classical-musician subjects (Westmore and Eversden 1981). Another researcher found that during practice time, there was an average sound level of 100 dBA for several different types of bands (Early and Horstman 1996), showing that performances aren't the only dangerous times for a musician's ears. In general, most researchers report sound levels of about 80-100 dBA (average, for the performance) for classical music (Arnold and Miskolczy-Fodor 1960; Lebo and Oliphant 1968; Axelsson and Lindgren 1981; Westmore and Eversden 1981; Jansson and Karlsson 1983; Szymanski 1983; Royster, Royster et al. 1991; McBride 1992; Sabesky and Korczynski 1995; Fisk 1997; Teie 1998; Laitinen, Toppila et al. 2003; Lee, Behar et al. 2003), with short-term peaks of up to 137 dBA (Westmore and Eversden 1981). Choirs have been reported to produce sound levels of about 100 dBA as well, which is important to know for professional singers and the musicians that may accompany them (Steurer, Simak et al. 1998).

For rock/jazz/pop music performances, the dynamic range of the music is somewhat less (i.e. – once a rock song starts, there isn't much variation in the sound level as compared to say, a symphony) (Hart, Geltman et al. 1987). This also means that rock music is on average louder, because there aren't as many quiet spots in the arrangements (Gunderson, Moline et al. 1997). The literature indicates that an average sound level during a rock performance is likely to fall between 90 and 105 dBA (Lebo and Oliphant 1968; Dey 1970; Gunderson, Moline et al. 1997; Jaroszewski, Fidecki et al. 1998; Henoch and Chesley 2000; Bray, Szymanski et al. 2004), with peaks up to around 150 dB (Hart, Geltman et al. 1987). As an interesting aside, there is a small body of literature on professional pannists (steel drum players); they can produce average sound levels of about 110 dBA with their drums (Griffiths and Samaroo 1995; Juman, Karmody et al. 2004).

So as one can see, there is a large potential for hearing damage to musicians. Average sound levels are often above the recommended safety level of the WCB, and peak levels are sometimes high enough to cause pain in listeners. This begs the question: are musicians more at risk for hearing loss, given all this exposure to loud noise?

Hearing loss in musicians - Is there a problem?

Most people are aware that loud noises are bad for your ears, and might lead to hearing problems down the road. Since listening to music is a positive, pleasant, and desirable activity for many people, it may come as a surprise that music can have a negative effect on hearing too.

Work-related hearing loss is quite a different problem for those in the music industry than it is for industrial workers. Musicians and DJs regard themselves as having superior hearing, specially trained to detect nuance or tone, and consider that their hearing is their livelihood (Axelsson and Lindgren 1981; Early and Horstman 1996). A slight hearing loss that may not bother an industrial worker may cause difficulties for a musician. In addition, controlling musicians' exposures poses a different challenge than it does for other types of employees.

Even though sound levels can be exceedingly high at music venues, very few investigations on the hearing of musicians had actually taken place as of the early 1980's (Axelsson and Lindgren 1981). An early study on the hearing of orchestral musicians at an opera house found that 42% of participants had hearing loss that was greater than expected for their age (Axelsson and Lindgren 1981). Many other studies, including both classical and pop musicians, have found similar results: musicians have worse hearing than would be expected based on their age (Lebo and Oliphant 1968; Westmore and Eversden 1981; Jansson and Karlsson 1983; Hart, Geltman et al. 1987; Ostri, Eller et al. 1989; Royster, Royster et al. 1991; Fearn 1993; Jaroszewski and Rakowski 1994; Jaroszewski, Fidecki et al. 1998; Eaton and Gillis 2002; Kahari, Zachau et al. 2003). Other researchers report no difference between musicians and other workers (Arnold and Miskolczy-Fodor 1960; Karlsson, Lundquist et al. 1983; Johnson, Sherman et al. 1985; McBride 1992; Kahari 2001); this difference in finding may be due to varying definitions of what constitutes hearing loss, difficulties in quantifying leisure noise exposure, or poor study quality (Sataloff 1991).

The general consensus in the literature suggests that **hearing loss is a problem for musicians**, and this varies across type of music played (i.e. – rock or jazz or classical), and type of instrument played (Palin 1994; Mikl 1995). It has been suggested that since sound pressure levels (SPL) produced by music can be (and often are) well above the recommended 85 dB, we have good reason to be concerned about musicians' hearing.

Another complaint from some musicians (but more typically of industrial workers) is a disease called "tinnitus", which is a permanent ringing in the ears caused by *chronic* exposure to loud noises (Axelsson and Ringdahl 1989; Axelsson and Prasher 2000; Lockwood, Salvi et al. 2001). More research needs to be done on the musician's experience with this often highly debilitating disease.

How well do classical musicians hear?

Estimates by several researchers on the incidence of hearing loss among classical musicians range from 4-43%, however these losses are usually slight (Arnold and Miskolczy-Fodor 1960; Axelsson and Lindgren 1981; Westmore and Eversden 1981; Hart, Geltman et al. 1987; Behroozi and Luz 1997; Chesky and Henoch 2000). "Hearing loss" can be defined in many ways, but it is usually measured using *audiometry*, which tests at what sound pressure level a certain frequency (or pitch) of sound is barely audible to the person being tested. This is recorded as an "audiogram", which is a graph of frequency (pitch) against sound level (measured in dB). The audiograms of a musician being tested can be compared to an average audiogram for that person's age and sex, and differences can be assessed for their relation to noise. Usually, a downward "notch" in an audiogram (meaning it takes a higher sound pressure level for the person to hear) around 4000 Hertz (between the notes B7 and C8, if middle C is C4) indicates that noise might have caused some damage.

The most important factors in assessing the hearing of classical musicians is **what instrument you play** and **where you sit in the orchestra**. Some typical sound levels by instrument type, when performing solo, are presented in Table 3. The values in the table are given as a range, and this reflects sound levels produced during varying musical compositions (i.e. – piano versus fortissimo).

Table 3: Sound levels by instrument type (adapted from (Hart, Geltman et al. 1987; Sataloff and Sataloff 1991; Teie 1998)).

Instrument	Typical sound levels (dBA)
Trombone	85-114
Piccolo	95-112
Flute	85-111
French horn	90-106
Clarinet	92-103
Violin	84-103
Piano	92-95
Oboe	80-94
Xylophone	90-92
Cello	84-92
String Bass	75-83

In particular, brass musicians and certain woodwind players showed an increased risk of hearing loss (Axelsson and Lindgren 1981), although Karlsson reported that double bass and flute players are at increased risk (Karlsson, Lundquist et al. 1983). For French horn players, but also for some others, sound levels come from the instruments around them rather than their own instruments (especially from drums, which are usually right behind the horn section).

What about rock musicians?

Estimates of the number of rock and pop musicians with some level of hearing loss range from 13 to 30% (Axelsson and Lindgren 1981; Hart, Geltman et al. 1987; Jaroszewski and Rakowski 1994; Chesky and Henoch 2000). Indeed, there are many anecdotal reports of hearing loss in rock and pop musicians, brought to attention by rockers like Pete Townsend, Eric Clapton, and Sting (*http://www.youth.hear-it.org/page.dsp?forside=yes&area=782*). The sound pressure levels measured in rock music venues are often especially high and fairly constant, such that ears aren't offered any break. The performers themselves also spend time in practice, and attending other rock concerts, and therefore may receive substantial doses of loud music on a regular basis.

Dey reported that about 16% of young men exposed to 2 hours of rock music at a sound pressure level of 110 dBA experienced "unusually severe" temporary threshold shift (Dey 1970). It seems that hearing damage from rock music may lead to more severe hearing losses than the "slight" ones mentioned above for most classical musicians. One study found that 51.1% of their cohort had hearing threshold deficits of 20 dB or greater (Fearn 1993). This study also revealed that most of this hearing loss occurs at the pitch of 6000 Hz (between F6# and G6, if middle C is C4), and may occur in one ear only (on the side closest to amplifier/speaker, or cymbal/drums) (Sataloff 1991; Fearn 1993). Sataloff cited the results of a study by Speaks (1970), where temporary threshold shifts occurred in about half of the rock musicians studies, and permanent threshold shifts existed in one quarter (Sataloff 1991). Twenty-five percent of the subjects in Axelsson & Lindgren's study were also affected by hearing loss (greater than 20 dB) attributable to their pop music exposures, and the largest notch in the audiogram was at 6000 Hz (also cited in (Sataloff 1991).

Given the measured sound levels in bars and the substantial body of evidence (both in scientific and popular sources), there is ample reason to believe that rock and pop musicians are at risk of hearing loss, beginning at the 6000 Hz frequency, and perhaps in one ear more than the other.

What about other people who work around music, like bar and club staff?

According to Meyer-Bisch (Meyer-Bisch 1996), the sound level on a typical dance floor ranges from 95-110 dBA, and rock concerts almost always fall between 100 and 115 dBA. Given that many people are employed in these venues and would be expected to be exposed to these levels for several hours during a shift, the potential for hearing loss could be quite high.

A comprehensive review of the exposures of bar and club staff was conducted at the Health and Safety Executive in the United Kingdom in 2002 (Smeatham 2002), and this report should be consulted for specific questions.

The following table (Table 4) summarizes the results of all the studies reviewed by Smeathem with regards to noise exposure of bar staff, by occupation. These sound exposures are loud enough to cause permanent noise damage to the average person, based on calculations presented in the report (Smeatham 2002); the longer a person is exposed, the higher the risk!

> Many studies in these venues test what is called "temporary threshold shift", or TTS, where some sensitivity in hearing is lost right after a loud concert, but returns after a rest. Hearing loss can be thought of as a "permanent threshold shift"; it has been suggested that experiencing TTS 5 times a week for 10 years can cause a permanent hearing loss of that level (Jaroszewski and Rakowski 1994). However, the relationship between TTS and PTS is not clear at this point (Gunderson, Moline et al. 1997; Smeatham 2002).

Table 4: Average noise exposure of various bar staff (accumulated results)

Task/ occupation	**Number of measurements**	**Average dB(A)**	**Average hours per week**	**Time per day permitted at this sound level**
DJ	53	96.3	16.5	• 36 minutes/day • 3 hours/week
Bar staff	204	92.3	15.7	• 1.5 hours/day • 7.5 hours/week
Floor staff	32	92.9	Not given	• 1.3 hours/day • 6.5 hours/week
Security (bouncers)	10	96.2	Not given	• 36 minutes/day • 3 hours/week

What factors increase the risk of noise-induced hearing loss in musicians?

There are several risk factors for noise-induced hearing loss (NIHL) in musicians of all types. Some are quite obvious, such as playing music that is consistently loud (i.e., non-classical) (Chesky and Henoch 2000; Kahari, Zachau et al. 2004), or playing music with high intensity at high frequencies (as in some symphonies). Perhaps equally obvious is the observation that being exposed for longer periods of time, whether over a period of one day or over a lifetime, poses a higher risk for developing hearing loss (Kahari, Axelsson et al. 2001). Playing some of the "louder" instruments (such as bassoon, French horn, trumpet, double bass, flute, and trombone) has also been associated with poorer hearing (Axelsson and Lindgren 1981; Karlsson, Lundquist et al. 1983; Eaton and Gillis 2002). In many cases, this may also be related to the musician's position in the orchestra, with those sitting in front of the brasses or percussion section reporting worse hearing (Westmore and Eversden 1981). Violinists and flautists may also be at increased risk for developing worse hearing losses in their left and right ears, respectively, due to the placement of their instruments (Ostri, Eller et al. 1989).

Many researchers have noted that male musicians tend to have more pronounced hearing losses than females; whether this has a biological cause, or is a function of men playing louder instruments is not clear (Axelsson and Lindgren 1981; Steurer, Simak et al. 1998; Kahari, Axelsson et al. 2001; Kahari, Zachau et al. 2003). Musicians who have had a longer career are also at increased risk of hearing loss. In older people the natural loss of hearing with age (called 'presbycusis') seems to be worsened with increasing noise exposure (Kahari 2001). Since musicians and entertainment professionals often spend a great deal of their leisure time partaking in the music of others, it is important that they use hearing protection during these times to give their ears a rest (DeLay, Hiscock et al. 1991). If they do not, they increase their risk of hearing loss in the long run (Bray, Szymanski et al. 2004). Poor acoustic design of venues, especially important for rock music, may pose a greater risk for musicians' hearing as well (Hart, Geltman et al. 1987).

What do we recommend that you do to protect your hearing?

There are many different options and methods to reduce the risk of noise-induced hearing loss depending on your instrument type, or your job. An interesting observation is that many of today's "innovations" to make music "better" might actually hinder a musician's ability to monitor the sounds that they produce. For example, you might have seen or used baffles or overhangs to dampen the sound in your orchestra pit or on stage. While these may help in some situations, they can also make it hard for the musician to get a feel for their tone, and how loud they are playing (Chasin and Chong 1995). Overcompensation is common, and the musician is more likely to play louder so that they can hear themselves properly. This creates a situation that may be dangerous to hearing, as well as to the wrists and hands, resulting in ergonomic problems . For example, they reported a drummer who used inappropriate earplugs that blocked *too much* sound; he ended up overplaying and developing sore wrists.

In general, the use of baffles, sound shields, transparent shields and the like is rather limited. This appears to be because not enough research has been done on their effectiveness in preventing hearing loss among musicians, and doubt about preserving the quality of the music if they are used (Hart, Geltman et al. 1987; Daum 1988; Teie 1998; Eaton and Gillis 2002).

Following are suggestions from the literature for preventing hearing loss in musicians:

Changes to the environment or to technique

Since it is not often possible to reduce the intensity of music at its source, here are some features that can be changed about the way your band or orchestra is *organized* that may help reduce noise exposure.

1. ***Elevate speakers and amplifiers off of the floor*** (Chasin and Chong 1995)
   When these instruments are set on the floor of the stage, low frequency sound is absorbed by the floor, causing the sound engineer to turn up the volume to create the feeling of "loudness". This creates a potentially dangerous situation for excessive noise exposure. If the speakers are elevated, less low-frequency noise is lost to the floor, and the desired sound can be delivered at less intensity.

2. ***Make sure that the small strings (violin/viola) do not have any overhangs above them (for at least 2 meters of unobstructed space)*** (Chasin and Chong 1995)
   It is common, especially in orchestra pits, to place the small stringed instruments underneath an overhang. This usually dampens the sound in the higher frequencies. While this may appear to be a positive development, because we know that the higher frequencies are most damaging to the ear, this is not the case. If the musician can't properly monitor the tone of their instrument, they tend to play *louder*, with negative effects on themselves (strain injuries, higher noise exposure) and their neighbours.

3. ***Make sure that there is at least 2 meters of unobstructed space between the front of the orchestra and the audience*** (Chasin and Chong 1995)
   Having floor space in front of the orchestra creates a surface for shorter sound wavelengths (higher frequency) to reflect off of, allowing these notes to be better monitored by the musicians. When the musicians can hear the full tonal quality of their music, they are not required to overcompensate and risk overuse injuries and louder sound exposures.

4. ***Place the treble brass instruments on risers*** (Hart, Geltman et al. 1987; Daum 1988; Chasin and Chong 1995)
   The treble brass instruments produce high intensity sounds at high frequencies, making them especially hazardous to hearing. In addition, these instruments produce a sound that is highly directional, so that people sitting in front of brass

musicians are at highest risk for hearing damage. By directing the treble brass sounds out and over the heads of those musicians, less sound will reach their ears.

5. ***Do not stand or sit directly in front of speakers (for rock musicians) – move slightly to the side*** (Sataloff 1991; Hall and Santucci 1995)
Amplifiers and speakers project their sound outwards. Standing behind the speakers is not feasible, as too much sound quality is lost, but standing slightly to the side of the equipment will reduce the intensity of the music without losing too much in the way of quality.

6. ***Avoid overcrowding of musicians whenever possible*** (Hart, Geltman et al. 1987)
Having a smaller distance between musicians increases the sound delivered to the ear, especially when the instrument's sound is highly directional (like trumpets) (Kahari 2001). In addition, the increased sound levels from neighbouring players may reduce the individual's ability to monitor their own sound, which may encourage louder playing.

7. ***Let your ears rest*** (Fearn 1993) for at least 12 hours after a loud concert, and wear ear protection during your leisure noise exposures.

Hearing protection devices

The use of hearing protection devices (earplugs) by musicians has been historically undesirable or even somewhat taboo (Chasin and Chong 1992). It has been undesirable for 2 main reasons: 1) the *occlusion effect*, which causes the user to feel stuffed-up or "echoey", and 2) the stronger attenuation of high frequency sounds relative to low frequency (Killion and Stewart 1988; Chasin and Chong 1991). It has been considered taboo because a musician doesn't want their peers or their audience to perceive them as having less-than-perfect hearing (Ostri, Eller et al. 1989).

Luckily, hearing protection devices (earplugs) have come a long way, and there are several commercially available models specially designed for use by musicians. Table 5 gives a recommended earplug by instrument type; the earplugs are described in more detail below. Most of the research on the protection of musicians' hearing has been undertaken by two research teams led by Marshall Chasin, as well as Michael Santucci.

Also note that more specialized earplugs are available today (Chasin and Santucci made their recommendations in 1991). Etymotic Research (ER) makes "filter buttons" that fit into plugs that you have made by an earmold lab. Therefore, it is easy to substitute in a button that provides a different amount of attenuation if the musician requires it. Currently, ER makes buttons with 9, 15, and 25 dB uniform attenuation, as well as their non-custom ER-20 (all described below, and at www.etymotic.com).

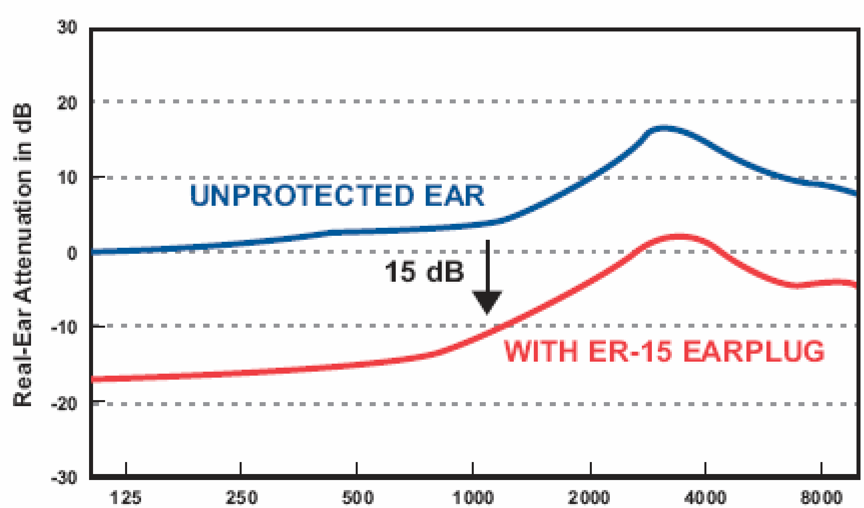
Table 5: Optimal earplug by instrument type (Chasin and Chong 1991)

What instrument do I play?	Which instruments are likely to affect my hearing?	What plug should I use?
Reeded woodwind	The brass section (to the rear)	ER-15 (vented/tuned)
Flute	Flute section	ER-15 (vented/tuned)
Small strings	Small strings	ER-15
Large strings	Brass section	Vented/tuned
Brass	Brass section (or percussion)	Vented/tuned
Percussion	Percussion	ER-20/Hi-Fi
Vocalist (solo)	Soprano singers	Vented/tuned
Vocalist (non-solo)	Other instruments	ER-15
Amplified instruments	Amplifiers	ER-15

The ER-15 earplug

This custom-made earplug (developed by Etymotic Research) has an acoustic amplifier built right inside it. Since higher frequencies are inherently attenuated more strongly, this device pre-emphasizes this range, and the net result is uniform attenuation of about 15 dB (Killion and Stewart 1988; Santucci 1990; Chasin and Chong 1991). What this means in practical terms is that all frequencies of the music are reduced in *intensity* at the ear by 15 dB, with no change in the fundamental or harmonic structure of the music (see Figure 1). The sound filter is purchased from Etymotic Research, but a mold of the ear must be taken at a registered lab, so these plugs can be costly (about $150-$200).

Figure 1: Response of the unprotected ear versus an ear protected by the ER-15 *(from http://www.etymotic.com/pdf/erme-er20-fittingguide.pdf)*



The ER-20/HI-FI earplug

This is a *non-custom* (one-size-fits-most) earplug (pictured in Figure 2) that aims to match the fundamental and harmonic structure of music at the ear, only at a sound pressure level of about 20 dB lower than at the unprotected ear (Chasin and Chong 1991). Because of the non-custom fit, there is a slightly higher attenuation at higher frequencies (called "roll-off"). The ER-20 is a lower-cost (less than $20 a pair) alternative to the ER-15, and works well for percussionists whose highest-risk sound exposure comes from the high-hat cymbals. The slight high-frequency roll-off helps to prevent damage at a frequency of 6000 Hz (mostly from the cymbals). The sound attenuation provided by the ER-20 is shown in Figure 3, as compared to 2 common foam earplugs. If required, it is possible to make a custom version of the ER-20 is with the help of an earmold lab.

Figure 2: Diagram of the ER-20/Hi-Fi earplug *(from http://www.etymotic.com/pdf/erme-er20-fittingguide.pdf)*

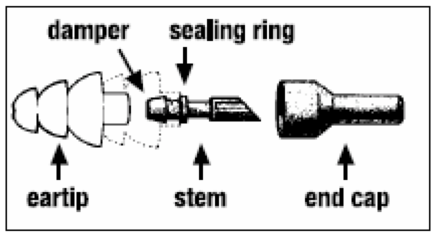
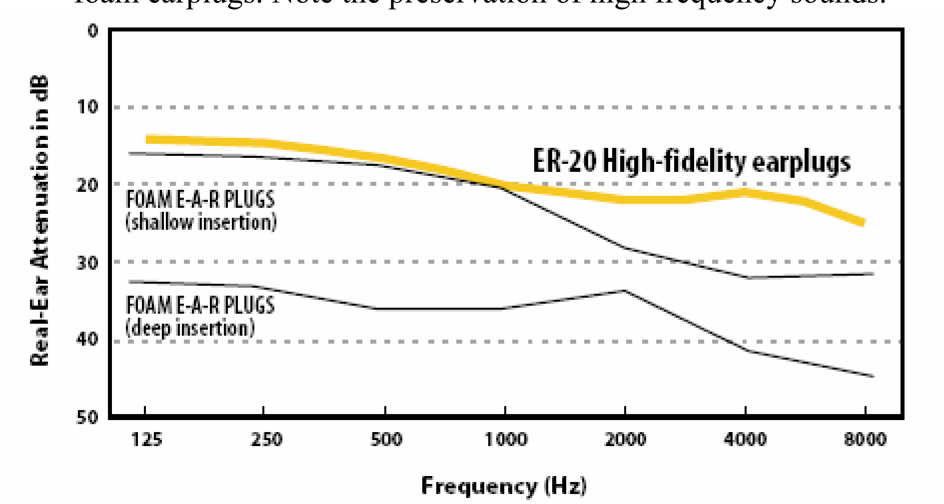


Figure 3: The real-ear attenuation of the ER-20/Hi-Fi as compared to 2 types of regular foam earplugs. Note the preservation of high frequency sounds.



The Vented/Tuned earplug

This type of plug was also developed by researchers specifically for musicians. It consists of a swimmer's earplug with a tuneable vent or "Select-A-Vent" drilled through the center (Chasin and Chong 1991). When the hole is at its largest (about 3mm), the earplug is "transparent" up to about 2000 Hz, but has about 30 dB of high frequency attenuation. By varying the diameter of the hole, this acoustic signature can be altered, depending on the type of sound being filtered. This is a highly specialized earplug that is especially useful for musicians who don't require much attenuation at lower frequencies (because their instrument is not capable of producing very loud noises at these pitches), and also don't need to bother much with high frequency sounds to monitor their tone. An example of this is the large stringed instruments.

In summary, there are many feasible options for the at-ear protection of musician's hearing. Those interested are encouraged to visit the websites for Etymotic Research at www.etymotic.com, and Sensaphonics, another designer and developer of hearing protection for music venues and musicians (www.sensaphonics.com).

Conclusions and Recommendations

Based on this comprehensive literature review, it is evident that all types of musicians are at increased risk of developing hearing loss as a result of their exposure to music. Some factors that may increase this risk include playing louder instruments (brass or drums, for example), position in the orchestra or on stage, longer career length (regardless of age), and playing in acoustically unsuitable venues. Despite these risks, however, there are many techniques that can be used to control exposure and help to prevent hearing loss. These may be behavioural (such as avoiding loud noises outside of work), engineering (such as modifying the seating positions of loud instruments), or varying techniques for protection at the ear (such as the ER-15 earplug).

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Appendix 1: Literature Search Strategy

Four bibliographic databases were used to identify the literature for this review: PubMed, CCINFOWeb, Compendex, and Web of Science. PubMed, produced by the U.S. National Library of Medicine, specializes in health literature. CCINFOWeb, produced by the Canadian Centre for Occupational Health and Safety, specializes in occupational health and safety literature. Compendex contains information on engineering, and some noise measurement papers were located using this database. The search was conducted in February 2005 and employed combinations of the following keywords: noise, hearing, hearing loss, noise-induced hearing loss, tinnitus, audiometry, dosimetry, TTS, PTS, hearing conservation program and musicians, classical, rock music, pop music, musical instrument, symphony, orchestra, orchestral music, hearing protection devices. In addition, a significant portion of the literature cited within this review was identified through pearling, or hand searching of references found within other papers. We included all accessible scientific literature relating to noise exposure and hearing loss in musicians in general, but excluded articles which were written in languages other than English and French.

Appendix 2: Literature Review Summary Tables

Table 1: Epidemiology Papers: Exposure and Health Outcome Papers

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Arnold	1960	Pure-tone thresholds of professional pianists	(30) pianists who volunteered	cross sectional	piano music	NIHL	to examine whether piano music can cause hearing loss in professionals	SPL measured on the pianos were up to 95 dB; the group of pianists were all over the age of 60, and actually had better hearing than might be expected for their age group; however the SPLs were high enough that susceptible individuals might be expected to experience deleterious effects
Axelsson	1981	Hearing in classical musicians	139 musicians & 19 retired musicians	cohort	classical music	NIHL & tinnitus	To assess hearing damage among musicians using hearing tests combined with exposure measurements	Audiograms for all musicians indicated a slight hearing impairment; women had better hearing than men (but small # of women); sound levels ranged between 40 and 100 dBA; also mentions rehearsal time @ home, as well as tutoring as other exposures; highest Leq (5 hour) was 88 dBA; brass musicians had the most hearing loss
Behroozi & Luz	1997	Noise related ailments in performing musicians: a review	musicians	review			to review the influence of noise on hearing and the CV system of musicians	Evidence for auditory/non-auditory deleterious effects of loud music
Bray et al	2004	NIHL in dance music disc jockeys and an examination of sound levels in nightclubs	23 DJs (audiometry and exposure measurements)	cross sectional	club music	NIHL	to assess exposure and NIHL among DJ's (maybe only study of this kind??)	3/23 DJs had clear NIHL; most were concerned about hearing loss but did not wear HPD; non occupational exposures are particularly important for this group; tinnitus and TTS were common; Leq of 96.1 dB

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Chesky	2000	Instrument-specific reports of HL: Differences between classical and non-classical musicians	3292 musicians of varying types who filled in an online questionnaire	cross-sectional	all different types of music (jazz, rock, classical, etc.)	NIHL	"to examine the incidence of hearing problems reported from … musicians of both… performance area and …primary instrument"	21.7% of respondents reported hearing loss problems; highest in rock/alternative/rap/pop group; church & gospel music had the lowest reported problems; among musicians on the same instrument, those playing in nonclassical settings were more likely to report HL
Daum	1988	Hearing loss in musicians	musicians	review	music	NIHL, etc.	review; basics of hearing loss, measurement, controls	Nice introduction and format for the layperson; describes many forms of noise-induced hearing problems, regulations (current as of 1988), how the ear works, etc.
Delay et al	1991	The effects of music technology on hearing: a case study of St. John's bars	bar patrons, employees, and managers (15 popular bars in St. John's)	cross sectional	rock music	NIHL (measured by opinion survey)	to see whether sound levels exceeded regulations, and to gauge opinions on the sound levels	12 bars exceeded the ACGIH 1 hr. exposure limit (); average level measured was 102 dBA (safe unprotected exposure time = 49 minutes); 60% of patrons report tinnitus after leaving a bar; 70% of employees experienced ringing after their shifts, but 78% didn't think that noise could cause permanent damage; 60% of employees were positive about more strict noise regs., but patrons and managers were not as receptive;
Dey	1970	Auditory fatigue and predicted permanent hearing defects from rock-and-roll music	rock and roll listeners	clinical trial	rock music	TTS, NIHL	to find out how many people are likely to experience adverse and/or permanent ear damage under a damage-risk criterion of a 40 db TTS	2 hours of music at 110 dB (not uncommon at a bar/concert/disco) may leave an "unusually severe" TTS in about 16% of young men exposed, but if the noise level were reduced to 100 dB, only 2 would be affected in this manner
Fearn	1993	Hearing loss in musicians	many groups (volunteers exposed to pop music, student musicians, etc.)	cross-sectional	orchestral music, big band music, amplified music	NIHL, TTS	To examine hearing loss among young musicians of varying types, and also those who listen to amplified music	TTS has a large individual variation; older musicians had worse audiograms; people don't get hi exposure from their own instrument but from others around them (except for percussionists); sound levels in the orchestra are potentially harmful; 12 hours is a good time to wait between concerts;

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Fearn	1976	Hearing loss caused by different exposures to amplified pop music	leisure listeners of pop music; although this is a comment on another study	cross-sectional	pop music	NIHL	To highlight that frequency of visits to a music venue might not be a valid measure of exposure	Variability in exposure, variation in noise level, length of attendance, and different individual sensitivity to hearing loss would camouflage any effect that increased exposure has.
Fearn	1989	Hearing level of young subjects exposed to gunfire noise	gunfire exposed young adults	cross sectional	gunfire noise	NIHL	To compare the hearing of young people who were exposed to gunfire as compared to those who weren't	The percentages of gunfire exposed subjects with hearing loss are 3-4 times higher than for the control group
Griffiths	1995	Hearing Sensitivity among Professional Pannists	steel pan players	case-control	steel drums	NIHL & tinnitus	To compare the hearing of pannists with non-exposed people	Used questionnaire & hearing test + dosimetry; 72% of pannists had abnormal audiograms (and was worse than in regular orchestras); mean exposures as high as 110 dBA
Hart	1987	The musician and occupational sound hazards	musicians	review	different types of music	tinnitus & NIHL	Review of hearing problems in musicians	There are real risks to musicians and rock concert-goers (some researchers have measured over 150 dB); acoustically non-treated rooms and reverberations in the venue can also contribute to noise exposure (especially for rock music); definition of what constitutes "HL" is important; clarinetists can't wear HPD; mention of a company called Sensaphonics making HPD for musicians
Smeathem (HSE)	2002	Noise levels and noise exposure of workers in pubs and clubs: A review of the literature	all workers in pubs and clubs	review	music	NIHL, etc.	review	
Ising et al	1997	Loud music and hearing risk	569 teenagers exposed to discotheque noise and Personal Cassette Players (PCP)	cross sectional	loud music		to assess the average exposure times and noise intensities of PCP use and disco visits, and to make a prognosis of hearing risk with these 2	Researchers had the kids set their desired volume level on their PCPs and then measured it; about 5% of the group adjusted to 110 dBA (loudest group was the 13-yr olds); kids who had attended discos or other musical venues were 1.3 times more likely to have hearing loss than those who

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
							exposures in mind	did not
Jaroszewski & Rakowski	1994	Loud music induced thresholds shifts and damage risk prediction	4 musicians using high powered electronic equipment	cross sectional	rock/jazz music		to measure sound pressure distribution during performance, followed by hearing thresholds	Direct measures oscillated between 90 and 120 db; if an exposure producing a TTS @ 2 minutes is repeated 5 times a week for 10 years, a PTS of that TTS level can be expected; median TTS reached 30 dB at 1 kHz, and just above 40 dB @ 4 and 6 kHz for both ears; but as high as 70 dB @ 6kHz for one subject
Jaroszewski et al	1998	Hearing damage from exposure to music	musicians, people listening to loud music	review	rock/ classical music	NIHL, TTS	to review the literature on various components of hearing impairment in club goers, rock/classical musicians	Problems include decrease in sensitivity leading to distorted frequency discrimination, loudness perception; early changes that may not affect the musician should not be expected to stop, and may lead to more severe impairment later on; in their tested sample of 214 people, 68% had permanent threshold shifts of 10 dB or more
Johnson et al	1985	Effects of instrument type and orchestral position on hearing sensitivity for 0.25 to 20 kHz in the orchestral musician	musicians	cross sectional	orchestral music	NIHL	to relate hearing sensitivity to musician instrument type, years of playing and orchestral stage position	Average hearing sensitivity in musicians was similar to the hearing of control group; no greater hearing loss in one type of instrumentalist vs. others, also no significant association with placement in the orchestra
Juman et al.	2004	Hearing loss in steelband musicians	pannists	controlled cross sectional	steel drums	NIHL/tinnitus	to determine the difference in hearing between pannists and a control group	Pannists had significantly worse hearing than controls, except the young musicians (<30); 4/10 platers for 10-19 yrs. Had HL, and 9/12 players for >20 yrs. Had HL (66%!!)

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Kahari	2003	Assessment of hearing and hearing disorders in rock/jazz musicians	rock/jazz musicians	cross-sectional	rock/jazz music	hearing loss, tinnitus, hyperacusis (age related hearing loss)	to assess hearing disorders among the musicians	Hearing loss & tinnitus were more common among men, 74% of the group had hearing disorders
Kahari et al	2001	Hearing assessment of classical orchestral musicians	orchestral musicians	cross sectional	classical music	HL	to examine hearing loss among classical musicians	No severe hearing losses attributable to music exposure; may be important later in life (additive effect with aging)
Kahari et al	2004	The influence of music and stress on musicians' hearing	279 classical & rock/jazz musicians	cross sectional	music of varying types	audiometry and questionnaire used to assess HL	to evaluate hearing disorders, and explore psychosocial factors in musicians	Overall, hearing thresholds were well preserved; although woodwind and brass players had worse hearing; rock and jazz musicians had worse hearing than classical musicians; all thresholds had a "notch" configuration, indicating NIHL; 74% of musicians suffered from different hearing disorders; more men than women; no convincing connection between social factors and hearing
Karhari et al	2001	Hearing development in classical orchestral musicians: a follow-up study	classical musicians (56 total)	follow-up of x-sect (by Axelsson & Lindgren, 79-80)	classical music		to investigate hearing development in classical musicians, to look at female/male differences and to compare thresholds w/ control groups	Pure-tone thresholds did not decrease faster than normal; men had worse hearing, but also played the loudest instruments (in this study)
Karlsson	1983	The hearing of symphony orchestra musicians	417 symphony orchestra musicians (123 measured twice over 6 yrs.)	cohort	classical music	higher pure tone threshold	To investigate whether the pure tone thresholds of symphony musicians are higher than an unexposed group (using a relatively large sample size)	From the audiograms, they found that there was no increased risk of impaired hearing for musicians; when grouped by instrument, the double bass players and flute players had very slight NIHL though; former military musicians had worse hearing than others;

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Meyer-Bisch	1996	Epidemiological evaluation of hearing damage related to strongly amplified music…	1364 volunteers who underwent audiometric testing and questionnaires	case control	rock music, discotheque noise, PCP	NIHL	to assess whether leisure exposures cause hearing damage (separated by each exposure)	Disco patrons presented no hearing losses; people who use PCPs had significantly worse hearing, as did those who attended a rock concert at least twice a month
Nodar	1993	Hearing Loss in a Professional Organist: A Case Study	1 professional organist	case study	organ music	hearing loss	the woman had complaints that she was playing too loud, and actually couldn't hear herself play	Measurement of hearing showed that she had moderate to severe hearing loss
Ostri	1989	Hearing impairment in orchestral musicians	96 Danish orchestral musicians	cross-sectional	symphonic music	hearing loss	to assess the hearing of musicians	Has results of hearing self-assessment (interesting); musicians do have increased hearing thresholds compared to the general population
Palin	1994	Does Classical-Music Damage The Hearing Of Musicians - A Review Of The Literature	classical musicians	review	orchestral instruments	NIHL	To assess whether classical music damages the hearing of musicians	Poor design of many studies makes generalizations harder
Sataloff	1991	Hearing loss in musicians	review	-	-	-	-	-
Sataloff	1997	Hearing loss in singers and other musicians	musicians/singers	review	all types of music	HL	to do a thorough review of the subject of hearing loss in musicians	Review (n/a)
Schmidt	1994	Hearing loss in students at a conservatory	79 students at the Rotterdam conservatory	case control (med students as controls)	orchestral music	NIHL	to test the hearing of musicians at the start of their career, and assess possible damage caused by music	High percentages of audiometric noise dips (16%) and Hi-f losses (20%), and extended hi-f losses (72%); however, no different (and sometimes less) than the control group

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Steurer	1998	Does choir singing cause noise-induced hearing loss?	62 opera choir singers	cross sectional measured hearing loss	choir singing	hearing threshold impairment	to investigate hearing impairment in choir singers (major lack of studies in the literature)	Hearing loss was greater in all female groups (compared to reference group) with few exceptions; older men had worse hearing for their age, but younger showed no differences; women hear better at high frequencies than men
Teie	1998	Noise-induced hearing loss and symphony orchestra musicians: risk factors, effects, and management	symphony orchestra musicians	review	classical music	NIHL	to put forth suggestions for monitoring and protecting the professional ear	NIHL can make it difficult or impossible to hear some musical tones; balance of tones is hard to accomplish (especially important for singers and sound engineers); reducing sound levels at the ear may be the most appropriate; deep insertion plugs (ER) can help reduce the occlusion effect;
Westmore & Eversden	1981	NIHL and orchestral musicians	orchestral musicians	cross sectional	classical music	NIHL	to make a connection between sound pressure levels and NIHL	Short term measurements >120 dB; sound levels depend on type of music (i.e. the composer); substantial # of people had NIHL (~50% of woodwinds)

Table 2: ***Exposure assessment papers***

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Early	1996	Noise Exposure to Musicians during Practice	marching bands, concert bands (7 different types of arrangements)		musical instruments	TTS, NIHL	Determine the noise exposure of musicians at practice	Many musicians' exposures are above the OEL of 85 dBA, even if they only practice for 1-3 hours per day; also considers determinants (including time of year)
Fisk	1997	Sound pressure levels during amplified orchestra rehearsals and performances	professional orchestral musicians	exposure assessment	orchestral music + country & pop	NIHL, but complaints of tinnitus & dulled hearing after performances too	To assess noise exposure of an orchestra at their request	Sound levels ranged from 70 - 89 dBA, with a max of 100 dBA; sound levels were lower during rehearsals as compared to performances (more breaks)
Gunderson et al	1997	Risks of developing noise-induced hearing loss in employees of urban music clubs	employees of live music clubs (not musicians themselves)	cross sectional	live music performed in urban clubs	NIHL (using audiometry and exposure meas.)	to determine whether a hazard of NIHL exists for music club employees other than musicians themselves	Range of average sound level (over performance and intermission times) was 91.9 to 99.8 dB, which is above the OSHA standard of 90. sound levels varied by music type, with hard rock being the loudest, closely followed by blues; sound levels were usually too high, although they did have a small sample size
Henoch	2000	Sound exposure levels experienced by a college jazz band ensemble - Comparison with OSHA risk criteria	college jazz band members	exposure assessment	jazz music (rehearsal)	NIHL	To measure sound levels for different instruments in the jazz band	10 out of 15 measurements had mean exposures over 100 dBA, and lead musicians in each section had the highest exposures
Jansson	1983	Sound levels recorded within the symphony orchestra and risk criteria for hearing loss	classical musicians	cohort	classical music	NIHL	To map sound levels and spectra within the symphony orchestra	

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Laitinen	2003	Sound exposure among the Finnish National Opera personnel	personnel of an opera (conductors, dancers, musicians, singers)	exposure assessment	musical instruments and singing	hearing loss	to evaluate exposure to noise by all types of musicians and workers	Most of the personnel were exposed to noise levels that were hazardous to hearing; rehearsals and performances had high levels; recommends HPDs and motivation to wear them
Lebo & Oliphant	1969	Music as a source of acoustic trauma	musicians (rock and symphony)	exposure assessment	rock music, compared to symphonic music	-	to map out the acoustical properties of symphony music to compare to rock music	Rock groups were usually louder than 95 db in the lower frequencies, while the symphony rarely achieved such levels; the highest noise levels of the rock groups were at and below 500Hz, while symphonies were higher than this
Lee	2003	Noise exposure of opera orchestra players	73 Opera orchestral musicians in an orchestra pit	exposure assessment	opera music	not measured	to examine noise exposure during rehearsal and performance of 2 operas	Measured exposure with noise dosimeters; determinant of exposure was proximity to the brass section (which also had the highest noise measurements)
McBride	1992	Noise And The Classical Musician	63 of 89 City of Birmingham Symphony Orchestra	exposure assessment	symphonic music	NIHL	to test the hypothesis that noise exposure may cause hearing loss in classical musicians	Half of rehearsal measurements were above 85 dB; high risk group was woodwind and brass, strings were low-risk, but comparison of hearing showed no difference between the groups; however potential exists for hearing loss in the orchestra according to measured noise levels
Mikl	1995	Orchestral music: an assessment of risk	orchestral musicians in an opera pit		opera music	NIHL	To do area measurements of noise during rehearsal and performance in an orchestra pit over an entire musical season	Audience and conductors are not at risk; the tight performance schedule and pit placement are risk factors for NIHL

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Patel	2002	Assessment of the noise exposure of call centre operators	150 call centre operators	cross-sectional (measurements done with a man-nequin)	background at work + headset noise	NIHL (though the paper is exposure-focused)	To see if either background noise or headset noise exceeds OEL	Mean personal exposures were unlikely to exceed 85 dBA
Royster et al	1991	Sound exposures and hearing thresholds of symphony orchestra musicians	symphony orchestral musicians (Chicago S. O.)	cross sectional	symphonic music	NIHL	to assess the risk of NIHL in the Chicago symphony orchestra (using dosimetry and audiology)	Mean Leq 89.8 dB; peak 125 dB; 68 measurements; small amount of NIPTS risk for average musician, but high for susceptible individuals
Sabesky & Korczynski	1995	Noise exposure of symphony orchestra musicians	classical musicians (Winnipeg S.O.)	surveillance	classical music	only measured exposure	to see if noise exposure was within Manitoba standards (testing 3 playing events)	Noise exposure was in excess of all provincial standards
Szymanski	1983	The sound of music	n/a	exposure assessment	orchestral music	NIHL	to see whether participants at symphonies are exposed to unacceptable noise levels (as people at discotheques are)	Data presented by musical piece, the loudest of which was 85.3 dBA Leq; also considered the effect of audience applause, which was very loud, but too short to exact any risk; overall, there was no danger of NIHL to concertgoers

Table 3: ***Disorders other than noise-induced hearing loss***

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Axelsson & Prasher	2000	Tinnitus induced by occupational and leisure noise				noise induced permanent tinnitus (NIPT)		Tinnitus usually develops slowly (not as the result of one high exposure); tinnitus is commonly reported after a rock concert; basic message: more research needed
Axelsson & Ringdahl	1989	Tinnitus - a study of its prevalence and characteristics	3600 residents of GothenburgSweden, randomly chosen by age	surveillance	varied	Tinnitus	to estimate the prevalence of tinnitus in this population	66% response rate; 14% of respondents reported tinnitus "often" or "always"; it was more often reported in the left ear, especially in males; tinnitus was more severe in older vs. younger females, but there was no such difference in the men; tinnitus was generally more common in those with other hearing loss (subjective measure though)
Lockwood	2001	Tinnitus and the performer	Performers of all types	General review of tinnitus etiology and therapy	Various; music, environmental	Tinnitus	to encourage prevention, as the treatment isn't very good	To conserve musician's hearing: change in seating, addition of risers, sound shields between players, HPD
Metternich	1999	Acute hearing loss and tinnitus related to strongly amplified music	24 patients with music-related acoustic trauma	retrospective cohort	67%: rock concert; 17%: discotheque; 12%: parties; 4%: walkman	Hearing loss & tinnitus	to look at the risk of hearing loss from a short term or one-time exposure to loud music	Risk of permanent hearing loss is low compared to tinnitus. Rheologic therapy helped with hearing loss.
Rosanowski	1996	External auditory canal in situ measurement of sound pressure in a professional violinist suffering from bilateral tinnitus	1 violinist	case study	Vuillaume & Carcassi violins, up to 90 dB	bilateral tinnitus	to see if the different sound spectra of the 2 violins was the cause of the musician's enhanced tinnitus	It is possible that the different violin sound spectra caused the enhanced tinnitus, but it couldn't be verified

Table 4: ***Controls and preventive measures***

Author	Year	Title	Purpose	Results
Chasin	1995	Four environmental techniques to reduce the effect of music exposure on hearing	to describe 4 methods that may help to reduce hearing loss (also outlined in the Ontario Min. of Labour document- Live Performance Industry	(1) Elevate speakers & amps (such that low freq. sounds are not absorbed and technicians don't turn up the volume to compensate); (2) Put treble brass on risers (to protect those directly in front of them); (3) ensure 2m of unobstructed floor in front of the orchestra; and (4) ensure small strings have 2m above them (so that they don't overcompensate and risk HL & other injury
Chasin & Chong	1992	A clinically efficient hearing protection program for musicians	to review clinically efficient HPP's for musicians	Problems with HP: 1) occlusion effect (causes hearer's voice to sound loud and hollow); 2) non-uniform attenuation (more at high freq.); HPD options: 1) acoustic attenuator inserted into custom earplugs, the net result is flat attenuation @ the eardrum; 2) tuned or adjustable vent --> allows lower frequencies to pass unattenuated but filters the high freq.
Chasin & Chong	1991	An in situ ear protection program for musicians	to showcase a few earphones that may be useful for musicians' hearing protection; also separated by instrument	Three plugs are the ER-15, the ER-20, and vented/tuned; variability among instruments and musicians is important for choosing the right earplug; broken down individually in this paper
Eaton & Gillis	2002	A review of orchestral musicians' hearing loss risks	to determine exposure levels; evaluate risk; evaluate HL; examine effectiveness of controls	Engineering controls may be counterproductive to the musical experience
Groothoff	1999	Incorporating effective noise control in music entertainment venues? Yes, it can be done	to see whether noise control is viable in an industry that sells loud noise; follow up with venues where excessive noise was a problem	14 venues were followed up; all surveyed sites exceeded 85 dB regulation; owners knowledge had increased re: obligations to health and safety
Hall & Santucci	1995	Protecting the professional ear: conservation strategies and devices	to present some case studies of the range of experiences of music professionals re: hearing loss; to outline some strategies for prevention	Hearing loss in musicians is a very different problem than in industrial workers because hearing is so important for their livelihood; high-fidelity hearing protection as well as in-ear monitoring may be able to help

Author	Year	Title	Purpose	Results
Killion et al	1988	An earplug with uniform 15 dB attenuation	to highlight the use of the ER-15 earplug (how it works, why it may be the best solution)	Normal earplugs muffle the sound too much (give too much attenuation at higher frequencies than lower); the ER-15 better matches the natural frequency response of the open ear, but at a reduced level
Santucci	1990	Musicians can protect their hearing	to outline a method for an HCP for musicians (including case history, education, testing)	Important in HCP: case history; audiology; sound measurements; preventive measures (good part on HPD's); education

Table 5: ***Papers not used for this review***

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Berger & Killion	1989	Comparison of the noise attenuation of three audiometric earphones, with additional data on masking near threshold	n/a	testing attenuation props. Of audiometric earphones	any loud noises	none	to compare noise attenuation of a few earphones that are used to give hearing tests	The purpose of the earphones is to block a good deal of outside noise, and so they are not likely to be appropriate for musicians;
Crnivec	2004	Assessment of health risks in musicians of the Slovene Philharmonic Orchestra, Ljubljana, Slovenia	70 philharmonic musicians	case control	orchestral instruments	MSI mostly, but minor hearing impairment too	to compare Slovenian and German musicians' health problems	Mostly MSI reported; 22.8% of Slovenian musicians had "minor performance-related hearing impairments"
Dibble	1995	Hearing loss and music	review	-	loud music	hearing impairment	to ascertain the relationship between exposure to loud music and hearing impairment	Rock and roll "does not work" below about 96 dB; weight of evidence suggests that music is not as big of a risk as occupational noise because it is "wanted noise"
Fearn	1976	Hearing loss caused by amplified pop music	50 pop music event attendees	cross sectional	pop music	NIHL	-	Not measuring occupational exposures of musicians
Galbraith	1977	Rock music and NIHL: The British scene	n/a	-	-	-	-	Not measuring occupational exposures of musicians

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Gittens	1986	Entertainment noise	many groups	review	many different leisure noises	NIHL	to review studies of leisure exposure to live rock music, classical music, earphones, fireworks, guns	
Harper	2002	Workplace and health: A survey of classical orchestral musicians in the United Kingdom and Germany	musicians	questionnaire	music	NIHL, but many others	to identify the health concerns of musicians	Noise was ranked high by the most people, and woodwind players were frequently more susceptible
Hellstrom	1998	Temporary threshold shift induced by music	Teenagers using personal cassette players	-	-	-	-	-
Henoch	1999	Hearing loss and aging: Implications for the professional musician	musicians	online survey (self-reported)	orchestral instruments, but more focused on age	hearing loss (NIHL and age-related)	to review knowledge on age-related hearing loss among musicians	hearing loss may occur earlier in life among musicians than the general population
Hohmann	1999	Effects on hearing caused by PCPs, concerts, and discotheques and conclusions for hearing conservation in Switzerland	-	-	-	-	-	-
Hoppmann	2001	Instrumental musicians' hazards	instrumental musicians	review	orchestral instruments	mostly MSI	largely looking at MSI, but a small part on NIHL	Only a brief description of NIHL; not useful for this review

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Jaroszewski	2000	The extent of hearing damage from exposures to music	Discotheque attendees & musicians/music students	review	-	-	-	-
Kahari et al.	2003	Associations between hearing and psychosocial working conditions in rock/jazz musicians	139 rock/jazz musicians (volunteers that filled out a questionnaire)	cross sectional	stress, loud music	no exposure measured (questionnaire only)	to explore associations between psychosocial work conditions, mental load, and hearing disorders	Assessed such stressors as work, family, sleep-related, mood. Musicians were compared with white-collar workers for stress levels based on these stressors.
Liebel	1996	Measurement of noise effects in a discotheque by means of otoacoustic emissions	disco visitors	cross sectional	dance music	TTS	to investigate the difference in techniques for assessing TTS	The threshold shift occurred @ 4000 Hz in the group exposed for 1 hr @ 105 dBA, and was spread over all frequencies when the time increased; after 2 hours of exposure, the threshold shift was 10.1 dB
Lipscomb	1976	Hearing loss of rock musicians	young people potentially exposed to loud music (total people measured = 7179)	cross sectional	rock music	NIHL	to use hearing screening tests to map the high frequency hearing impairment with age (from 6th grade to first year of college)	32.9% of college freshmen had HFI (high frequency impairment); boys were worse off than girls; exposure was not assessed, so these results are only postulated to be explained by loud music; besides all this, rock musicians seem to have low hearing loss overall- protective mechanism?
Lipscomb	1969	Ear damage from exposure to rock and roll music	Guinea pigs	-	-	-	-	Talks about the destruction of hair cells in the cochlea resulting from 122 db; irreversible damage in nearly 20% of cells

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Lockwood	1989	Medical problems of musicians		review			to review some of the med. problems (noise not included)	-
MacPherson	1991	A method for assessing and controlling noise exposure of employees and patrons in entertainment (music) venues	patrons and employees @ live band performances, clubs, and the theatre	surveillance	music	n/a (only area exposure measurements)	to validate an assumption made in a previous study (that "room loss' was constant from one performance to the next)	"room loss' was generally consistent for a venue
McCann	1992	Occupational Hazards in the Arts and Professions	visual & performing artists, TV production	n/a	musical instruments	NIHL	very broad review of hazards of many types of artists	None- suggests ear plugs and plastic shields to limit exposure
Merry	1995	Historical assessment and future directions in the prevention of occupational hearing loss	review	-	-	-	-	Has some info about different hearing conservation programs and hearing protection, but is really about occupational hearing loss in general
Okada	1991	Morphological-Changes Of The Spiral Vessel After Rock-Music Exposure	Guinea pigs	animal study; case control	rock music	dilation/constriction of the spiral vessels	to investigate potential physiological causes of temporary threshold shifts	At sound levels of ~115 dB, there was no change in the spiral vessel; results convoluted

Author	Year	Title	Study Group	Study design	Noise source	Health outcome	Purpose	Results
Okamoto	1986	Hearing loss after exposure to musical sounds	not clear	not clear	Musical sounds	hearing loss	to look at hearing loss caused by music (rock, discotheque, headphones)	Not given
Peters	1999	Progress in industrial noise control	review	-	-	-	-	Industrial noise control not useful to this reveiw
Prince	2002	Distribution of risk factors for hearing loss: Implications for evaluating risk of occupational NIHL	-	-	-	-	-	Not specific to musicians
Schuele & Lederman	2004	Occupational disorders in instrumental musicians	musicians	review		HL	to determine the frequency of occupational disorders in instrumental musicians; compensation issues too	Mostly based on MSI/neuropathies
Wallis & Marsh	1978	Control of noise in places of entertainment	-	-	-	-	-	Focused on reducing noise for the neighbours of clubs because people on the inside "are there because they enjoy it"