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An Analysis of Sound Exposure in a University Music Rehearsal

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Exposure to high sound levels may lead to a variety of hearing abnormalities, including Noise-Induced Hearing Loss (NIHL). Pre-professional university music majors may experience frequent exposure to elevated sound levels, and this may have implications on their future career prospects (Jansen, Helleman, Dreschler & de Laat, 2009). Studies suggest that college students (aged 18–25) who participate in instrumental music activities are particularly vulnerable to hearing damage and NIHL (Phillips, Henrich, & Mace, 2010).

Additional research has focused on the relationship between musicians' activities and hearing loss. For example, a study by Kähäri, Axelsson, Hellström and Zachau (2001) reported that noise notches at 6,000 hertz were discovered in a selection of professional musicians, although the notches were not outside of normal limits. Another study (Parving, Ostri, Poulsen, & Gyntelberg, 1983) administered audiometric pure tone examinations to a population of musicians from the Royal Danish Theatre. Findings revealed that when testing hearing acuity in one or both ears at levels below 20 dB, a total of 58% of the musicians had a hearing impairment. The study concluded that the impairment might be related to the frequent sound exposure inherent in symphonic music.

NIHL has become a medical issue for a large portion of the population, rating as the second most common form of sensorineural hearing deficit, and surpassed only by presbycusis (age-related hearing loss) (Rabinowitz, 2012). Uncertainty concerning the risk factors and prevalence of NIHL and other hearing ailments among student musicians creates problems for researchers hoping to establish evaluative criteria for the safety of musical venues.

Current American standards regarding acceptable levels of sound exposure are defined by two agencies: the Occupational Safety and Health Administration (OSHA), and the National Institute of Occupational Safety and Health (NIOSH). OSHA standards for sound levels were last revised in October 1974, and remain as the maximum allowable noise levels in the workplace as enforced by law in the United States (U.S. Department of Labor, 2009). The standards are based on a permissible sound exposure of 90 dB for a duration of up to eight hours. Currently, the OSHA decibel exchange rate is set at 5 dB, with exchange rate defined as the amount of decibels at which the permissible sound level is reduced by 50%. For example, a 10-decibel exchange rate would allow that for every increase of 10 decibels, the allowable exposure time would be cut in half. NIOSH, on the other hand, recommends no more than 85 dB for up to eight hours with a 3 dB exchange rate (Center for Disease Control and Prevention, 2011). Figure 1 illustrates the relationship between dosage and decibel level as described by both agencies.

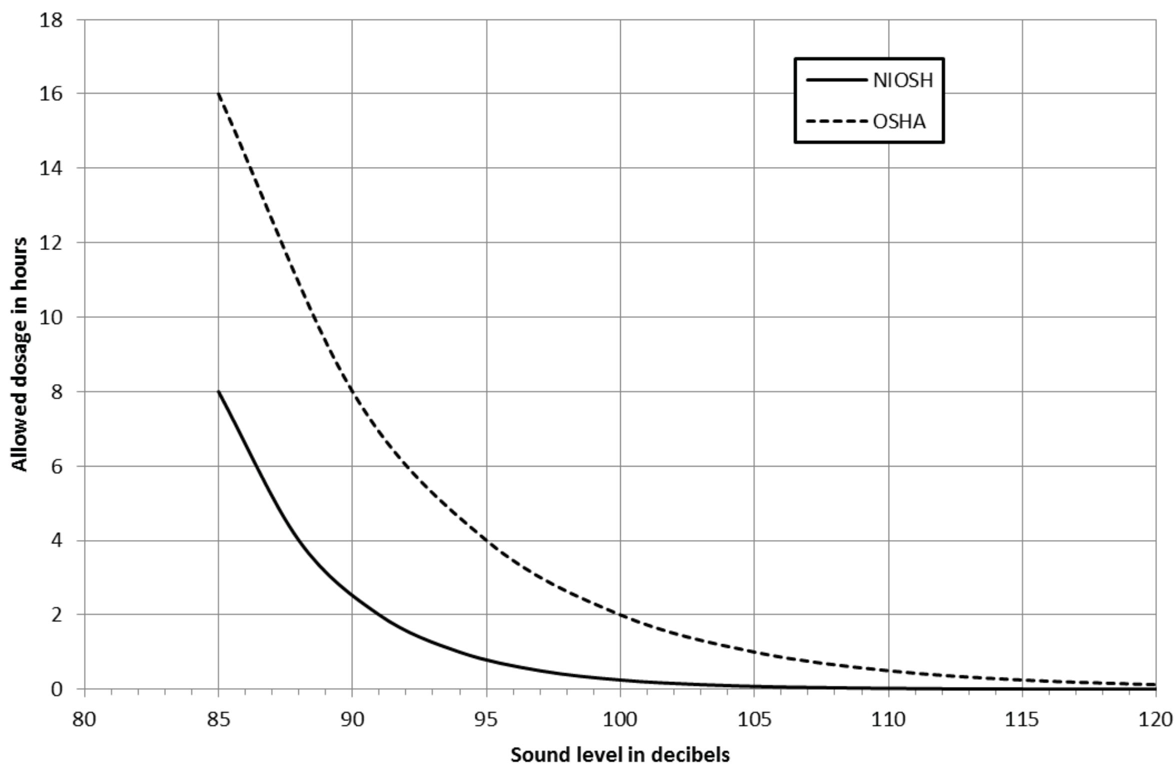

Figure 1. Permissible Noise Dosage as a Function of Sound Level.

In 1981, OSHA required that all employers implement a hearing conservation program. The mandate limits workers to a time-weighted average noise level of 85 dB or lower over an 8-hour shift (United States Department of Labor, 2009). The program requires employers to track sound level readings, to educate employees on hearing loss, and to provide free annual hearing health screenings.

OSHA and NIOSH standards are applicable to most workplace and noise level applications. Although no music-specific sound level standards have been described, several studies use OSHA and NIOSH standards as the standard by which to assess the safety of music venues. For example, an investigation of 130 student music majors at the West Virginia University College of Creative Arts documented that all participants experienced daily noise doses that exceeded both OSHA and NIOSH standards (Callahan et al., 2011). In addition, Chesky (2010) found that students participating in a university wind band program experienced sound exposure levels that exceeded recommended safety standards.

Student musicians devote many hours both to individual practice and group rehearsal. According to the 10,000-hour hypothesis (as set forth by Ericsson, Krampe, & Tesch-Römer, 1993), a student majoring in the art of music with the intention of mastering his/her instrument is likely to practice 10,000 hours over the course of 10 years, or the equivalent of almost 3 hours per day. In 2011, the National Association of Schools of Music affirmed that “music program policies, protocols, and operations must reflect attention to maintenance of health and injury prevention," and that "students enrolled in music unit programs and faculty and staff with employment status in the music unit must be provided basic information about the maintenance of health and safety within the contexts of practice, performance, teaching, and listening" (NASM 2011-12 Handbook Addendum, 2012). Consequently, efficient tracking and evaluation of the relative safety of venues for music instruction and performance has been defined as a key element in effective music pedagogy. The purpose of this study was to collect and analyze the sound load exposure of a population of university music students participating in instrumental music ensemble rehearsals.

Method

The subject venue is described as Fine Arts Center (FAC) 2007, located within the Cowan Fine Arts Center on the campus of the University of Texas at Tyler. This room serves as a rehearsal venue for a student jazz ensemble, a student jazz combo, and the university Wind Ensemble, all of which were recorded for this study. The venue measures 29 feet by 45 feet (1,305 square feet), with a ceiling height of 12 feet. This results in a total room volume of 15,660 cubic feet. The venue is equipped with 39 sound absorption panels mounted on standard sheetrock walls. These panels range in size from 2' x 4' to 4' x 8'. Panels are constructed from dense foam material wrapped with fabric, and measure 3 inches deep in the center. In addition, sound-absorbing pyramidal ceiling tiles are installed on the ceiling to further disseminate sound. These ceiling tiles are composed of fiberglass and form only a single three-dimensional protrusion per tile.

The Wind Ensemble and jazz combo met three times per week on Monday, Wednesday, and Friday from 12:30 to 1:45 and 3:00 to 4:15, respectively, while the jazz ensemble met twice a week on Tuesday and Thursday from 2:00 to 3:15. The Wind Ensemble is comprised of 34 instrumentalists, the jazz combo has 8 instrumentalists, and the jazz ensemble includes 11 instrumentalists.

All measurements were taken using an ExTech 407764 Datalogging Sound Level Meter. The instrument was placed on a tripod and permanently set at a height of 6 feet from floor level. The tripod was set at the front of the room directly behind the instructor's podium. This point was chosen due to its location at which the majority of the instruments were focused. A research assistant engaged the instrument before each rehearsal session and disengaged the instrument immediately following the end of the rehearsal.

The sound level meter was calibrated and programmed so that the duration, time, and date of each recording was assigned to respective sound level data. The instrument was programmed to record on slow response at 1-second intervals. This setting was chosen so that no peaks in the sound levels were lost. The frequency filter was set to A-weighting and the range of sound levels to be recorded was preset at 30dB to 130dB to represent the average sound level over the duration of the class. Data was collected every week and saved to an external memory storage device. The datalogger was then cleared and reset to collect subsequent data sets.

The data collected from the datalogger each week was uploaded to a workbook and categorized based on the time and date at which it was recorded. The data was then uploaded to a separate workbook, where the sound levels were placed into a single column and labeled with their respective class name and date. For references purposes, a histogram was created for each rehearsal's data set. Standard calculations were performed for all data sets for analysis purposes. These calculations included the duration of rehearsals in seconds, the maximum and minimum sound levels recorded in each rehearsal, and a mean dB value for each rehearsal. Mean dB values were not used for analysis purposes due to the fact that means do not represent the data in a way that is relevant to safety concerns. After all data points were loaded into the worksheet, Equation (1) (the L_{eq} definition for the exposure period, or shift), was used as the primary data analysis tool. In Equation (1), T is the duration in hours of the particular sound level L_n in dBA.

$$L_{eq,shift} = 10\ log\ \left[\left(\frac{1}{T}\right)\times\left(T_1\times10^{0.1\,L_1} + T_2\times10^{0.1\,L_2}+\ldots+T_n\times10^{0.1L_n}\right)\right] \quad (1)$$

Due to the fact that each class period had a slightly different duration, the definition of $L_{ex,8}$, Equation (2), was used in order to have a parameter for comparison. In Equation (2), T is the shift duration in hours, and $L_{ex,8}$ took each $L_{eq,shift}$ result and converted it to its equivalent 8-hour counterpart.

$$L_{ex,8} = L_{eq,shift} + 10\ log\ \left(\frac{T}{8}\right) \quad (2)$$

Using the information collected from both the $L_{eq,shift}$ and $L_{ex,8}$ it was possible to also calculate the sound dosage for each particular setting in accordance with Equation (3).

$$Dose = 100\times\left(\frac{T}{8}\right)\times10^{\frac{\left(L_{eq,shift}-85\right)}{10}} \quad (3)$$

Sound dosage is a calculation of how much exposure has been processed before the setting approaches dangerous levels, where T is the total recording time in hours for calculating $L_{eq,shift}$. As discussed in the background of this report, it is important to consider both OSHA and NIOSH standards when studying musicians' proximity to dangerous sound level exposure. With this in mind, the dosage equation was altered in a fashion that would produce a result for both agencies according to their unique 8-hour dosage indications.

Results

The results of the study were based on data retrieved from the datalogger over a period of eight weeks, spanning September 19 to November 24, 2012. During this time, a total of 33 recordings were collected, each with an average duration of 1.28 hours (1 hour and 17 minutes). The lowest decibel values recorded fell below the minimum value of the range set for the meter (30dB), whereas the loudest recorded noise levels reached 130 dB, which was the highest value of the range set for the meter. Results were obtained for each individual rehearsal assuming that students were only involved in one of the three rehearsals. However, during a student's academic career it is common to be involved in multiple rehearsal activities over the course of a single day. With this in mind, it is important to not only evaluate each rehearsal as a single entity, but also to combine rehearsal recordings that fall on the same day. For this particular study, only two of the three classes fell on the same day, jazz combo and Wind Ensemble, with results given in the Combo Class column in Tables 1 to 3.

Table 1 presents summary data for recordings made of each of the three ensembles over this 8-week period: mean duration, standard deviation, and the range of rehearsal durations observed.

The information is reported in seconds, because that is the resolution of the data collection; for every second there is one sample of the decibel level. The data can also be seen in hours on the right column to provide a better idea of the actual length of the class. Rehearsal duration data were quite varied; the longest recorded rehearsal lasted 3.89 hours while the shortest was only 0.23 hours. For the purpose of data analysis, however, mean rehearsal durations were consistent with expected rehearsal durations (based on scheduled class length) within 2 minutes.

Table 1
Rehearsal Duration

	Jazz Combo (MUEN 1131)		Jazz Ensemble (MUEN 1135)		Wind Ensemble (MUEN 1140)		Combo Class (MUEN 1131) + (MUEN 1140)	
	Seconds	Hours	Seconds	Hours	Seconds	Hours	Seconds	Hours
MEAN:	3878	1.08	3453	0.96	6526	1.81	9142	2.54
SD:	1427	0.40	2281	0.63	3795	1.05	4821	1.34
MIN:	1690	0.47	831	0.23	1771	0.49	2851	0.79
MAX:	5601	1.56	6904	1.92	13986	3.89	14631	4.06

$L_{eq,shift}$ and $L_{ex,8}$ values for each recorded rehearsal appear in Table 2, which lists the mean, standard deviation, and the range of rehearsal durations for every ensemble. Similarly, Table 3 illustrates the equivalent dosages experienced during the class times listed. This data serves as a guide for determining how close the sound level was to approaching dangerous dosages. For each respective standard (NIOSH and OSHA), the percentage represents the proximity of exposure to harmful levels (0% being no exposure and 100% representing the maximum allowed exposure).

Table 2
dB Level Results

	MUEN 1131		MUEN 1135		MUEN 1140		Combo Class	
	$L_{eq,shift}$ (dB)	$L_{ex,8}$ (dB)	$L_{eq,shift}$ (dB)	$L_{ex,8}$ (dB)	$L_{eq,shift}$ (dB)	$L_{ex,8}$ (dB)	$L_{eq,shift}$ (dB)	$L_{ex,8}$ (dB)
MEAN:	84.9	75.9	88.3	77.9	83.2	75.2	83.9	78.2
SD:	3.3	3.4	1.5	4.6	4.2	8.2	2.8	3.2
MIN:	79.6	72.4	85.5	71.0	76.7	48.5	79.5	74.4
MAX:	89.7	81.5	90.7	83.0	97.4	89.9	87.0	82.9

Table 3
Dosage Results (%)

	MUEN 1131		MUEN 1135		MUEN 1140		Combo Class	
	NIOSH Dosage	OSHA Dosage	NIOSH Dosage	OSHA Dosage	NIOSH Dosage	OSHA Dosage	NIOSH Dosage	OSHA Dosage
MEAN:	16.3	5.1	29.0	9.2	31.7	10.0	26.3	8.3
SD:	14.7	4.6	22.1	7.0	71.5	22.6	19.7	6.2
MIN:	5.5	1.7	3.9	1.2	0.0	0.0	8.7	2.8
MAX:	44.9	14.2	62.9	19.9	306.0	96.8	61.1	19.3

Discussion

In order to define whether or not a class is being exposed to a dangerous sound dosage, it is helpful to refer to the dosage value (%) in the related tables. Out of a total of 33 recording sets, none exceeded the mandatory OSHA values for safety regulations, and only one exceeded the recommended NIOSH values. This information suggests that the room in which the recordings took place is safe for the amount of sound being produced according to the legal OSHA workplace values; however, due to the proximity of some recording sets to the maximum allowable dosage level, it would be common in most manufacturing industries to implement a hearing conservation program as mentioned in the background of this report. The dosages measured by NIOSH standards consistently fell within the safe range with the exception of one session. This indicates that a corrective action may be needed.

Inconsistencies in dB data can be rationalized given the general nature of a performing ensemble. Because each piece of music is unique in terms of style and composition, there will be a wide range of volume differences within each recording set. In addition to stylistic and compositional variation, conductors also introduce variation in ensemble volume in a rehearsal due to their own interpretation of how pieces should be performed. Because of the variation associated with volume levels experienced from piece to piece, between rehearsals, and with different conductors, it is important to utilize a data analysis method which takes all data sets into account and weights them according to their $L_{eq,shift.}$ Data show that the mean dosage for each ensemble rehearsal fell below 30%, with the next highest dosage measuring 62.9% of NIOSH allowances for jazz ensemble. This trend shows that the maximum NIOSH dosage of 306% recorded in Wind Ensemble rehearsals cannot be thought of as an outlier, but rather as an uncommon situation. It is important to note that this high value (306%) is related to the dependent measure's (dB) logarithmic behavior. The recording set for this particular data has several seconds of high dB values which indicate that for the sake of hearing health, these performers should take a break from sound exposure. However, this is the only data set that indicates any inherent danger.

Aside from the high values previously discussed, the rehearsal room remains in a safe range of dB values for both NIOSH and OSHA regulations. With the majority of the recording sessions not exceeding 50% of the maximum allowable dosage on a regular basis, the data indicate that these teachers and students are not consistently exposed to dangerous dB levels.

Although these data support the idea that this rehearsal space is a safe environment for hearing health, a single research investigation can never predict the needs and tolerances of each individual's hearing tolerances. The results included in this paper are based on standards set forth by two major agencies that are believed to be indicative of healthy dB levels that function for a majority of the population; individual tolerances for dB levels may vary from these standards, though.

Conclusion

Students majoring in music devote many hours to individual practice and rehearsing, causing them to be exposed to sound levels that could lead to a variety of medical conditions. In this sense, the overall purpose of this study was to determine the hearing safety of students practicing in the rehearsal room identified as Fine Arts Center (FAC) 2007 at the University of Texas at Tyler. Results from this study suggest that the risk of approaching dangerous dosages of noise may be of intermittent concern. The safety of a specific venue may be compromised by allowing students or teachers to remain active in the venue for excessive periods of time in a single day, and future research might explore this idea further due to the influence that data could have for rehearsal scheduling decisions. Utilizing the protocol described in this study may potentially assist musicians and engineers to better manage possible risks to hearing health.

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