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Sound Exposure Characterization for Student Musicians: A Hearing Loss Prevention Initiative

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a Hearing Loss Prevention Initiative

Capstone Document

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By

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ABSTRACT

There is an increased risk for occupational and recreational noise induced hearing loss (NIHL) and tinnitus among those who are exposed to prolonged and elevated sound intensities. For musicians, education and hearing conservation programs are rarely accessible. The purpose of this project was to measure, quantify, and more clearly understand the exposure risk for student musicians. Dosimetry and area sound level data were used to evaluate the exposure levels of students in a university music department while they practiced in ensemble rooms and a concert performance hall. Sound maps were used to illustrate the most intense positions in each music-practice environment. For all ensembles, the highest sound intensities were measured in the center of the room. For the performance hall, the greatest intensity-level of sound measurements occurred in various room positions. From these data, we learned that strategies should be implemented to protect music students, and their instructors, to prevent auditory injury.

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VITA

EDUCATION

Doctor of Audiology, Illinois State University, Normal, IL May 2020

Bachelor of Arts, Augustana College, Rock Island, IL November 2015

EXPERIENCES

Capstone Project September 2017-2019

- Developing a foundation for a hearing conservation program with Illinois State University's School of Music
- Collecting approximately 20 hours of sound level measurements and dosimetry data

Dosimetry In-service September 2017

- Instructed students on proper use of a dosimeter

Audiology Internships

Carle Hospital, Urbana, IL September 2018-December 2018

- Sustaining independence during Audiological Comprehensive Evaluations and Pediatric appointments
- Growing understanding and hands on experience with Cochlear Implants

Advocate Bromenn Medical Group, Normal, IL May 2018-August 2018

- Evaluated culturally and linguistically diverse clientele
- Self-sufficiently completed:
  - Audiological Comprehensive Evaluations
  - Hearing Aid Repairs
  - Videonystagmography
- Refined skills pertaining to:
  - Pediatric appointments: Visual Reinforcement Audiometry, Conditioned Play Audiometry, Auditory Brainstem Response Threshold Testing, & Otoacoustic Emission Testing
- Established skills for:
  - Diagnostic Auditory Brainstem Response Testing
  - Bone Anchored Hearing Aid Fittings and Checks
- Assisted in shutdown protocol and hearing aid processing procedures

Bob Michel VA Outpatient Clinic, Peoria, IL January 2018-May 2018

- Honed services pertaining to:
  - Audiological Comprehensive Evaluations
  - Hearing Aid Fittings and Selections

Illinois State University, Normal, IL August 2016-May 2018

- Observed and developed practical clinical skills pertaining to:
  - Pediatric appointments: Visual Reinforcement Audiometry, Conditioned Play Audiometry, Auditory Brainstem Response Threshold Testing, & Otoacoustic Emission Testing
- Developed independence during appointments relating to:
  - Audiological Comprehensive Evaluations
  - Tinnitus Evaluations and Treatment
  - Hearing Conservation Testing
  - Hearing Aid appointments: Selections, Fittings, Checks, Repairs, & Verifit usage
- Performed listening checks and acoustic calibration

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CHAPTER 1

Introduction

There is an increased risk for occupational and recreational noise induced hearing loss (NIHL) and tinnitus among those who are exposed to prolonged and elevated sound intensities. To combat this problem, the Department of Labor instituted an occupational hearing conservation program (HCP) mandate for workers who are exposed to hazardous noise and known to be at-risk for NIHL. This federal regulation from the Occupational Safety and Health Administration (OSHA, 1983) did not apply to all workers, including musicians, entertainment personnel, and similar non-industrial fields. Certainly, musicians are exposed to excessive high-intensity sounds regularly, for extended time periods, which can result in music-induced hearing loss (MIHL). Such exposure occurs during individual practice, rehearsal, and performance (Henning & Bobholz, 2016). As studio technology has advanced, it has become easier for musicians to produce damaging, high-intensity sound (Chesky, 2011). Musicians appear to lack cognizance of hearing-loss prevention and the effects of hazardous sound on human hearing.

For this project, dosimetry and area sound-level measurements will be conducted to evaluate the exposure levels that music students experience during ensemble practice in various settings. The project will focus on students in the *brass* and *percussion* sections who are at-risk for excessive noise exposure (Chesky, 2011).

Literature Review

Populations at Risk

Relevant publications discovered during the literature review have been listed in **Table 1**. Music-induced hearing loss is more prevalent in musicians than non-musicians (Jin et al., 2013). Virtually all genres of music can produce a negative auditory outcome when exposures are at high intensities for prolonged time periods (Blum, 2006). When compared to classical musicians, non-classical musicians may be at greater risk for MIHL due to increased reports of hearing problems (Chesky, 2011). Individual risk may be predicted from the intensity and duration of a sound exposure. According to the National Institutes for Occupational Safety and Health (NIOSH, 1998), the maximum permissible exposure to sound is 85 dBA for eight hours. The duration of allowable exposure time is halved with every 3-dB increase in average intensity.

While brief exposures to intense sounds can lead to temporary threshold shifts that usually resolve within a day of the exposure, cumulative exposure to intense sounds may result in permanent hearing loss (Chesky, 2008). This position suggests that college music students may be at-risk for MIHL. They are frequently engaged in music activities throughout the day, which includes multiple ensembles and events that involve intense sound (Chesky, 2008; Jin et al., 2013). A study of music majors who played piano reported that they practiced, on average, twenty hours per week with some practicing more than forty hours a week (Yoshimura, Paul, Aerts, & Chesky, 2006). Even more concerning, musicians who specialize in brass and percussion sections are at increased risk for MIHL, due to excessive-sustained peak sound exposure (Henning & Bobholz, 2016; O'Brien, Wilson, & Bradley, 2008).

Tinnitus, hearing loss, auditory hypersensitivity and pitch distortion are problems presented by musicians (Blum, 2016) that can negatively impact their careers. In these instances, prescription of amplification and education on healthy hearing and methods to preserve residual hearing may be warranted (Blum, 2016).

Dosimetry and Sound-Level Measurements

Dosimetry and sound-level meter measurements can be used to estimate the amount of sound produced during an ensemble and the risk classification associated with that exposure

(Chesky, 2008). The intensity of music is difficult to quantify due to significant variability of sound intensities that occur over time (Jin et al., 2013). A variety of factors, such as position within the ensemble, size of the ensemble, type of ensemble, genre of music, dynamics at which the music is played, acoustical environment, and how the musicians play their instrument affect the average sound levels produced within an ensemble (Chesky, 2008). For example, indoor rehearsal sound-level measurements of a university marching band identified that intensity levels could cause MIHL, despite the intermittent nature of the exposure (Jin et al., 2013).

Audiometric Findings

Audiometric threshold testing may not be sensitive enough to differentiate MIHL (Jin et al., 2013). Hearing thresholds of marching band students revealed hearing within normal limits, with slight threshold elevation at 6000 Hz, although the authors suggested that slight threshold elevation might be due to calibration error (Jin et al., 2013). Unilaterally or bilaterally, subjects revealed a 12.4% noise-notch rate versus 8.6% for controls (Jin et al., 2013); however, noise notches may be false positives and not true indicators of MIHL in teenage subjects (Schlauch and Carney, 2011). Jin et al. (2013) observed that noise notches disappeared during follow-up testing but attributed some errors to calibration. This suggests that some noise notches may be transient and due to audiometric variability (Jin et al., 2013).

No consistent changes in hearing thresholds were seen with marching band musicians, which contradicts the idea that these exposures contribute to MIHL (Jin et al., 2013). The authors suggested that young and healthy people may be less susceptible to high levels of intermittent sound and the outdoor nature of marching band practice reduces MIHL risk (Jin et al., 2013). Skeptical about the accuracy of diagnosing noise notches, Schlauch and Carney (2011) suggested use of repeated hearing thresholds, which includes retesting all individuals, retesting and averaging 6000 and 8000 Hz, and retesting audiograms that had noise notches. Retesting the audiograms of those meeting noise notch criteria emerged as the best method of reducing false positives (Schlauch & Carney, 2011). And, according to Jin et al. (2013), use of earphones was found to provide lower variability for 6000 to 8000 Hz.

Otoacoustic Emission Findings

Otoacoustic emissions (OAEs) testing is used to record the response of the outer hair cells in the cochlea. Outer hair cells are among the first structures damaged from exposure to high-intensity sound (Nordmann et al., 2000). Otoacoustic emissions testing may be beneficial for MIHL diagnosis, particularly because reduced otoacoustic emissions may be seen before loss of hearing thresholds (Lapsley-Miller, Marshall, Heller, & Hughes, 2006). The ability for early identification of MIHL with use of otoacoustic emissions even before audiometric threshold change would allow intervention to occur prior to the realization of permanent hearing loss (Lapsley-Miller, Marshall, & Heller, 2004).

From the outset, individuals in an HCP may already have decreased otoacoustic emissions amplitudes so examiners must ensure that responses are above artifact levels. Test-retest reliability needs to be considered, so responses should be repeatable bilaterally. Other factors include stimulus level, frequency range, and the time allowed per measurement (Lapsley-Miller, Marshall, & Heller, 2004).

When comparing various levels of Transient Evoked Otoacoustic Potentials (TEOAEs) with various levels and frequencies of Distortion Product Otoacoustic Emissions (DPOAEs) in US Navy personnel with varying levels of noise exposure, Lapsley-Miller et al. (2004) suggested that TEOAEs had broader and more consistent measurements of temporary threshold and permanent threshold shifts. More changes in lower frequencies in the TEOAEs were detected than in the actual hearing threshold shift revealed by audiometric monitoring. Here, only two cases demonstrated permanent changes in OAEs while audiometric results suggested temporary changes (Lapsley-Miller, Marshall, & Heller, 2004). Jansen et al. (2009) suggested that TEOAEs are the best indicators of high-frequency hearing threshold shifts and noise notches; however, Jin et al. (2013) discovered that TEOAEs did not differ between individuals with and without noise notches.

Henning and Bobholz (2016) examined DPOAEs in music and non-music majors and found that 21% of their music majors had absent DPOAEs for at least one frequency in at least one ear while none of their non-music majors had absent DPOAEs despite a lack of audiometric differences between music and non-music majors. It is important to note that the music majors with absent DPOAEs played their instruments longer and practiced more hours that the rest of the music majors. DPOAEs may be useful in establishing a baseline and determining when musicians start showing signs of cochlear damage (Henning & Bobholz, 2016). Brass players, in particular, displayed a 2-3 dB greater DPOAE amplitudes at 1500 Hz and 1906 Hz and a 2-3 dB lower amplitudes at 3031 Hz, 3812 Hz, and 4812 Hz in comparison to musicians that do not play brass (Henning & Boblholz, 2016).

Hearing Conservation

To assist in the development of effective hearing conservation programs in public schools, development of public policy, public awareness, and an effective way to distribute lesson plans and teaching materials to public schools should be addressed (Chesky, 2018). Chesky (2011) recommended continuous sound exposure assessments for music programs, because dosimeters may be extremely variable, even when measuring the same ensemble.

Protection of Hearing

Musicians appear reluctant to wear hearing protection devices (HPDs) and those who do seek audiologic services often do so because of MIHL symptoms (Blum, 2016). It is also known that conventional HPD may compromise musical performance. A musician's level of performance can take a higher precedence over healthy hearing (Blum, 2016). Research on the association between hearing protection attenuation effectiveness and music perception is limited. When HPDs affect the perception of sound, musicians increase the intensity-level of their instruments to counterbalance any loss of sound perception (Chesky, 2008). So, for this reason, the author recommended adjusting how music is played instead of using HPDs.

Few studies are available about flat-attenuating earplugs; therefore, it is difficult to determine if they can be universally recommended for musicians (Chesky, 2011). Laitinen (2005) reported that music students had poorer self-monitoring ability and difficulty communicating musically when using Etymotic ER-20 earplugs. Other reported issues with hearing protection include the inability to hear other musicians, complications with occlusion, difficulty assessing the sound quality of your own instrument, problems with HPD insertion and removal, and difficulty adapting to altered sound perception incurred by HPD use (O'Brien, Ackermann, & Driscoll, 2014). This inability to hear important sounds may contribute to the lack of hearing protection uptake by the musician population, which emphasizes the importance of developing enhanced HPDs for musicians (Laitinen, 2005).

Musicians should wear HPDS during all exposures to high-intensity sound (Blum, 2016); however, as an added measure, percussionists may be positioned behind plexiglass shields to protect other musicians (Blum, 2016). These shields are available in absorbent wrap-around and small Perspex personal acoustic screens, as well as larger acoustic screens, although, they may interfere with line of sight between the musician and conductor. Screens can also act to alter the sound quality of an orchestra and introduce sound exposure for neighboring musicians due to sound reflection. Acoustic screens are limited to approximately 3 to 6 dB of attenuation, making them less protective against high-intensity instruments (O'Brian, Ackermann & Driscoll, 2014). Nevertheless, all options should be considered in order to provide a safe environment for every musician, music educator, and music student, including administrative options.

Hearing-Loss Prevention Program

Although HPDs and engineering controls may be feasible, implementing administrative controls for musicians in ensembles is more difficult. Administrative control strategies, such as isolation from high-intensity instruments, changing the layout of the ensemble, or limitation of practice (exposure) time would negatively impact an ensemble. These impactful strategies or the use of HPDs that do not truly attenuate equally across the frequency range, ultimately affect sound quality and the productivity of musicians (O'Brien, I.O., Driscoll, T., & Ackermann, B., 2015). More sophisticated HPDs that do not interfere with sound perception, but lower the intensity to a safe exposure level, should be available for musicians and other consumers.

Chesky (2006, 2008) suggested that the director of every ensemble should provide hearing-health education at the beginning of each semester, discussing the following:

1. Foster an awareness of risks associated with MIHL, its effects, and its symptoms
2. Promote prevention of MIHL for students, faculty, and staff, explaining how hearing loss could impact their perception of sound
3. Educate students and faculty about how to effectively reduce their exposure and protect their hearing, explaining the warning signs of intense sound exposure, obtaining baseline audiograms, and providing strategies for hearing protection
4. Avoiding hazardous sound environments, and rest hearing after exposure to loud sound

The Queensland Symphony Orchestra (QSO) developed a hearing-loss prevention program (O'Brien et al., 2015) that included:

- ongoing exposure monitoring
- regular plotting of noise maps
- high quality HPDs for musicians
- constant refinement of engineered controls
- a noise committee
- seat rotation according to exposure
- evaluation of artistic impact of controls
- a consistent hearing evaluation program
- an ongoing educational package
- ongoing research about available technological solutions

The QSO program was implemented in two stages. First, exposure monitoring and mandatory annual audiological assessments of musicians were administered. Risk awareness was reinforced using a weekly roster and musicians were provided annual education sessions. Custom, level-dependent electronic, and passive commercial HPDs for musicians were fitted and HPD use and maintenance were checked during annual assessments (O'Brien et al., 2015). Next, management administered engineering controls by way of acoustic screens and treatments as well as scheduling, rostering, and seat rotation. Unfortunately, despite increased awareness of MIHL and implementation of an HCP, 70% of the QSO reported infrequent to no HPD use due to inability to adjust, negative impact on sound quality, and inability to hear other musicians.

There are over 600 university music departments with over 100,000 students. These individuals are not receiving adequate hearing loss and tinnitus-prevention education (Chesky, 2008; Chesky et al., 2009). To address the misconceptions of HPDs, university music departments should receive training about the effects of music on hearing, methods to prevent hearing loss, and attitude adjustment for improved HPD use (Chesky 2011). Henning and Bobholz (2016) suggested that at-risk musicians should be prioritized for HCP services, including those who use brass and percussion instruments. Thus, the purpose of this report was to characterize the exposure profile of percussion and brass sections in a music department during group practices in practice environments to determine if an HCP is indicated.

CHAPTER 2

Methodology

Subjects

Our campus music department at Illinois State University volunteered to participate in this project, including faculty and student musicians in the Symphonic Band, Symphonic Winds, Wind Symphony, Ensemble Jazz I, and Ensemble Jazz II. Ensemble practice and performance rooms were targeted for sound-level and dosimetry measurements. Our affected population included the following:

- The Symphonic Band consists of 57 student musicians: 10 flute, one oboe, ten clarinet, four saxophone, four horn, six trumpet, seven trombone, four euphonium, three tuba, and eight percussionists.
- The Symphonic Winds and the Wind Symphony were conducted by the same conductor. Symphonic Winds was comprised of 51 student musicians: five flute/piccolo, two oboe, ten clarinet, two bassoon, five saxophone, four horn, four trumpet, five trombone, four euphonium, two tuba, five percussionists, one string bass, one pianist, and one harpist. Symphonic Winds also had five additional faculty players at the rehearsal in the Center for Performing Arts Concert Hall (CPA) for one song, including two trumpets, one horn, one trombone, and one tuba.
- The Wind Symphony had 52 student musicians: four flute, three oboe/English horn, nine clarinet, three bassoon/contrabassoon, five saxophone, five horn, five trumpet, four trombone, three euphonium, two tuba, six percussionists, one string bass, one pianist, and one harpist (percussionists were not present for the measurements in Cook Hall 212).
- Jazz I and II were conducted by the same individual. Jazz I consisted of 18 student musicians: five saxophone, four trombones, four trumpet, one pianist, one guitarist, one double bass, and two drummers. To join the Jazz I ensemble, tryouts were required, so this group, which also tours, was comprised mostly of graduate students. Jazz II consisted of 17 student musicians: five saxophone, four trombone, four trumpet, one pianist, one double bass, and two drummers.

Instrumentation

An Extech SL-355 Personal Noise Dosimeter^{TM} (FLIR Commercial Systems Inc., Nashua, New Hampshire) was used to collect dosimetry data. A Quest Sound Pro Type 1 precision sound-level meter (SLM) was used to produce sound maps and conduct area-monitoring measurements. A Quest QC-10 Calibrator was used to calibrate the instruments. Dosimetry and SLM samples were obtained in the ensemble practice rooms: Cook Hall rooms 305 and 212 and the CPA.

Environment

Cook Hall 305 was a smaller room. It had a hard-wood floor. There were floor-to-ceiling mirrors on the front corner near the door, a whiteboard in the middle of the front wall, a chalkboard on the opposite side of the whiteboard, and another door. There was padding across the front wall where the mirrors and boards are not located. The rest of the walls were stark plaster, with windows on the right and back walls. Two of the three windows on the right wall had light-weight curtains and two of the four windows in the back of the room had curtains. The room had two closets in the back corners for storage that jutted out into the room, creating an odd plus-sign shape to the room. The students were arranged in an arch in rows that faced the white board. The ceiling was flat and paneled with lights and vents scattered throughout.

Cook Hall 212 was substantially bigger than Cook Hall 305. The wall with the entrance door was brick and had three windows with lightweight curtains. From the vantage position of the doorway, the left wall was solid brick with four curtained windows. The wall opposite the door was padded except for an area that included whiteboard and mirror. The right wall was covered with long wooden closets and plaster. The floor was hardwood with no carpeting. The ceilings were vaulted with visible beams and air vents that stretched throughout the expanses.

The room reverberated even when it was essentially empty. The students were seated in rows in an overall-arched shape in the middle of the room with all students angled and facing toward the whiteboard.

The CPA was a large, elongated hexagon shaped room with a stage on the shorter portion of the hexagon and seats in the longer part of the hexagon. The seating in the main area were angled down toward the stage so that the front row was sitting below the level of the stage floor. A balcony ran in a narrow strip around the perimeter where a choir and organist could sit above the stage and more audience members could sit toward the back and sides. While the ceilings were vaulted, they were also padded like the walls of the balcony. Curtains lined select areas of the walls, including down the sides of the hexagon and in the corners of the back of the hall. The floors were carpeted. The sides underneath the balcony formed tunnels with pillars on either side of the room that led to the entrance doorways and the backstage doorways. Some of the audience seating were in these tunnels and were level with the stage. Behind the stage were several curtains that could be drawn to conceal the wooden walls.

The Symphonic Band practiced for almost two hours in Cook Hall 212 and 305. They occasionally divided into sectionals between Cook Hall 305 and Cook Hall 308 and practiced in the CPA during a sound check rehearsal just prior to a concert. Dosimetry and SLM measures were conducted in Cook Hall 305 and the CPA, the week prior to a concert and on the day of the concert, respectively. During their rehearsal, the side doors of the stage were open, and the back-drop curtains were not extended. The conductor asked students to play their instruments quieter to spare energy for the CPA concert. The conductor expressed that rehearsals after a concert were louder because students were learning new music material. In other words, students were more focused on musical precision versus execution of dynamics. Symphonic Winds practiced for nearly two hours in Cook Hall 305 and 212. They have occasional sound check rehearsals in the CPA during concert week. Dosimetry and SLM data were sampled in Cook Hall 212, Cook Hall 305, and the CPA. During rehearsal measurements, the side doors of the stage were closed, and the backdrop curtains were open. Wind Symphony practiced for about two hours in Cook Hall 212 with rare sound check rehearsals in the CPA prior to concerts. On the day of their first concert, SLM data were obtained in the CPA. During their rehearsal, the side doors of the stage were closed, but the backdrop curtains were not spread out. Jazz I practiced for almost two hours in Cook Hall 305 with occasional sessions in the CPA during sound checks prior to concerts; however, measurements in the CPA were not obtained due to band travel plans. Lastly, Jazz II practiced for 50 minutes in Cook Hall 305. Dosimetry and SLM data were sampled in Cook Hall 305 and in the CPA. During rehearsal, the side doors of the CPA stage were closed with backdrop curtains spaced evenly.

Procedures

A meeting with the music department faculty was made to describe the initiative. A follow-up meeting was held to gather ideas about rooms and ensembles. Calibration of equipment was performed prior to and after SLM and dosimetry sampling sessions. Individuals performing sound measurements used HPDs. A slow response A weighting sound level meter protocol was used to measure peak intensities at ear level in the corners, center, and between center and corner positions in each space. A SLM measurement was also created near the conductor. All SLM samples were conducted at ear level in either a standing or sitting position based on how nearby students were positioned. For example, percussionists tend to stand in the back row, so measurements in the back of the room were taken in a standing position while other instruments in the front and middle of the room tend to be seated, so measurements were taken in a sitting position. All SLM measurements for the conductor were obtained standing up.

The dosimeter was clipped on an outer garment, close to ear level, on the student with the highest reported level of exposure. This was based on the following recommendations from the conductor and a student:

- Symphonic Band recommended dosimetry for a euphonium player positioned in front of the percussionist section, emphasizing cymbals, snare drum, and bass drum
- Jazz Bands recommended dosimetry for the saxophone players adjacent to the drum set
- Symphonic Winds and Wind Symphony did not make a recommendation, so the dosimeter was placed on trumpet players in the center of the back row positioned in front of percussionists
- Dosimetry was not performed elsewhere due to scheduling conflicts

CHAPTER 3

Results

Tables 2 to 5 are displays of SLM and TWA numerical data for the various music spaces, and **Figures 1 to 4** are the associated graphs of the area sound maps and sampling positions. Each position on a **Figure** is marked with a letter that corresponds to a lettered row on its associated **Table**.

Peak Intensity Data

Peak SLM and dosimetry data were measured for the Symphonic Band, Symphonic Winds, Jazz I and Jazz II in Cook Hall room 305 (**Table 2**). For these ensembles, the range of peak-intensity during rehearsals was 74.6 dBA to 105.3 dBA and the average peak intensity was 93.2 dBA. For the Symphonic Band, Symphonic Winds, Jazz 1, and Jazz II, the center of room 305 demonstrated the highest sampled intensity, 76.8 dBA, 105.3 dBA, 104.4 dBA, and 104.1 dBA, respectively (**Figure 1,** position marked E). The ensemble with the highest intensities in room 305 was Jazz I with a peak intensity range of 95.4 dBA to 104.4 dBA (**Table 2**). Symphonic Winds showed the second-highest peak intensity, with a range of 91.2 dBA to 105.3 dBA. The highest measurement was in the center of the room at position E, and the lowest measurements were in the rear-right corner, (91.2 dBA), the front-right corner (93.5 dBA), and in the conductor’s position (93.5 dBA). At the conductor’s request, a measurement was taken at his designated position while the symphony performed with full effort, revealing an intensity of 99.6 dBA.

Peak SLM and dosimetry data were obtained in the CPA for the Symphonic Band, Symphonic Winds, Jazz II, and Wind Symphony. The average peak intensity was 89.6 dBA with a range from 74.6 dBA to 103.1 dBA (**Table 3**). The location with the highest intensity in the

CPA was at the conductor's position for the Symphonic Band, Symphonic Winds, and Jazz II, 75.6 dBA, 96.4 dBA, and 98.2 dBA, respectively (**Figure 2**). The highest intensity measured on the stage was for the Wind Symphony in the rear-left corner, 103.1 dBA (**Figure 3**, position B) with a range of 98.1 dBA to 99.4 dBA (**Table 4**). For the CPA, the Wind Symphony ensemble revealed the highest average peak intensity (93.1 dBA) with a range of 84.7 dBA to 103 dBA. The highest peak intensity was measured at position B in the rear-left corner of the stage, with lowest peak measured at position C, the rear-left corner of the audience (**Figure 2**).

Sound-intensity data were obtained in Cook Hall 212 for the Symphonic Winds and the Wind Symphony. The average peak intensity across the two bands was 97.1 dBA with a range of 94.7 dBA to 100.7 dBA (**Table 5**). The position with the highest average peak intensity in 212 was 100.0 dBA at position E in the center of the space. Position E was the position with the highest peak intensity for both ensembles with peak intensities of 99.2 dBA for the Symphonic Winds and 100.7 dBA for the Wind Symphony (**Figure 4**).

Area Sound Mapping

In order to characterize positions within each practice room that presented potentially hazardous high-intensity sound, intensity measurements were plotted on a sound map. Physical room arrangement and instrument proximity were charted and compared in order to determine if specific factors contributed to higher-intensity positions. The area sound maps in **Figures 1 to 4** are not scaled exact dimensions of our measured spaces. Solid circles represent sound map positions. Measurements obtained from a sitting position are shown with green circles, while data obtained from a standing position are shown with red circles. For each ensemble, the dosimeter measurement location and SLM position with the highest intensity have been identified on the sound map using other symbols.

CHAPTER 4

Discussion

The Symphonic Band was arranged in arched rows. The back row consisted of the percussionists including bells, xylophone, marimba, and glockenspiel. The snare drum, gong, cymbals, and bass drum were in the center with tympani drums on the right. The next row was brass with trumpets on the left, tubas in the middle, euphonium players to the right, and trombones to the far right. The following row included clarinets, alto clarinets, saxophones, and French horns. The front row included clarinets, an oboe, and flutes. Slight variations of this arrangement are made based on room size and student attendance. In Cook Hall 305, the Symphonic Band position with the highest sound level measurements was the center of the room, which was two rows in front of the snare drum, bass drum, and cymbals; one row in front of the tubas and immediately in front of the alto clarinet. In the CPA, the Symphonic Band's most intense positions were the rear-left corner of the audience at a location where the conductor is situated.

The Symphonic Winds were arranged in an arch across the room with the percussionist located in the rear in the same general order as the Symphonic Band. A notable difference was that the percussion rows included the glockenspiel, piano, harp, and vibraphone on the left. There was a drum set positioned in the middle of the arch to the left of the tympani. In front of the percussionists from left to right were the French horns, trumpets, trombones, and the tubas. The ensuing row included French horns, saxophones and euphoniums with flutes, clarinets, and alto clarinets. The first row consisted of flutes, oboes, and bassoons. Slight variations on this order were possible due to room size and student attendance. In Room 305, the highest sound level for the Symphonic Winds was the center of the room between the saxophones and trumpets. In

Room 212, the highest sound level measured was in the center of the room between the saxophones and the clarinets. At the CPA, the Symphonic Winds were accompanied by the faculty brass ensemble positioned on the front-left side of the stage. The most intense position was where the conductor was standing.

The Wind Symphony was arranged like the Symphonic Winds, however there was no drum set used and a gong was in the rear-left corner. In Cook Hall 212, the highest sound intensity was measured in the center of the room between the clarinets and saxophones. In the CPA, the most intense sound level for the Wind Symphony was measured at the rear-left corner of the stage behind the glockenspiel, close to the bells and gong.

For Jazz I, musicians were not seated in an arch arrangement but in straight rows. The piano was located on the left of the ensemble with percussionists, flugelhorns and trumpets in the rear. The ensuing row included a drum set and trombones with a guitarist, accordion player, saxophonist, and clarinets in the front row. In Room 305, the highest sound level was measured in the center of the room between the trumpets and trombones. Although like Jazz I, Jazz II did not contain clarinets or a guitarist, but had a double bass on the left side of the drum set. In room 305, the highest sound intensity for Jazz II was also measured in the center of the room. In the CPA, the highest sound level was where the conductor was standing.

From our measurement data and observations of musician-seating arrangements in each of the practice rooms, it is evident that the center position in these rooms consistently demonstrated the highest sound-intensity level. Most importantly, this was true for all ensembles. Our data also indicated that the Symphonic Wind musicians may be at greater risk for MIHL than those in the Symphonic Band, Wind Symphony, Jazz I, and Jazz II ensembles. All sound-level measurements for Symphonic Band indicated that their exposures were below 80 dBA, so the risk of MIHL would be essentially 0%. By comparison, all other ensembles exceeded the damage-risk intensity level (e.g., 85 dBA) at some point during the practice session. Because students practice repeatedly and generally do not use HPDs, at a minimum, they should receive audiometric monitoring and annual health-wellness education.

Many students may be involved in ancillary music programs, such as secondary ensembles, music lessons, and individual music practice. Students also may engage in recreational music and jobs or hobbies that are associated with high-intensity noise. All music students should receive a full case history and be counseled on the risk for permanent hearing loss and tinnitus that is associated with high-intensity music, especially when their lifestyle includes limited time without excessive sound.

Engineering and administrative controls should be considered to produce a safer environment for music students, staff, and faculty. To reduce sound-intensity levels in the center of practice rooms, acoustic materials should be installed within each space, on walls and hard surfaces, to decrease reverberation and distortion. By increasing the quality of sound in these spaces, the overall intensity may be subsequently reduced. Other engineering controls might include placement of sound absorptive materials such as rugs for floors in the center area, tapestries on walls and corners, and a soft barrier between musicians in the rear, especially percussionists. Lastly, conductors and other educators who are frequently exposed to these levels of sound should be fitted with level-dependent HPDs, filtered custom-molded HPDs, or standard off-the-shelf musician earplugs. Student musicians positioned in the center of practice rooms should do the same if engineering controls are not feasible.

Conclusion

Since high frequency hearing loss occurs in 16-20% of children age 12-19 years due to potential exposure to excessively loud music, it is suggested that music education majors and music teachers in elementary, junior high, and high school could be educated on MIHL prevention to initiate a change of behavior at an early stage in the life of students (Shargorodsky et al., 2010). For earlier intervention, education on hearing wellness in preschool children might help young musicians become better advocates of their own hearing health. Chesky (2011).

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TABLES AND FIGURES

Table 1. Reference Counts.

Where Sources were Obtained	Total Number	Retained
Articles from advisor	12	7
References from advisor	173	18
Recital pamphlets	2	2
References from AuD contact	2	2
References from AAA posters	18	0
Sources from classmate	24	1

Tally of the source of references, including number identified and retained.

Table 2. Sound Level Measurements for Cook Hall Room 305.

Location	**Symphonic Band**	**Symphonic Winds**	**Jazz I**	**Jazz II**
A	74.6 dBA	93.5 dBA	95.5 dBA	97.3 dBA
B	75.2 dBA	100.7 dBA	95.4 dBA	97.3 dBA
C	76.6 dBA	96.6 dBA	101.1 dBA	95.1 dBA
D	75.7 dBA	91.2 dBA	98.8 dBA	96.6 dBA
E	76.8 dBA	105.3 dBA	104.4 dBA	104.1 dBA
F	75.2 dBA	99.7 dBA	101.5 dBA	95.5 dBA
G	74.6 dBA	102.2 dBA	102.4 dBA (standing)	100.6 dBA (standing)
H	75.5 dBA	101.8 dBA	100.9 dBA (standing)	95.1 dBA
I	75.8 dBA	98.2 dBA	103.9 dBA	98.1 dBA
J	76.2 dBA	93.5 dBA	103.2 dBA	102.3 dBA

Table 3. Sound Level Measurements for the CPA Concert Hall.

Location	Symphonic Band	Symphonic Winds	Jazz II	Wind Symphony
A	74.6 dBA	94.8 dBA (90.7 dBA Balcony)	91.3 dBA	99.4 dBA
B	75.0 dBA	95.6 dBA (91.3 dBA Balcony)	89.3 dBA	103.1 dBA
C		87.5 dBA (88.0 dBA Balcony)	86.9 dBA	84.7 dBA
D	75.6 dBA	89.8 dBA (88.1 dBA Balcony)	88.8 dBA	89.3 dBA
E		90.6 dBA	89.4 dBA	92.0 dBA
F		86.8 dBA	89.0 dBA	89.1 dBA
G		91.0 dBA	90.3 dBA	91.2 dBA
H		91.9 dBA	89.4 dBA	90.7 dBA
I		89.6 dBA	88.1 dBA	93.4 dBA
J	75.6 dBA	96.4 dBA	98.2 dBA	98.1 dBA

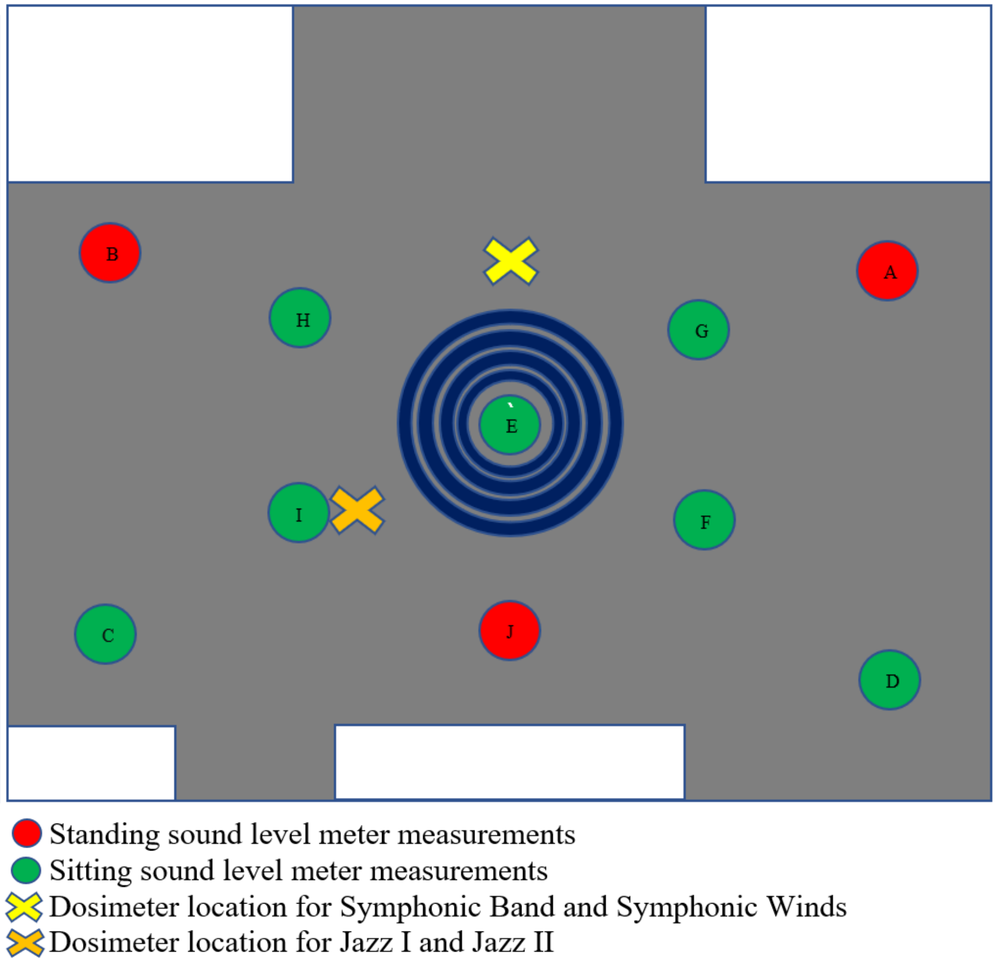
Table 4. Sound Level Measurements for the CPA Concert Hall Stage.

Location	Symphonic Band	Symphonic Winds	Jazz II	Wind Symphony
A	74.6 dBA	94.8 dBA (90.7 dBA Balcony)	91.3 dBA	99.4 dBA
B	75.0 dBA	95.6 dBA (91.3 dBA Balcony)	89.3 dBA	103.1 dBA
C	76.3 dBA			
D	75.6 dBA			
E	76.7 dBA			
F	75.7 dBA			
G	75.6 dBA			
H	75.6 dBA			
I	76.9 dBA			
J	75.6 dBA	96.4 dBA	98.2 dBA	98.1 dBA

Table 5. Sound Level Measurements for Cook Hall 212.

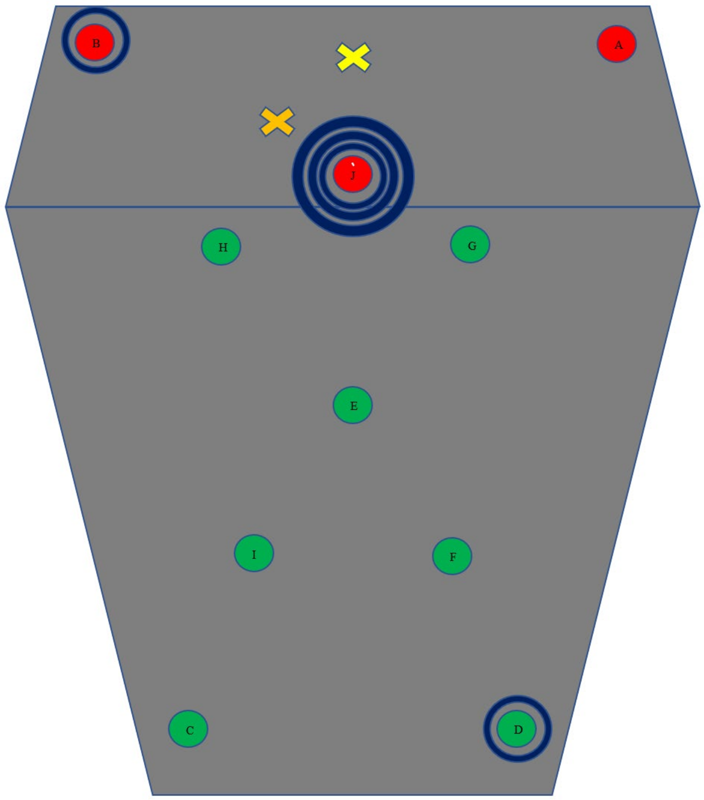
Location	**Symphonic Winds**	**Wind Symphony**
A	95.4 dBA	96.2 dBA
B	94.7 dBA	96.7 dBA
C	95.5 dBA	96.7 dBA (sit)
D	94.8 dBA	96.2 dBA
E	99.2 dBA	100.7 dBA
F	97.4 dBA	98.2 dBA
G	98.0 dBA	98.3 dBA
H	96.3 dBA	97.3 dBA
I	98.0 dBA	98.8 dBA
J	97.1 dBA	97.2 dBA

Figure 1. Area sound map and measurement positions for Cook Hall Room 305



Note: Cook Hall Room 305 sound map (not to scale). Solid circles represent sound map positions. Green circles represent measurements taken at a sitting ear level. Red circles represent measurements taken at a standing ear level. X represents dosimeter locations in the room with yellow representing the location for Symphonic Band and Symphonic Winds and orange representing Jazz I and Jazz II. Hollow navy circles represent the position with the highest intensity sound level measurement for each ensemble.

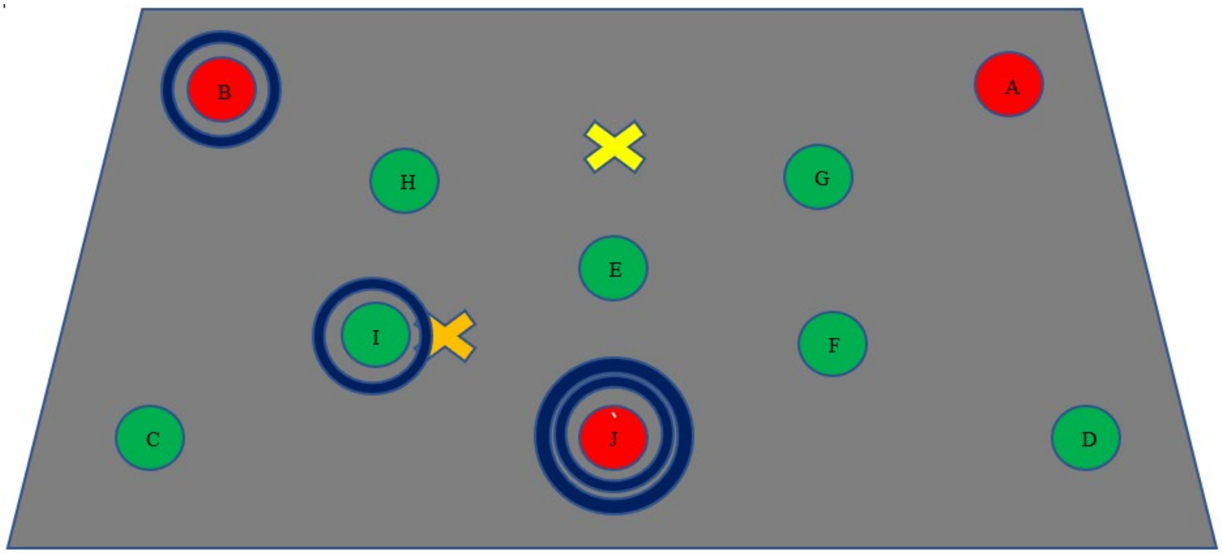
Figure 2. Area sound map and measurement positions for the CPA Concert Hall



Standing sound level meter measurements
Sitting sound level meter measurements
Dosimetry location for Symphonic Band and Symphonic Winds
Dosimetry location for Jazz II

Note: CPA sound map (not to scale). Solid circles represent sound map positions. Green circles represent measurements taken at a sitting ear level. Red circles represent measurements taken at a standing ear level. X represents dosimeter locations in the room with yellow representing the location for Symphonic Band and Symphonic Winds and orange representing Jazz II. Hollow navy circles represent the position with the highest intensity sound level measurement for each ensemble.

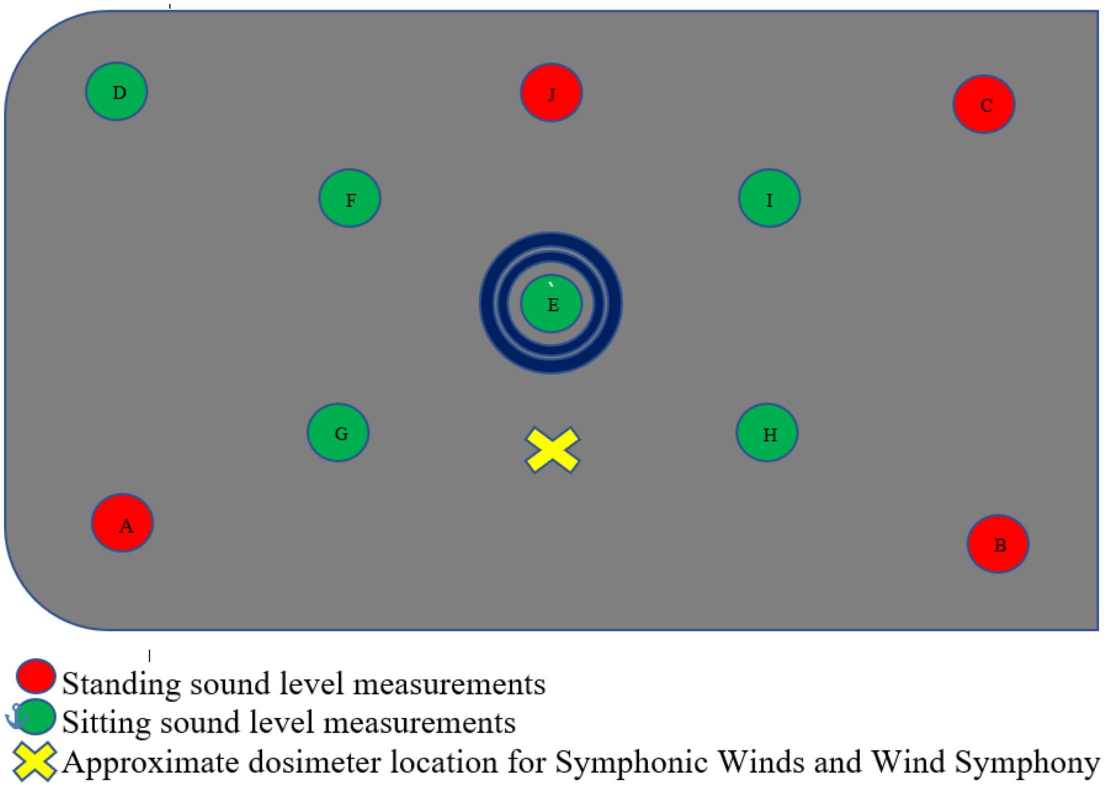
Figure 3. Area sound map and measurement positions for the CPA Stage



Standing sound level meter measurements
Sitting sound level meter measurements
Dosimetry location for Symphonic Band and Symphonic Winds
Dosimetry location for Jazz II

Note: CPA stage sound map (not to scale). Solid circles represent sound map positions. Green circles represent measurements taken at a sitting ear level. Red circles represent measurements taken at a standing ear level. X represents dosimeter locations in the room with yellow representing the location for Symphonic Band and Symphonic Winds and orange representing Jazz II. Hollow navy circles represent the position with the highest intensity sound level measurement for each ensemble.

Figure 4. Area sound map and measurement positions for Cook Hall 212



Note: Cook Hall Room 212 sound map (not to scale). Solid circles represent sound map positions. Green circles represent measurements taken at a sitting ear level. Red circles represent measurements taken at a standing ear level. Yellow X represents dosimeter locations in the room with yellow representing the location for Symphonic Band and Symphonic Winds. Hollow navy circles represent the position with the highest intensity sound level measurement for each ensemble.