Sound level measurements in music practice rooms

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Abstract:

Average sound levels and percentage of daily dose of noise exposure were measured in the practice rooms of a university school of music, with the primary objective of determining whether sound levels in student practice rooms were high enough to warrant concern for hearing conservation. A secondary objective was to determine whether any instrument group was at higher risk for music-induced hearing loss due to exposure levels. Students representing 4 instrument groups were tested: brass, wind, string and voice. Measurements were taken using a dosimeter or DoseBadge clipped to the shoulder during 40 students' individual practice sessions. These readings provided average exposure levels as well as the percentage of total allowed exposure (dose) obtained during the practice session. The mean measurement time for this study was 47 minutes (*SD* = 22). Mean sound levels measured averaged 87-95 dB(A) (*SD* = 3.5-5.9). Mean average levels for the brass players were significantly higher than other instrument groups. Using the mean duration of daily practice reported by the participants to estimate dose, 48% would exceed the allowable sound exposure. Implications for professional musicians are discussed, including the need for 12-hour breaks and the use of musicians' earplugs. The implementation of a Hearing Protection Policy in the School of Music will also be discussed.

Keywords: Music-induced hearing loss, hearing loss risk in musicians, sound exposure levels, hearing protection

Article:

Full-time college-level music students are immersed in an intensive programme of study toward a professional career in music. Success as a student, and subsequently, a professional, requires many hours of practice. Most undergraduate music students spend a greater number of hours practising their instrument (both individually and in ensembles) than was possible prior to coming to a university. Assuming the 10,000-hour hypothesis (10,000 hours of study toward expertise) of Ericsson, Krampe, and Tesch-Ršmer (1993) is correct, a musician is likely, in the course of 10 years of study, to practise three hours per day (at least) on average. Students spend many of these hours in relatively small practice rooms, where exposure to high sound pressure levels may be a threat to the hearing sensitivity of the student musician. Because hearing requirements for the careers of professional musicians are high, requiring accurate pitch, loudness, and timbre perception, it is crucial that students and instructors become aware of excessive sound levels in order to protect their hearing.

The underlying pathology in noise-induced hearing loss is damage to the inner ear. Specifically, this damage affects the outer hair cells of the organ of Corti, which are responsible for the enhancement of hearing sensitivity and tuning. The outer hair cells have a motor function that amplifies soft sounds along all frequency points in the cochlea (Kiang, Liberman, Sewall, Et Guinan, 1986). When outer hair cells are damaged, low-level sounds are perceived as softer or not heard at all while mid and high-level sounds can be perceived as loud. Outer hair cell damage also can widen cochlear auditory filters thereby leading to a loss of frequency specificity. These alterations in auditory perception can have deleterious effects on the perception of music. Of particular concern is the perception of timbre, which is the relationship of harmonics and overtones for a given instrument. These harmonics are high frequency sounds even for a bass instrument. Although for speech, two formants, or overtones, differentiate vowel identity, for a vocalist there is a third formant called the singer's formant, which falls between 2800 and 3500 Hz, and gives professional voices "brilliance" in their tone quality. A vocalist who possesses a hearing loss in the frequency range of the singer's formant would be lacking information when making judgments about voice quality.

Although not typically applied to education and performing arts, in the United States industrial facilities in which employees are exposed to high sound levels are regulated by the Occupational Safety and Health Administration (OSHA, 1983). For the purposes of this study, criteria set out by the National Institute for Occupational Safety and Health (NIOSH, 1998) were used. NIOSH criteria were chosen because OSHA criteria are based on an "acceptable risk" of hearing loss basis, and for musicians, there is no acceptable risk. NIOSH criteria are the more stringent and protective of the individual's hearing sensitivity, and are therefore considered to be "best practice" (Suter, 2000). Many of the NIOSH criteria are based on standards of the International Standards Organization.

NIOSH exposure regulations are based on a time-intensity relationship. The amount of time an individual can spend in a high-intensity environment depends on the sound level of that environment. NIOSH criteria indicate that a Hearing Conservation Programme should be established which includes annual audiometric testing, education and training for employees in environments where they are exposed to 85 dB(A) or more over an eight hour period. These more recent recommendations by NIOSH may be implemented by federal agencies in future regulations. The OSHA and NIOSH levels can be seen in Table 1.

Table 1

NIOSH Allowable Noise Exposure Levels

Max. Exposure level in dB(A)	NIOSH Recommendations
80	Begin conservation programme
85	8 hrs.
88	4 hrs.
90	2 hrs., 31 min., 11.4 sec.
91	2 hrs.
94	1 hr.
95	47 min., 37.2 sec.
97	30 min.
100	15 min.
103	7 min., 15 sec.
105	4 min., 43.47 sec.
106	3 min., 37.5 sec.
109	1 min., 48.75 sec.
110	1 min., 29.292 sec.
112	54.38 sec.
115	27 seconds

Previous investigations of high sound level exposure in musicians have been restricted to studies of professional musicians during full rehearsals or full orchestra performance. All have recorded both average sound levels in excess of 85 dB(A), though not for eight hour periods of time in every case (Westmore Et Eversden, 1981; Royster, Royster, Et Killion, 1991; Sabesky Et Korczynski, 1995). Peak measurements reach sound levels much higher 85 dB(A). For example, Chasin and Chong (1991) measured levels of 126 dB(A) at the shoulder of a piccolo player during a relatively quiet etude. Although peak sound levels are of interest to musicians, peaks are usually very limited in time, and in this study, the effect was small enough that they will not be discussed in detail.

Laitenin, Toppila, Olkinuora and Kuisma (2003), taking measurements for the Finnish Opera, found average levels across instruments to be 88-98 dB(A), while averages for solo vocalists were 97-105 dB(A). Laitenin et al. also found that sound levels of individual rehearsals were often 6-20 times higher than levels during group rehearsals and performance, and were the major source of exposure for vocalists, percussionists and woodwind players, except for the flute/piccolo players. These higher levels may be due to the smaller size of practice rooms and also to the lack of a need to blend or match tone quality with other musicians.

Another way to look at exposure is in terms of allowable time spent at elevated sound levels. Jansson and Karlsson (1983) evaluated sound level exposures for symphony orchestra musicians based on allowed exposure levels for an industrial worker for a 40-hour working week. Results indicated that, depending upon the location of the musicians within the orchestra, musicians received a maximum allowable exposure in 10-25 hours of working time. In this case, the allowable exposure for a 40-hour work week was experienced after 10 hours for musicians in locations with exposure to the highest intensities and 25 hours for musicians in other positions.

One previous study examined the sound exposure of students of classical music during full ensemble rehearsal (Backus, Clark, Et Williamon, 2007). Seven of ten students had maximum exposure levels above 85 dB(A). No study has examined the sound exposure incurred by students during individual practice. Only one study has looked at levels of exposure incurred by professionals during individual practice, and found that it was the major source of exposure for many professional musicians. Therefore, the present study examined sound levels produced in practice rooms by student musicians.

The purpose of the current investigation was to determine whether sound level exposures in the practice rooms warranted the inclusion of a hearing protection programme into the programme of study in the School of Music at the University of North Carolina at Greensboro (UNCG). The primary purpose was to determine whether sound levels in the practice rooms would exceed levels at which NIOSH would mandate such a hearing conservation programme. A secondary purpose was to determine whether the type of instrument played would identify additional risk factors for noise exposure which might be pertinent in designing a hearing conservation programme in the School.

METHOD

Participants

Fifty undergraduate student-musicians (aged 18-22) from The University of North Carolina at Greensboro School of Music participated in the study. There were 10 students in each of four instrument groups: brass (2 female, 8 male), string (5 female, 5 male), woodwind (6 female, 4 male), percussion (4 female, 6 male) and voice (4 female, 6 male). Participating students reported that they had played their instruments for eight to fourteen years, with no significant differences between groups. All participants signed an informed consent form prior to data collection. Participants completed a brief survey in which questions were answered regarding instrument played, number of hours a day of practice, and number of practice sessions per week.

Instrumentation

Average sound levels were measured over the duration of a practice session using a personal sound level dosimeter (Metrosonics dB-3080 or Cirrus Research ® DoseBadge CR100B). Both types of dosimeters used were set to calculate dose percentages based on ISO/NIOSH recommendations. Care was taken to position the measurement instruments such that normal posture and musical instrument position were not compromised. For some of the practice sessions, travel between buildings on campus was required. Added travel time may have shortened the practice sessions due to time constraints. While a few sessions occurred at the end of the fall semester, the majority of sessions occurred during the middle of the spring semester.

The dosimeter or DoseBadge calculated the runtime of the measurement, range (dB SPL), the average sound level over the 80 dB(A) criterion (Lavg), the time-weighted average (TWA) levels in dB(A), and the dose for the measured time. The TWA averages the sound over an eight-hour period. The TWA will be less than the Lavg if the measured time period is less than eight hours. Dosimeters and DoseBadges were calibrated before each use with the provided compatible acoustical calibrator. Comparative dosimeter and Dose- Badge measurements found the resulting sound levels to be within two dB.

Procedure

Measurements were taken using ISO/NIOSH standards which include a 3 dB exchange rate (reducing the allowable duration of exposure for every 3 dB increase in intensity) and slow response. Use of the slow response setting reduces the likelihood of an overestimation of sound levels. Measurements of one practice session (mean length = 46.54 minutes) were made in School of Music practice rooms, most of which measured 3.05 x 3.66 x 2.29 metres. Each practice room has seven acoustic panels on the walls, made of fabric- covered dense foam, that measure 124 x 63.5 x 5 cm. Percussion practice rooms measured 3.35 x 3.96 x 2.28 metres with 10 acoustic panels on the walls.

The average sound level (Lavg) was computed for the total measurement time. These average levels determine whether the ISO/NIOSH maximum safe exposure level of 85 dB(A) is reached. Dose is defined as the percentage of noise exposure measured over time, typically eight hours, with 100% as the maximum exposure allowed for one day. For example, 85 dB(A) for eight hours would be a 100% dose, and 88 dB(A) for eight hours would be a 200% dose. If the measured levels vary between 85 and 88 dB(A), the dose would be between 100% and 200%. When determining the necessity of a hearing conservation programme, individual exposure must be measured. To verify sound levels measured with personal dosimeter systems, a Quest Model 1700 Sound Level Meter was used to measure levels during random practice sessions in the practice rooms, using the NIOSH standard of a slow response time and an A-weighted scale.

Results

Survey results indicated that the mean number of years student participants had been playing their instruments was 9.7 years, (*SD* 3.34 years). The number of hours of practice per day was similar between groups with a mean of 2.3 hours. Voice majors tended to practise less at 1.4 hours while the other groups ranged from 2.5-2.7 hours. Differences between instrument groups on these two questions were not significant. There were significant differences between groups on the number of individual, $F(3, 29) = 4.296$, $p < .05$, and ensemble practice sessions $F(3, 29) = 3.691$, $p < .05$ per week. Voice students reported significantly fewer individual practice sessions (4.6) than woodwind players (6.7), and brass players reported significantly more ensemble practice sessions (4.67) than woodwind or string players (both at 3.1).

Average measurement periods and average sound levels (Lavg) during exposure are presented in Table 2 for each instrument group. Average measured levels were 87-95.2 dB(A) (SD = 3.5-5.9) across the instrument groups. Some students' sound level exposure, in one practice session, was above the allowed daily exposure. Average measured doses for these short individual practice sessions ranged from 27.9-118.7% of the daily allowed dose. The last column indicates the estimated dose for the mean reported hours of practice per day for each instrument group.

Table 2
Average Sound Exposure Dosimetry Results

Instrument group	Mean(*SD*) number of minutes in measured period	Mean Lavg (*SD*) in dB(A)	Mean Measured dose	Est. dose for 3 hours
Brass	38.4(10.8)	95.2(3.9)	118.7%	180%
String	47.8(24.5)	87.0(3.8)	27.9%	59.5%
Vocalist	39.3(13.1)	88.4(5.9)	30.7%	82.3%
Woodwind	62.3(29.2)	90.4(3.5)	68.1%	130.6%
Percussion	66.7(42.2)	90.1(4.7)	66.5%	121.8%

Note. Lavg: Average sound level during run. At eight hours TWA and Lavg will be equal. Dose: Percentage of maximum allowable exposure to noise.

An analysis of variance (ANOVA) was run on mean sound levels to determine whether there were differences in the exposure of music students based on the type of instrument played. The ANOVA on average sound levels, in dB(A) during exposure, demonstrated significant differences between instrument groups, $F(4, 49) = 4.87$, $p < .05$, observed power .937. Post hoc tests (Tukey HSD) indicated that average levels during practice were significantly higher for the brass players when compared with levels for the string players and vocalists ($p < .01$). There were also significant group differences on measured dose, $F(4, 49) = 3.5$, $p < .05$, observed power .824. No other group differences were significant. Post hoc Tukey HSD tests revealed significant differences in measured dose between the brass players and string players and vocalists (all $p < .05$).

Dosimetry results for all instrument groups are presented in Tables 3-7. Lavg levels are above 85 dB(A) for all brass and woodwind players. This is not true for all vocalists or string players. The Lavg's indicate that most of these students are exposing themselves to levels which would mandate a hearing conservation programme if they were working in industry. The Dose column indicates the percentage of total allowable exposure has been met in the practice session. It is

Table 3

Noise Dosimetry Results for String Instruments with Estimated Dose Measurements Based on Mean Reported Practice Time for this Group

Subject #	Instrument	Run Time Hr.Min.	Lavg dB (A)	Dose %	2.5 Hr Dose %
1	Violin	0.35	87.8	13.92	59.7
2	Violin	0.35	85.5	8.21	35.1
3	Viola	0.46	84.1	7.84	25.4
4	Viola	1.51	92.9	143.35	193.9
5	Viola	0.34	90.7	26.54	116.6
6	Viola	0.51	82.5	6.00	17.5
7	Viola	0.46	88.8	23.20	75.2
8	Bass	0.22	80.5	1.69	11.1
9	Cello	0.37	88.6	30.27	71.8
10	Viola	0.59	88.9	17.66	77.0

clear from Table 3 that Musician 4 reached one third of her allowed exposure in a little less than two hours. The column furthest to the right indicates what the dose level would be for a typical 2.5-hours of individual practice per day. It must be remembered that this represents only the accumulated dose for the one measured practice session, which is not likely to be the only time the student played his or her instrument during the day.

Musicians who would have exceeded the allowable dose played at sound pressure levels over 90 dB(A). Of the 10 string players, data for whom are shown in Table 3, two viola players would have exceeded the allowable dose in the mean reported hours of practice for this group. With only one exception, all the brass players, data for whom are shown in Table 4, would have exceeded the allowable dose in the 2.7 mean reported hours of practice for this group; five of the ten did exceed maximum exposure levels in just one individual practice session. The specific instrument played did not necessarily predict the level of exposure. Although the trumpet players played at uniformly high sound pressure levels, levels for the horn and trombone players were more variable.

Table 4

Noise Dosimetry Results for the Brass Group with Estimated Dose Measurements Based on Mean Reported Practice Time for this Group

Subject #	Instrument	Run Time Hr.Min.	Lavg dB(A)	Dose %	2.7 Hr Dose %
1	Trombone	51.30	98.0	215.5	680.4
2	Trumpet	42.50	98.0	178.5	680.4
3	Trumpet	16.00	97.6	61.2	620.3
4	Horn	41.00	98.6	197.8	781.5
5	Trumpet	51.50	98.5	242.8	763.7
6	Trombone	31.82	92.3	22.5	182.3
7	Horn	33.68	90.2	23.5	112.2
8	Horn	43.00	97.5	168.4	606.1
9	Tuba	30.00	87.9	12.6	66.0
10	Trombone	43.00	93.5	63.9	240.5

Table 5
Noise Dosimetry Results for the Woodwind Group with Estimated Dose Measurements Based on Reported Mean Practice Time for this Group

Subject #	Instrument	Run Time Hr.Min.	Lavg dB(A)	Dose %	2.45 Hr Dose %
1	Flute	72.15	88.6	34.60	70.4
2	Flute	102.92	95.5	240.40	346.5
3	Flute	49.00	90.6	37.20	111.7
4	Sax	43.87	88.2	19.20	64.2
5	Sax	23.43	92.0	24.60	154.3
6	Oboe	40.53	95.2	89.07	323.3
7	Clarinet	54.37	85.3	12.15	32.8
8	Flute	61.47	87.1	20.81	49.8
9	Oboe	120.00	88.3	53.59	65.7
10	Oboe	51.00	93.5	81.67	218.3

Five of the ten woodwind players, data for whom are shown in Table 5, would have exceeded the allowable dose in the 2.45 mean reported hours of practice for this group. Two of ten vocalists, data for whom are shown in Table 6, would have exceeded the allowable dose in the 1.4 mean reported hours of practice for this group; one baritone exceeded the maximum allowed exposure in one practice session. Six of the ten percussionists exceeded the maximum exposure with pianists being the least likely to do so (Table 7).

Table 6
Noise Dosimetry Results for the Vocalist Group, with Estimated Dose Measurements Based on the Mean Reported Practice Time for this Group

Subject #	Instrument	Run Time Hr.Min.	Lavg dB(A)	Dose %	1.4 Hr Dose %
1	Soprano	50	88.3	22.14	37.5
2	Baritone	24	99.0	126.99	444.5
3	Voice	50	79.0	2.60	4.4
4	Baritone	26	85.6	6.08	20.1
5	Mezzo-soprano	24	95.1	51.57	180.5
6	Tenor	50.5	82.7	6.20	10.3
7	Tenor	24	88.8	12.03	42.1
8	Bass	46	92.5	53.60	99.0
9	Mezzo-soprano	52	87.0	17.20	27.8
10	Tenor	49	85.5	11.46	19.6

Table 7
Noise Dosimetry Results for Percussion instruments with Estimated Dose Measurements Based on Mean Reported Practice Time for this Group

Subject #	Instrument	Run Time Hr.Min.	Lavg dB(A)	Dose %	2.4 Hr Dose %
1	Drumset	51.00	93.50	77.21	213.8
2	Drumset	56.00	94.60	107.21	275.7
3	Marimba	56.00	95.00	117.59	302.4
4	Marimba	185.00	91.30	165.23	128.6
5	Marimba	34.00	94.10	58.00	245.6
6	Piano	54.00	84.80	10.74	28.7
7	Piano	55.00	95.30	123.80	324.1
8	Piano	52.00	84.70	10.11	28.0
9	Piano	62.00	87.10	20.98	48.7
10	Marimba	55.00	83.50	8.10	21.2

Discussion

This study was undertaken to determine if students in a university music programme are exposed to sound levels which are high enough to warrant a hearing conservation programme. Mean sound levels (Leq) for instrument groups in this study were 87-95 dB(A), which clearly suggests the need for attention to hearing health. These results are comparable to the mean sound level found by Royster et al. (1991), which was 89.9 dB(A), and those of Laitenen et al. (2003), which ranged across instruments from 88-98 dB(A). Average levels for brass players were significantly higher than those of other instrumentalists by about 5 dB. Due to the potential for damage to the auditory system and the obvious benefits of instruction in hearing health, hearing conservation programmes are suggested for higher education music programmes.

Sound level measurements only tell part of the story. The amount of time spent practicing at these levels is crucial to an understanding of the risk involved to hearing. Participants in this study indicated that they spend an average of 1.4 hours (for vocalists) to 2.7 hours (brass players) per day in individual practice, and that they practice on their own between 4.6 and 6.7 times per week. In addition, they reported rehearsing within ensembles an average of 3.1 to 4.7 times per week. Trombone player #1, who had an Lavg or 98 dB(A), reported that he practises individually for 3 hours per day seven days per week. He reported also that he practises in an ensemble five days per week. If ensemble sound levels are similar to those of his individual practice sessions, and last approximately one hour, then in a four-hour practice day (including ensemble practice) he would accumulate over 10 times more than the allowed sound exposure, or dose. With similar estimations, nine out of ten brass players, two out of ten string players, two out of ten vocalists, five out of ten woodwind players, and four out of ten percussionists would have exceeded their allowed daily dose with one individual practice session and one ensemble practice session. Some of these students did not have ensemble practice every day, which gave their auditory systems a much-needed break.

Laitinen et al. (2003) reported that the average professional musician plays an average of 5.5 hours per day. A student musician may practise alone for 2.5 hours per day in addition to playing in one or two ensembles each day for another 2-3 hours. However, when rehearsing for a major opera production, additional evening rehearsal time may be five hours per day for several weeks. Fearn (1993) reports that student musicians practise 10- 35 hours per week during the school year and additionally perform in orchestras for 2-3 hours 56 times per year. One concern Fearn raises is that students practise throughout the day with short breaks, which does not allow for the 12 hours of rest from noise exposure required to reduce temporary threshold shift (NIOSH, 1998).

Measurement of only one practice session is a limitation of this study. Another potential limitation is the brevity of some of the measured practice sessions. It may be that a short practice session allows for greater sound levels without endurance difficulties. If that were true, then sound levels may have been higher for shorter sessions than they might be for longer sessions. Two examples can be seen in two of the vocalists in Table 6, where sound levels were high and practice times short (24 minutes). However, several of the brass players, as well as one or more of the string and woodwind players also have high sound level averages with longer practice sessions.

Does exposure to these high sound levels cause hearing loss in musicians? According to Hart, Geltman, Schupbach, and Santucci (1987), 52% of classical musicians exhibit a hearing loss. These findings suggest that permanent hearing loss is greater among classical musicians than pop/rock musicians, which is only 37% even after 25 or more years of playing (Axelsson, Eliasson, Et Israelsson, 1995). The lower incidence among rock musicians may be due to several factors, including the low-frequency emphasis of the music, the absorption of sound by the crowds of people listening, and the amount of time spent in practice. Classical musicians often play 5-10 hours per day, including individual practice, ensemble practice and teaching, while rock musicians may only play on weekends (Shafer, 2006).

Permanent hearing loss has also been found in classical musicians by several other investigators (Axelsson Et Lindgren, 1981; Westmore Et Eversden, 1981; Karlsson, Lundquist, Et Olaussen, 1983; Ostri, Eller, Dahlin, Et Skylv, 1989; Royster, Royster, Et Killion, 1991). Kahari, Axelsson, Hellstrom, and Zachau (2001) found that the noise notches typically found with noise exposure occurred in orchestral musicians at 6000 Hz, but were not outside normal limits. Noise notches are a decrease in sensitivity related to noise exposure that occurs between 3000-6000 Hz. There is some dissent among these researchers about whether the losses incurred can be interpreted as being outside the expectations for normal aging. It is noted that the results of these studies are similar; however, the interpretations tend to vary.

In another study that involved music students, Fearn (1993) reported that one third of student orchestral musicians had elevated thresholds, 75% of which were at 6000 Hz, with half of all hearing losses in one ear only. Fifty percent of student musicians on this campus of the current study demonstrated notches in their hearing sensitivity at 6000 Hz, with the majority in one ear only (Phillips, Shoemaker, Mace, Et Hodges, 2008). Fearn contrasts this with the 54.5% of orchestral musicians over the age of 30 who demonstrated a decrease in hearing at 6000 Hz.

Each musician is affected by sound exposure differently with regard to variables such as instrument type, age, seating position in the orchestra, the music played and overall length of time playing (Royster, Royster, Et Killion, 1991). Woodwind and brass players have been shown to be at most risk for hearing loss (Westmore Et Eversden, 1981; McBride, Gill, Proops, Harrington, Gardiner, Et Attwell, 1992). Unilateral hearing loss has been documented in the left ear of violinists (Axelsson Et Lindgren, 1981) and double-bass players (Karlsson, Lundquist, Et Olaussen, 1983). The right ear of violinists is protected by the "shadow" of the head and also by being farther from the sound source. It is therefore important to compare sound level exposure by instrument type.

All previous studies of hearing in musicians have been conducted as cross-sectional studies. The authors are currently conducting a longitudinal study of student musicians' hearing over the course of their four-year programme of study. Other areas for future study include real ear measurements of sound levels at the tympanic membrane, with and without musician's earplugs, to determine whether body-conducted sound is a contributing factor in musicians who create their music orally. Comparing frequency resolution among musicians with and without demonstrated high frequency loss is also an area of interest.

Additional measurements of sound levels during student ensemble practice and performance are also needed. Position of musicians within the orchestra vastly changes their level of exposure. Levels are highest in front of the brass instruments and near the percussion instruments. Musicians in these positions include woodwinds, second violins, violas and cellos. Brass players may receive high levels of exposure from their position relative to other brass and percussion as well. It is also important to measure exposure levels for conductors of the various ensembles. Long-term dosimeter studies are indicated.

All music students who participated in this study, regardless of instrument group, are at risk of experiencing sound levels that exceeded maximum permissible exposure levels as regulated by the NIOSH 1998 standard. If these musicians were working in industry and exposed to these levels for eight hours a day they would mandatorily be enrolled in a hearing conservation programme. As it stands, with the number of hours of reported individual practice at these levels, 48% exceeded allowed exposure levels. It is important to note that students also report participating in ensemble rehearsals, which increase sound level exposure. Since hearing requirements for the career of professional musician are high, it is crucial that university level music programmes provide instruction to their students on how to protect their hearing.

The hearing conservation programme as recommended by NIOSH would require the inclusion of five components: environmental noise measurements of all practice and performance spaces, audiometric testing of hearing for all students on an annual basis, introduction to and instruction in the use of hearing protectors, education and training, and record keeping. Routine audiometry can help specialists indicate which musicians are experiencing hearing loss, and environments in which continued measurements of sound levels are necessary.

Any student identified with a high frequency hearing loss should be required to wear hearing protection designed for musicians, which provides an even attenuation across the frequency range. Objections to wearing earplugs should be addressed by outlining the differences between traditional foam earplugs and musicians' plugs, emphasizing the need to protect hearing as a crucial part of their musical skill. Proper insertion is critical for maximal protection as well as reduction of the plugged-up sensation called the occlusion effect, and should be carefully practised during training sessions. The cost of musicians' earplugs ranges from minimal for the non-custom ETYPlugs/HI-FI (Killion, Stewart, Falco, Et Berger, 1992) to a cost similar to that of a textbook for custom earplugs. Earplugs could be considered a required expense for performance studio classes or large ensembles. The acoustic environment of the practice rooms deserves considerable attention in terms of acoustic absorption materials on walls, ceilings and floors. This is particularly important in small practice rooms.

The education and training portion of the hearing conservation programme should include an accurate description of the group's noise exposures, the group's hearing test results, the use, care and fitting of a variety of hearing protection devices designed for musicians, and any engineering controls which have been put in place or are planned for the future. Students should be taught the value of down-time from exposure to loud music, ideally 24-48 hours, but a minimum of 12 hours. Although music students are typically introduced to the concepts of acoustics and psychoacoustics, they would also benefit from a basic knowledge of the anatomy and physiology of hearing, and from understanding what happens to these anatomical structures during noise exposure. An additional segment on how these changes in physiology could result in hearing loss and tinnitus would motivate them to be more aware of their listening environment and to understand the importance of hearing protection. As part of the Hearing Protection Policy, such educational training would occur yearly. Students should be encouraged to avoid outside exposures to noise as well.

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