AN ANALYSIS OF THE SOUND-LEVEL EXPOSURES OF DRUM AND BUGLE CORPS MEMBERS DURING A FULL-DAY REHEARSAL

by

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A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Greensboro
2006

Approved by

Committee Chair

UMI Number: 3227701

PRESLEY, DOUGLAS L., Ph.D. An Analysis of the Sound-Level Exposures of Drum and Bugle Corps Members During a Full-Day Rehearsal. (2006)
Directed by Dr. Patricia E. Sink. 178 pp.

The purpose of this study was to describe sound-level exposures of Drum and Bugle Corps members during a full-day rehearsal. Using a personal dosimeter, sound-level exposures were measured across two rehearsal days during the corps' "Spring Training" schedule. The L_{eq} value and measured time were used to calculate the daily sound-dose percentage. The primary research question was as follows. Do Drum and Bugle Corps members experience sound levels that result in dose percentages that meet or exceed standards recommended by the National Institute for Occupational Safety and Health (NIOSH) resulting from various rehearsal activities throughout a full-day rehearsal? For exploratory purposes, average sound-level estimations were calculated based on hypothetical uses of various hearing protection devices (HPD) to determine the possible reduction of sound-level exposure. Additionally, of interest to the researcher was Drum and Bugle Corps members' answers to questions relative to hearing health and patterns of exposure based on involvement with other performance groups throughout the calendar year.

Thirty-two Drum and Bugle Corps members participated in the study. Each member wore a Cirrus Research CR:100B doseBadge personal dosimeter set to standards recommended by NIOSH. The dosimeter was attached to an athletic visor within four inches of the ear to collect sound levels experienced for the duration of the full-day

rehearsal. Additionally, the effects of other variables on sound-level averages were examined, including subjects' instrument and type of rehearsal activity.

All subjects experienced sound levels that resulted in dose percentages exceeding standards recommended by NIOSH for a full-day rehearsal. All instrumental subjects experienced an average sound level greater than 88 dBA, and thus all subjects experienced a daily dose percentage greater than 100%. The greatest average sound level, by instrument, was 102.05 dBA found with the snare drum subjects ($n = 4$). Across all participants, the four snare drum subjects experienced the greatest dose percentages with 8822.29%, 9455.49%, 9154.99%, and 5319.92%. Exploratory data analysis was pursued to examine effects of hypothetical hearing protection device (HPD) use on attenuation of sound level. The analysis revealed that all sound levels were hypothetically reduced to below the NIOSH standards using an HPD with a 30-dB attenuation.

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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March 20, 2006
Date of Acceptance by Committee

March 20, 2006
Date of Final Oral Examination

ACKNOWLEDGMENTS

I would like to express my sincere appreciation for my dissertation advisor, Dr. Patricia E. Sink. Dr. Sink has provided tremendous encouragement and support throughout this project and my degree program. Additionally, I would like to state my gratitude to Dr. Donald Hodges, Dr. John Locke, Dr. Jennifer Stewart, and Dr. Randy Kohlenberg for serving on my committee and for providing me expertise, insight, and encouragement.

Acknowledgment is made to all of the participants in this study. Their cooperation and enthusiasm made the project enjoyable, and their sincere interest was rewarding. I appreciate their willingness to give of their time and effort.

Thanks is given to the Music Research Institute (MRi) of the School of Music at the University of North Carolina at Greensboro. Use of equipment owned by the MRi was invaluable to completion of this study. Additionally, I would like to thank Dr. John Locke for providing compensatory materials for the participants in this study. Without the interest and support of the MRi and the School of Music, this research study would not have been possible.

Sincere appreciation is offered to family and friends for love and support throughout this project. Specifically, I would like to thank Sandra Mace who listened to descriptions of my discoveries and cheered me on throughout this project. Additionally, I would like to express my appreciation for my parents for their love and encouragement to attain goals such as this long-term educational endeavor.

My deepest appreciation, gratitude and thanks, however, is reserved for my wife Brooke Presley and three sons Sean, Wade, and Bryce. Their patience and support were foundational to the pursing of this degree and the completion of this project. Valuable liberties were afforded me over the past years because of their continual sacrifices.

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CHAPTER I

INTRODUCTION

Hearing is an important function for musicians during the performance of music. Musicians performing outdoors in a marching environment use the hearing mechanism for varied purposes, including: (a) individual performance accuracy relative to pitch, dynamics, and duration, (b) receiving instruction from conductors, other instructors, or drum majors, and (c) listening within small and large group rehearsal settings to adjust and practice for a desired musical performance. Additionally, the outdoor marching environment incorporates group movement synchronized with music, adding physical demand on the performers. Anything less than an acute sense of hearing would impair the abilities of an individual involved in a marching performance group.

Research supports that musicians are exposed to variable and intense sound levels that may place them at risk for noise-induced hearing loss (NIHL) during their years of music performance and practice routines. Although national and international standards are designed to verify that industrial workers experience safe sound levels, minimal, if any, long-term reliable descriptions of musicians' sound-level exposures exist. To date, examination of the sound-level exposures of musicians in an outdoor marching environment has been sparse, thus leading to vague descriptions of sound-level exposure.

Sound-level exposures for industrial workers are measured via a dosimeter that is set to standards established by the International Organization for Standardization (ISO), or by the United States Occupational Safety and Health Administration (OSHA). In particular, OSHA sound-level exposure standards are lenient. Because of the variability of musicians' sound-level exposures, they frequently are described at minimal risk for hearing loss due to their performance and/or practice environments (Karlsson, Lundquist, & Olaussen, 1983; Obeling & Poulsen, 1999; Owens, 2003). This conclusion, however, is not reliable relative to the cumulative process of NIHL during the progression of a performance and practice career including variable and intense sound-levels. This study collected dosimetric data from an outdoor marching organization and analyzed the findings to determine whether subjects were at risk for NIHL.

The researcher acknowledges that some of the terminology is specific to the study of acoustics, sound dosimetry, and audiology. In an effort to assist readers' understanding of terminology used in this research, definitions of terms are included in Appendix A.

Statement of Purpose

The purpose of this study is to describe the sound-level exposures of Drum and Bugle Corps members during a typical full-day rehearsal. The researcher determined sound-level exposures of Drum and Bugle Corps members using personal dosimeters. The dosimeters were set to standards of the National Institute for Occupational Safety and Health (NIOSH, 1998). Furthermore, this study collected dosimetric data in an attempt to provide musicians with sufficient and accurate information describing the extent to which they are exposed to sound levels that may place them at risk of NIHL. Specifically, the purpose of the study was three fold.

1. To describe the estimated average of sound-level exposures of Drum and Bugle Corps members during a typical full-day rehearsal.

2. To describe the estimated dose percentages of Drum and Bugle Corps members relative to the National Institute for Occupational Safety and Health (NIOSH) permissible sound-level exposure standards (i.e., 83 dBA with a 3 dB exchange for a 12-hour day, and 100% noise dose) during a typical full-day rehearsal.

3. To describe sound-level exposures by the following grouping variables: (a) instrument (i.e., front ensemble, battery percussion, and brass), and (b) type of rehearsal activity (e.g, full corps rehearsal, small group rehearsal, music rehearsal, marching rehearsal, etc.).

The Hearing Process

The sense of hearing involves a series of intricate and complex functions involving all parts of the ear. Hearing loss can be the result of mechanical destruction of the hair cells located within the inner ear. The anatomy and physiology of the auditory system are described in the following paragraphs. For purposes of this study, the description of the hearing process ends at the auditory nerve; the perception and cognition of sound is beyond the scope of this study.

The auditory system consists of four main divisions: (a) the external ear, (b) the middle ear, (c) the inner ear, and (d) the central auditory nervous system (Figure 1). Each of these divisions have specific functions that contribute to the hearing process. The physical properties of a sound wave affects each of these parts differently and results in transforming physical energy into mechanical energy, into hydraulic energy, and finally into electrochemical energy (Radocy and Boyle, 1997).

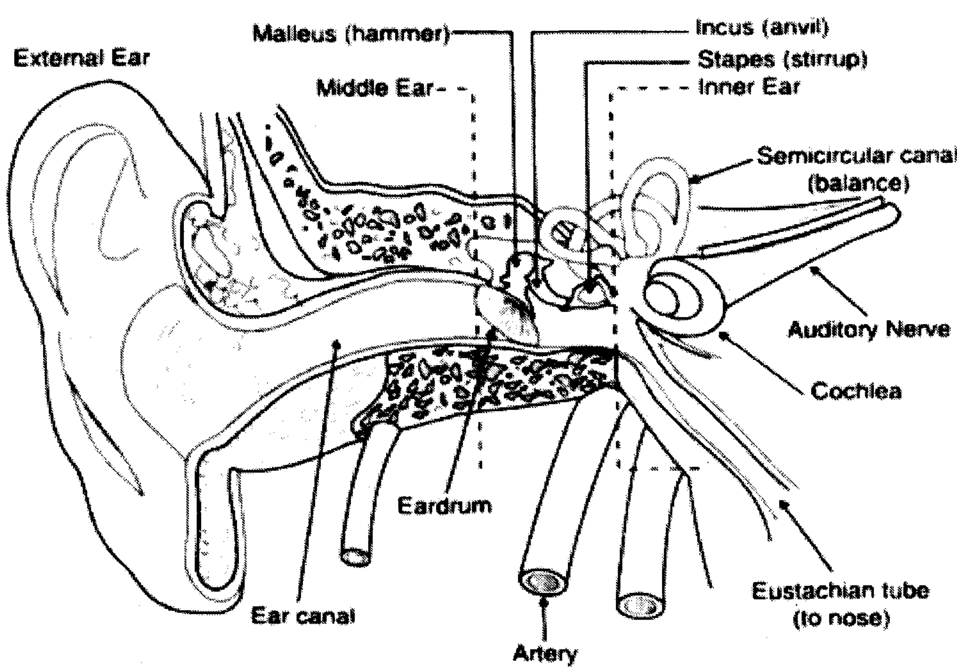

Figure 1. Cross-Section of the Human Ear. Reprinted with permission the *Hope for Hearing Foundation*, http://hope4hearing.org/anatomy.htm

Outer Ear

The outer ear consists of both the pinna and the auditory canal. The pinna (auricle) is the visible part of the ear that aides in the concentration of sound waves into the auditory canal (labeled "ear canal" in Figure 1). The auditory canal cavity has three characteristics that protect the ear from some environmental hazards, including: (a) regulation of humidity and temperature in the eardrum, (b) secretion of a waxy substance (cerumen) containing antibacterial agents, (c) lastly, prevention of dust particles from entering the canal via hair cells along the outer edges of the canal (Lipscomb & Hodges, 1996). Additionally, the canal amplifies frequencies between 1500 to 7000 Hertz (Hz) by 10 to 15 decibels (dB); this frequency range is important for music perception. Although the auditory canal affords some protection to the ear, the primary function of the canal is to direct sound waves to the eardrum or tympanic membrane.

The tympanic membrane is the boundary between the outer ear and middle ear (Backus, 1977). This membrane is attached along its perimeter by fibers and cartilage and seals off the middle ear. The tympanic membrane responds sympathetically to the compressions and rarefactions of a sound wave by moving back and forth. The thinnest portion of the eardrum is .055 mm thick, making it extremely sensitive to vibrations of sound (Lipscomb & Hodges, 1996).

Middle Ear

The inside of the eardrum connects to the middle ear by three small bones known collectively as the ossicles (Figure 2). The ossicles comprise the smallest bones in the human body. Individually the three bones are referred to as the malleus (hammer), incus (anvil) and stapes (stirrup). The ossicles are suspended by ligaments and muscle tissues and serve two purposes: (a) to deliver sound vibrations from the tympanic membrane to the oval window of the inner ear, and (b) to help prevent the inner ear from being damaged due to excessive sound vibrations (Zemlin, 1988).

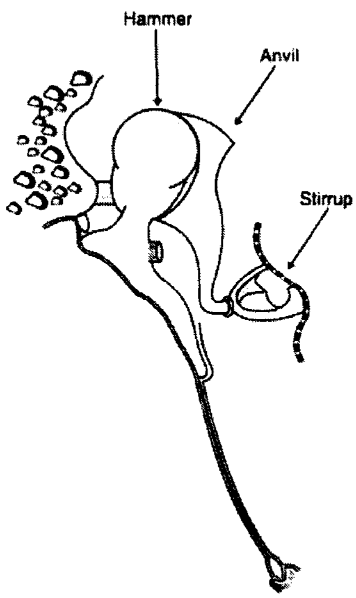

Figure 2. The Ossicles. Reprinted with permission from *Hope for Hearing Foundation*, http://hope4hearing.org/anatomy.htm

As the tympanic membrane moves in response to sound vibrations the malleus moves sympathetically as it is attached to the tissue fibers of the eardrum. The incus, dually connected to the malleus and stapes, moves in response to the malleus. Sound vibrations are passed along to the stapes that is connected to the cochlea at the oval window. The oval window separates the middle ear from the inner ear. Collectively, the movement of the ossicles is known as the ossicular chain. Through this process, sound vibrations are delivered to the inner-ear fluids at the oval window of the cochlea.

Although limited, muscles attached to the ossicles provide protection from intense sound levels. Sound intensities of 70 dB and above result in an acoustical reflex in the middle ear resulting in the connective muscles of the ossicular chain contracting (Radocy & Boyle, 1997; Zemlin, 1988). This contraction has been found to reduce the vibration amplitudes by both 10 dB (Gundersen & Høhmoen, 1976) and 30 dB (Yost, 2000) as they are transmitted from the malleus to the incus. Although these muscles offer some protection from intense sound levels, the protection is minimal due to the latency of the muscles' contractions and the limited endurance of the muscles.

Sound energy also increases as it moves through the middle ear to the oval window. There are three reasons for the increase in sound energy: (a) the eardrum is 23 times larger than the oval window, (b) the eardrum buckles toward the middle and doubles the pressure at the oval window, and (c) the ossicles, acting as levers, increase pressure by a ratio of 1.15 (Lipscomb & Hodges, 1996). The transmission of mechanical energy through the middle ear results in an increase of 31-33 dB once the sound energy reaches the oval window (Gelfand, 2001; Zemlin, 1988).

Inner Ear

The inner ear contains both the cochlea and semicircular canals (Figure 3). The cochlea houses the hearing mechanism, and the semicircular canals are responsible for maintaining equilibrium (Zemlin, 1988; Patton & Thibodeau, 2000). Specifically, mechanical sound energy traveling from the middle ear to the cochlea is transformed into hydraulic energy as the vibrations are transmitted through the oval window to the inner-ear perilymph fluid. The hydraulic energy travels via the perilymph fluid through the scala vestibule and scala tympani to the round window where the pressure is released. Hydraulic energy is transmitted through the perilymph fluid of the cochlea.

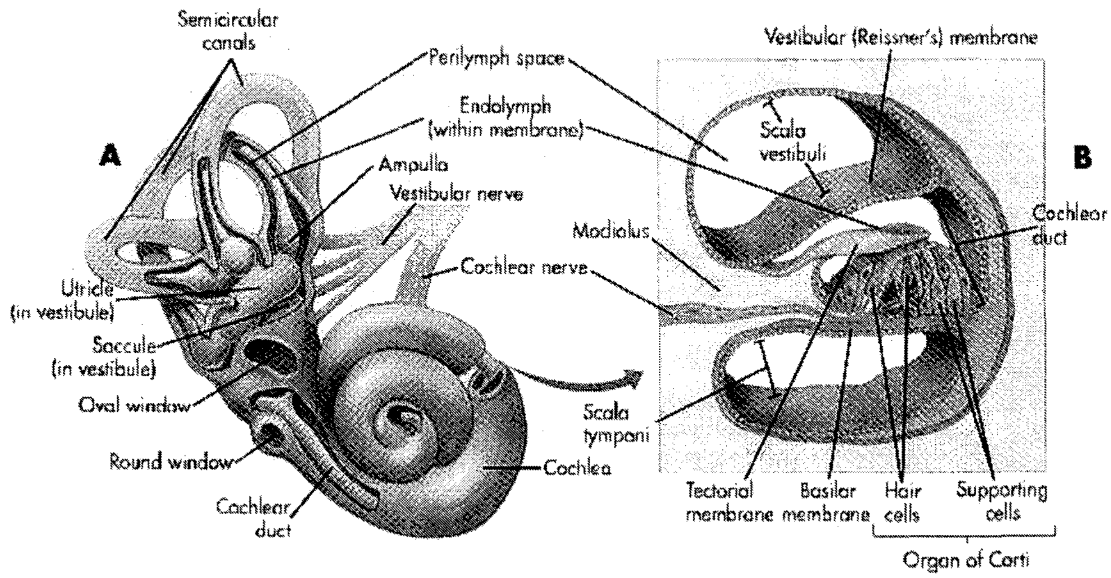

Figure 3. The parts of the inner ear. Reprinted from *Mosby's Handbook of Anatomy and Physiology*, Patton, K.T. & Thibodeau, G.A., p. 313, 2000 with permission from Elsevier

Between the scala vestibule and scala tympani is the cochlear duct (Figure 3). The cochlear duct is separated from the scala vestibule and scala tympani by Reissner's membrane and the basilar membrane, respectively (Patton & Thibodeau, 2000; Zemlin, 1988). Vibrations traveling through the perilymph fluid via the scala vestibule cause Reissner's membrane to displace, resulting in the movement of the endolymph fluid within the cochlear duct. The movement of the endolymph fluid by Reissner's membrane causes slight displacement of the tectorial membrane that stimulates the hair cells on the organ of Corti. As the vibrations travel to the scala tympani, the basilar membrane responds by flexing or bulging. The movement of the basilar membrane also results in the movement of the hair cells of the organ of Corti.

The organ of Corti houses rows of hair cells which rest upon the basilar membrane. There is one row of inner hair cells (approximately 3,500 hair cells) and three rows of outer hair cells; however, there are as many as four to five rows of outer hair cells near the apex. Combined, the outer and inner rows of hair cells account for approximately 20,000 total hair cells (Lipscomb & Hodges, 1996). The hair cells bend and flex when the basilar membrane is displaced, and shear against Reissner's membrane. High frequencies elicit hair cell movement closest to the oval window (i.e., at the base of the basilar membrane), and low frequencies elicit hair cell movement closest to the helicotrema, or apex of the basilar membrane (Gelfand, 1981; Lipscomb & Hodges, 1996; Radocy & Boyle, 1988; Zemlin, 1988).

Extending from the top of each hair cell is a group of tiny hair cells called stereocilia. These groups of hair cells are the primary hair cells responsible for hearing (Zemlin, 1988). There are approximately 50 stereocilia to each inner hair cell and approximately 150 to each outer hair cell (Lipscomb & Hodges, 1996). The stereocilia are graduated in length, with the longest stereocilia of the outer hair cells embedded in the tectorial membrane (Gelfand, 1981; Lipscomb & Hodges, 1996; Zemlin, 1988).

As the basilar membrane is displaced by hydraulic vibrations traveling through the endolymph fluid via the scala tympani, this results in the stereocilia shearing against the tectorial membrane (Figure 4). The bending or shearing of the stereocilia transduce hydraulic energy into electrochemical energy that is sent from the hair cells to the auditory nerve. Intense sound levels as well as long term exposure to sound levels exceeding 85 dB can handicap the transduction process which may result in noise-induced hearing loss (Yost, 2000).

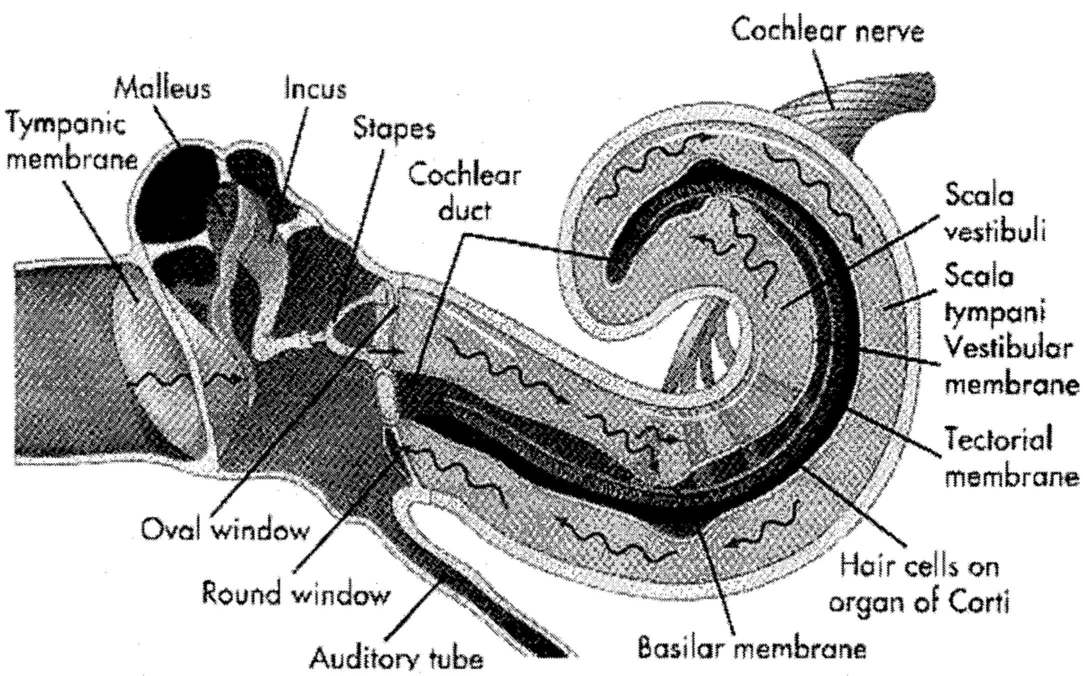

Figure 4. The effect of sound waves on the cochlea structures. Reprinted from *Mosby's Handbook of Anatomy and Physiology*, Patton, K.T. & Thibodeau, G.A., p. 314, 2000 with permission from Elsevier

Hearing Loss

The hearing organ contains many delicate, yet extremely active, components. The process of hearing is an activity that never ceases for those individuals with the ability to hear; however, if the hearing mechanism is subjected to intense sound levels without interruption, damage may occur.

The American National Standards Institute (ANSI, 1995) classifies hearing loss as either a temporary or permanent shift in the threshold of audibility for an ear resulting from exposure to high-intensity acoustic stimuli. Specifically, a temporary threshold shift (TTS) (Appendix A) occurs when the threshold of audibility returns to pre-exposure level within 16-18 hours after exposure (Chasin, 1996). A permanent threshold shift (PTS) is an increase in the threshold of audibility for an ear without recovery (ANSI, 1995).

Conductive Hearing Loss

Conductive hearing loss occurs when sound is not conducted efficiently via the mechanical components of the ear (i.e., from the external ear canal to the ear drum and ossicles). This type of hearing loss can be the result of poor eustachian tube function, ear infection, perforated eardrum, ossification of the ossicles, benign tumors, and an excessive amount of or impacted cerumen (American Speech-Language-Hearing Association, 2005). This type of hearing loss can often be surgically corrected.

Sensorineural Hearing Loss

Sensorineural hearing loss is a result of damage to the inner ear or to the nerve pathways from the inner ear (American Speech-Language-Hearing Association, 2005). Sensorineural hearing loss diminishes a person's ability to hear faint sounds and/or to understand speech, and produces a general reduction in sound level. Specifically, damage occurring in the cochlea results in the reduction of hair cells generating neurotransmissions to the auditory nerve. This type of hearing loss can be the result of excessive exposure to high-intensity sound levels. Acoustic trauma, a category of sensorineural hearing loss, is an instantaneous PTS resulting from very intense sound levels (i.e., greater than 140 dBA) experienced in a short period of time (Clark, 1992).

Another type of sensorinerual hearing loss occurs over time when damaged hair cells cease to respond to stimuli, causing other non-damaged hair cells to compensate; this process continues as more hair cells are destroyed. This gradually debilitating effect is referred to as noise-induced hearing loss (NIHL) that is often difficult to detect in the early stages.

Clark (1992) describes a three-stage process leading to NIHL. In stage one, sensory hair cells are destroyed by excessive exposure to highly intense noise leaving scar tissue in the inner ear. This destruction occurs in small amounts and is difficult to determine. The second stage is when the loss of sensory cells is so great that the resulting hearing loss can be measured audiometrically. This process can still be undetected by the individual as cumulative hearing loss occurs at frequencies higher than those needed to understand speech (i.e., 4 kilohertz (kHz)). In the third stage, sensory cells that have been destroyed due to continued exposure to intense sound at or above 4 kHz leave only sensory cells that respond to lower frequencies. These cells begin to respond and are ultimately destroyed.

Yamasoba, Nuttall, Harris, Raphael, and Miller (1998) state that the destruction of sensory cells in the cochlea may result from a molecular imbalance. Blood flow to the stria vascularis regulates the molecular balance of the cochlear duct, namely the supply of antioxidants (Gelfand, 2001). Yamasoba, et al. (1998) stated that prolonged exposure to high-intensity sound levels leads to oxidative stress, as blood flow to the stria vascularis is restricted. The restricted blood flow reduces the antioxidant level creating a molecular imbalance in the endolymph fluid and the release of free radicals. Free radicals are molecules that are unstable due to the loss of an electron (Health Check Systems, 2005). The free radical, seeking molecular balance, secures an electron from another molecule and begins a chain reaction that eventually destroys sensory hair cells in the cochlea.

Sensorineural hearing loss can also be the result of diseases, birth injury, toxins, genetic disorders, intense sound-level exposure, viruses, head trauma, aging, and tumors (American Speech-Language-Hearing Association, 2005). This type of hearing loss can be treated by cochlear implants, but the damaged hair cells cannot be restored.

Presbycusis

Presbycusis is generally defined as the gradual loss of hearing resulting from aging. Additional causes of presbycusis may be changes in the blood supply to the ear as a result of heart disease, high blood pressure, conditions caused by diabetes, or other circulatory problems. The National Institute on Deafness and Other Communication Disorders (NIDCD, 2005) estimates that 30-35% of adults between the ages of 65 and 75 years and 40-50% of adults 75 years of age and older have hearing loss that can be defined as presbycusis. This type of hearing loss affects the ability to discern speech patterns acurately. Presbycusis can be classified as both sensorineural and/or a conductive hearing loss.

Sound Level Standards and Hearing Protection

In the United States, reduction of NIHL as a result of industrial work environments is addressed by federal government regulations. The United States Congress mandates that the Occupational Safety and Health Administration (OSHA) is responsible for enforcing regulations within its jurisdiction, namely the United States.

Therefore, OSHA oversees government regulations and provides mandated standards for sound-level exposures relative to industrial work environments. The purpose of this administration is primarily to act as the enforcing agent to all industry engaging in interstate commerce (Berger, Royster, Royster, Driscoll, & Layne, 2000).

The National Institute for Occupational Safety and Health (NIOSH) is charged by the Occupational Safety and Health Act of 1970 (Public Law 91-596) with recommending standards relative to the conservation of health-related issues so as to insure that no worker will suffer diminished health as a result of their work experiences. In terms of sound-level exposure, NIOSH provides recommendations for occupational safety and health standards describing sound-level exposures that are safe for various periods of employment (NIOSH, 1998). Documents, such as *Occupational Noise Exposure: Revised Criteria* (NIOSH, 1998), serve as recommended standards which are communicated to OSHA. This NIOSH document suggests sound-level exposure standards that align with the International Organization for Standardization (ISO) recommendations.

The International Organization for Standardization (ISO) governs international standards associated with countries outside of the U.S. that protect workers. The organization is made up of representatives of over 150 countries from around the world. The purpose of the ISO is to act as a liaison between government and private agencies for the development of standards that help to improve the manufacturing of goods and services as well as protect the health of workers involved in the process. Specifically, the sound-level exposure standards developed by ISO and supported by NIOSH are more conservative or rigorous than current OSHA regulations.

Current OSHA regulations require that over an eight-hour work day an employee must not experience a sound-level average greater than 90 dBA. In addition, this sound-level criteria maintains a halving of exposure time for every 5 dB increase in sound level (i.e., a 5 dB exchange rate). Application of this exchange rate indicates that if an employee were to experience a sound-level average of 95 dBA, the exposure time could not exceed four hours. Current ISO standards require an 8-hour sound-level average of 85 dBA with a 3 dB exchange rate. With ISO standards an employee is required to not exceed an average-sound level of 88 dBA over a four-hour period. Comparison of these two standards indicates that ISO standards are more conservative in terms of sound-level exposure than the standard supported by OSHA.

Recommended occupational safety and health standards also include procedures to protect the hearing of employees if their work environment is in violation of sound level standards. Hearing conservation programs (HCP) serve to assist agencies by providing solutions to violations of OSHA or ISO regulations. A hearing conservation program may include several interventions related to employee safety regarding hazardous sound-level environments.

Because NIHL occurs as a result of excessive sound-level exposure across an extended period of time, an intervention established by an HCP may include measuring the sound-level environment to determine the extent of potentially damaging sound-level exposure. Dangerous sound levels are not only defined by intense sound power, but also by an employee's duration of exposure time to excessive sound levels. An HCP may also include the administration of audiometeric tests for employees to develop baseline readings of employees' current hearing acuity. Another intervention is the implementation of and instruction on the use of hearing protection devices (HPD) for those who work in environments that have sound levels exceeding an established criterion. Not only is the HCP designed to educate employees on the training and use of hearing protectors, but also additional information is provided relative to the physiology of hearing, and what happens to the hearing mechanism during exposure to loud sounds. The HCP also includes a component whereby the employer documents the results of the prescribed program.

Measuring Sound-Level Exposures Based on Dosimetry Theory

The physical properties of intensity and frequency contained in sound waves stimulate hair cell responses that result from a series of events throughout the ear. The delicate construction of the ear can experience permanent damage resulting from high-intensity sound levels as well long term exposure to variable sound-level environments. The purpose of measuring sound-level exposure is to identify harmful combinations of sound intensity and duration of exposure.

Measuring the Power of Sound and Human Perceptions

Loudness and intensity are terms frequently used when discussing noise without concern for their exact meaning. Intensity is an objective measurement of the physical power of sound. This measurement in an expression of power units per unit area, such as watts per square meter. Intensity is used to express the amplitudes of sound waves. Amplitude refers to the extent to which molecules of a sound wave are displaced resulting in the intensity and associated intensity level (i.e., watts per meter^2). Loudness is a psychological or subjective expression that approximates a perception of the magnitude or power of a sound. When reporting the physical power of a sound the term intensity or intensity level is used; conversely, when reporting the subjective or psychological power of a sound perceived by a listener, the term loudness is used. Typically, decibel (dB) is used as the measure of intensity level; whereas, phons is used as the measure of loudness level, expressed as dBA.

The quantification of intensity is often expressed by the term intensity level. The use of the term "level" implies a comparison. The comparison, in this case, is the measured intensity of a sound wave compared to an intensity reference threshold (Johnson, 2002). The comparison of these two intensities is defined by the term decibel (dB). The decibel is based on the logarithm of the ratio of two intensities. The result of this equation is an intensity level expressed as decibels. Therefore, if the measured intensity of one sound is less than the intensity reference level the resulting dB can be negative; if both are equal, the dB will be zero. Zero dB is associated with a sound being just below audibility for a listener.

Loudness is a prothetic variable that can be consistently quantified. The equal loudness curves were designed to approximate human perceptions of loudness at different intensity and frequency levels (Fletcher & Munson, 1933). The reference frequency for the equal loudness curves is a 1 kilohertz (kHz) pure tone at 40 dB (Campbell & Greated, 1996; Radocy & Boyle, 1997). Equal loudness curves demonstrate that loudness is not equal to intensity level across varied combinations of frequency and intensity level. Specifically, the equal loudness curves indicate how much increase in power or intensity level is needed for different frequencies to be perceived as equally loud.

Because a human's variable auditory perceptions of loudness are based on intensity and frequency combinations, there are different frequency-weighted baseline intensity levels that are used as criterion levels when measuring the sound level of an environment. These weighted response parameters are empirical estimates of the ear's unequal response to different frequencies and intensities. The A-weighting scale (dBA, Appendix A) is most commonly used for sound level meters as it is an approximation of human perception of equal loudness relative to moderate sound levels (i.e., a weight of 40 dB for octave centered frequencies of 1 kHz, NIOSH, 1998).

Measuring Sound-Level Exposure with a Dosimeter

Exposure time and intensity level are the two primary factors contributing to NIHL. Two devices allow for the measurement of intensity level and exposure time; they are a sound pressure level meter and a dosimeter. A sound pressure level (SPL) meter is a hand-held device used to determine measurements in real time; however, it does not have the capacity to perform calculations of time of exposure as related to OSHA and ISO standards and criteria. A dosimeter is a sound-level measurement device that computes sound levels over a period of time and computes these measurements in such a way that the average dBA and dose of sound-level exposure may be determined based on OSHA and ISO standards and criteria.

In the United States, dosimeters are programmed to regulatory parameters established by NIOSH (i.e., ISO) or OSHA. The dosimeter is worn on the body such that the microphone is within 12 inches of the ear. A dosimeter set to NIOSH standards reports daily dose percentages using 85 dBA with a 3 dB exchange rate for an eight-hour measurement period. A noise dosimeter reports the following data:

1. Run Time – amount of time during which sound levels are measured
2. Dose Percentage (%) – percent of maximum dose (100%) experienced during the Run Time (the Dose Percentage can be ≤ or ≥ 100%)
3. L_{eq} dBA – Average sound level experienced

When measuring sound levels that vary over time, an average sound level is reported. Expressed in decibels, an equivalent continuous sound level (i.e., L_{eq}, Appendix A) is the measurement of the average sound pressure level experienced during a specific period of time.

The average sound pressure level (L_{eq}) is an important measurement that is made available through the use of a dosimeter. The main purpose for reporting an L_{eq} is to determine the sound pressure level of a variable sound environment relative to a single constant sound level. For environments where the sound levels vary over time, the L_{eq} expresses a single, equivalent sound-level measurement. This is used as a reference point in determining the cumulative result of sound-level exposure if the sound level remains constant over the same measurement of time. This reference point is of particular interest in the music environment where sound levels consistently fluctuate.

Recommendations made by the National Institute of Safety and Health (NIOSH) relative to sound-level exposures in industrial environments are based on the variables of time and sound-level exposure that result in a sound-level dose percentage of 100 (NIOSH, 1998). When environments exceed these recommendations, (i.e., greater than 100% sound-level dose) an industrial worker is considered to be at risk for NIHL. The NIOSH-recommended exposure limit for occupational noise exposure is an L_{eq} of 85 dBA during an 8 hour exposure time with a 3-decibel exchange rate (NIOSH, 1998).

The exchange rate (Appendix A) can be defined as "the number of decibels by which the sound level may be increased for a halving of the exposure time" so as not to exceed a dose percentage of 100% (Embleton, 1995, p.16). NIOSH recommends a 3-dB exchange rate with 85 dBA for an 8-hour day; however, OSHA requires a 5-dB exchange rate with 90 dBA for an 8-hour day (United States Department of Labor, 1971). A 3-dB exchange is more robust relative to amount of sound-level exposures than a 5-dB exchange rate. The latter exchange rate affords longer exposure times to sound-levels at specified intensities (Table 1). Furthermore, the 5-dB exchange rate places an increased percentage of the population at risk (i.e., age 40, >10 years of exposure = 17.5% of population at risk). The 3-dB exchange only places 4.3% of the specified population at risk for NIHL (NIOSH, 1998). Table 1 shows the NIOSH and OSHA standards for sound levels and the associated exposure time for a dose percentage of 100%.

Table 1.
Sound-level Exposure Standards With Both an 85 dBA and a 3 dB exchange (NIOSH) and a 90 dBA With a 5 dB exchange (OSHA).

Duration of Exposure Time	NIOSH	OSHA
8 hours	85 dBA	90 dBA
4 hours	88 dBA	95 dBA
2 hours	91 dBA	100 dBA
1 hour	94 dBA	105 dBA
30 minutes	97 dBA	110 dBA
15 minutes	100 dBA	115 dBA
7.5 minutes	103 dBA	120 dBA

Because NIHL is a cumulative process, the reporting of the dose percentage, duration of exposure time, and average sound level are important factors in determining potentially hazardous sound-level environments. Particularly, a musical environment contains sounds that vary in both duration and magnitude, and a dosimeter can be used to inform the music profession of musical activities and events that warrant protection from NIHL.

Sound Levels of Music Environments

As stated earlier, loudness refers to terms used to approximate a sound intensity based on human perceptions of specific frequency and intensity combinations and comparisons (Campbell & Greated, 1996; Radocy & Boyle, 1997). The use of such terms is subjective and not an accurate measure of sound power. In the music community, the application of terms (e.g., *forte*, *piano*, *mezzo piano*, etc.) to approximate the perception of loudness increases subjectivity.

Printed manuscripts of music approximate loudness by using abstract, relative terms and symbols such as forte (*f*) to indicate a loud sound and piano (*p*) to indicate a soft sound. These terms or symbols are collectively referred to as dynamics and are commonly used in the music community; however, they are subjectively applied as they are not exact indicators of sound intensity levels. For example, a musician can perform a musical passage with the dynamic marking of forte, and the performance can be measured at a sound level of 95 dBA. Whereas another musician can perform the same passage with a performance of 110 dBA. Although dynamic perception is beyond the scope of this study, an understanding of the application of these subjective dynamic expression terms used by performers within the *context* of musical performance may yield insight as to why sound levels may exceed regulatory standards supported by OSHA and NIOSH.

To some extent, musicians control the intensity levels of their particular instruments through physical manipulations. For example, the amount of air that is supplied to a wind instrument results from a musician expanding and contracting the lung cavity; thus, the variation in intensity levels are relative to the amount of air supplied to the instrument. Percussion instruments produce sound through the vibration of a mass that is disrupted by being struck or scraped. The resultant percussion intensity levels are controlled to some extent by the magnitude or power of the striking or scraping motion.

During a rehearsal or performance, musicians also are involved in an elaborate set of comparisons and judgments based on intensity levels. The context of the music environment yields variable intensity levels that are decided upon by the musician or musicians to achieve a desired music expression. Clark and Luce (1965) maintain that musicians make subjective decisions about intensity levels regardless of the notated dynamic marking. This finding describes a sound-level environment that is not steady or consistent. The variability of sound-level exposures among musicians in a musical environment is the result of several factors that also may yield excessive sound-level exposures. These factors include physical fatigue, and the comparisons and judgments employed by musicians during a musical performance to produce a quality performance.

There is a small body of research exploring the sound-level exposure of musicians in musical environments. Given the complexity of the human hearing organ, and current regulations related to hearing conservation by NIOSH and OSHA, additional investigation of the sound-level exposures in musical environments is warranted. Currently, recommended standards were derived from measurements relative to industrial work environments that exclude music performing, teaching, and learning environments (NIOSH, 1998). Thus, many musicians are typically uniformed of the potential NIHL risks involved in their music environments. The current study is designed to address musicians' lack of information concerning NIHL as a result of their occupational environment.

The Drum and Bugle Corps Activity

A Drum and Bugle Corps is an organization comprised of instructors and performers who produce outdoor choreographed music performance with percussion instruments, brass instruments, and color guard. These performances incorporate marching, music, and color relative to the theme of the performance.

Drum Corps International (DCI), established in 1971, organizes and establishes rules for competitive activities of participating Drum and Bugle Corps. This organization has served the purpose of providing a summer-long competitive schedule of performances that culminate in a World Championship. During the summer months of June through August, DCI sponsors and promotes several competitions for cooperating Drum and Bugle Corps throughout the United States and overseas.

Excluding directors and staff, members of a Drum and Bugle Corps range in age from 14 to 22 years. Membership is contingent upon a successful audition and providing membership fees for the corps to which membership is attained. The audition process takes place on one weekend during the months of November through January. When the audition process is complete the corps begin to work on the competitive program with the same weekend schedule from February through April.

As a result of the competitive summer schedule, the corps participating in DCI schedule several hours and days of rehearsal to properly prepare for a summer of competitions. Additionally, members of a Drum and Bugle Corps are typically required to relocate to their corps' hometown during the month of May. During late May and early June, corps abandon the monthly rehearsal schedule used in the previous months and begin a rigorous series of daily rehearsals. Since the DCI circuit begins at the end of June, corps spend several weeks rehearsing, typically for at least 12 hours per day. This period of time is frequently referred to as "Spring Training." During the "Spring-

Training" period, corps members spend up to twelve hours per day in small group, large group, and full corps rehearsals, all of which contain extended periods of exposure time to potentially loud music.

When the "Spring-Training" period is over, the corps begin the competitive tour sponsored by DCI that spans the country throughout the months of June, July and August. During the competitive tour, the rehearsal time is sporadic as corps travel by bus between destinations. Aside from travel time, corps members also are given "free time" throughout the summer tour. These factors contribute to the variability of sound-level exposures by corps members throughout the summer while participating in this activity.

Value of the Study

Research related to noise levels and hearing loss among musicians supports the premise that Drum and Bugle Corps members may be exposed to sound levels that place them at risk for noise-induced hearing loss (NIHL). At the present time, there is a need for research related to sound-level exposures of Drum and Bugle Corps members. Additionally, this environment may encourage musicians to unknowingly produce sound levels that exceed health and safety standards set by OSHA and NIOSH. As a result of the competitiveness of the activity, Drum and Bugle Corps schedule several hours of rehearsals throughout the months of November through August.

Combinations of outdoor environments, possibilities of desensitized hearing acuity among musicians, and extended amounts of exposure times may result in sound-level environments that place members and instructors of Drum and Bugle Corps at risk for NIHL. Results of the current study are directed toward advancing the education of musicians and educators by providing accurate measurements of sound-level exposures. Additionally, the current study may provide evidence to support the implementation of a hearing conservation program, as well as to provide possible interventions prescribed by a hearing conservation program to reduce the effects of NIHL due to exposure to harmful sound levels while fulfilling Drum and Bugle Corps responsibilities.

CHAPTER II

REVIEW OF LITERATURE

There is a growing body of research related to musicians' sound-level exposures in musical environments. Existing research indicates that there is possible risk of noise-induced hearing loss (NIHL) within music performance environments. Although the degree of risk may vary, data indicate that musicians sometimes exceed even the most lenient of sound-level standards (e.g., OSHA, 1970). Moreover, musicians require an increased hearing acuity that may not necessarily be a requisite for industrial work environments; therefore, the music community needs to be aware of the effects of hazardous sound levels. The following review of literature includes reviews of research on noised-induced hearing loss (NIHL) among musicians, on conducting sound-level research, and on sound pressure levels produced in music rehearsals and performances.

Noise-Induced Hearing Loss Among Musicians

Researchers have examined rock, jazz, pop, marching band, concert band, pep band, and symphony orchestra musicians for NIHL, as well as sound-level exposures in the workplace that may place musicians at risk for NIHL. Researchers have focused on audiometric data indicating NIHL resulting from their musical participation. Clark (1992) described a process leading to NIHL by which hair cells in the 4 kHz range cease to respond as a result of prolonged exposure to sound levels between 90 and 140 dBA.

This report is supported in other studies relative to NIHL (Berger, Royster, Royster, Driscoll, & Layne, 2000; ISO, 1999; NIOSH, 1998; and Yamasoba, Nuttall, Harris, Raphael, & Miller, 1998). The following is a review of research relative to the presence of NIHL in musicians' audiograms.

Kahari, Zachau, Eklof, Sandsjo, and Moller (2003) conducted a study to assess the hearing and the incidence of hearing disorders in rock and jazz musicians in Sweden. Pure-tone audiograms and a questionnaire were administered to the sample population ($N = 139$). Data revealed that 74% of the sample indicated a hearing disorder as reported in the questionnaire (i.e., hearing loss, tinnitus, hyperacusis, distortion and/or diplacusis). Fifty-seven percent of subjects reporting one or more hearing disorder had a measurable hearing loss. Audiograms across all subjects indicated that male subjects ($n = 96$) had significantly worse ($p = .05$) hearing thresholds at 3-6 kHz than female subjects. The researchers concluded that due to musicians' dependency on optimal and functional hearing, results from this study indicate that musicians have a higher proportion of hearing disorders than non-musicians.

Kahari, Axelsson, Hellstrom, and Zachau (2001a) measured the hearing thresholds of members ($N = 140$) from the Gothenberg Symphony Orchestra and Opera in Sweden. Subjects were divided by gender, and six main instrument groups: (a) small strings (i.e., violin and viola), (b) large strings (i.e., cello and double bass), (c) woodwind (i.e., oboe, clarinet, bassoon and flute), (d) brasswind (i.e., trumpet, trombone, horn, and tuba), (e) percussion, and (f) others (i.e., piano and harp). Data analysis relative to the variable gender, indicated that females had significantly better ($p = < 0.05$) hearing thresholds at higher frequencies (i.e., 6-8 kHz) than male subjects. Across instrument groups, the percussion subjects displayed the greatest hearing loss, with noise notches at the 6-8 kHz level. Brass subjects displayed a significantly worse ($p = < 0.05$) hearing in the left ear when compared to other musicians. No suggestions for the bilateral hearing loss among brass subjects was provided. The authors concluded that no severe hearing loss was discovered that could be attributable to noise-induced hearing loss across all subjects. However, audiometeric data for all males displayed a noise notch at 6 kHz in the left ear which is similar to that of noise-induced hearing loss.

Axelsson and Lindgren (1981) measured hearing levels of 139 orchestra musicians from Göteborg, Sweden. The average work week for musicians was 29 hours, and 35% performed in an orchestra pit rather than on an open stage. Data indicated that the hearing acuity of bassoon, horn, trumpet, and trombone players was worse than those in a non-exposed reference population. The researchers concluded that the measured hearing loss found among orchestra subjects was attributable to music exposure, and not due to age or gender.

In a follow-up study to Axelsson and Lindgren (1981), Kahari, Axelsson, Hellstrom, and Zachau (20001b), conducted audiometric testing to determine hearing development of active orchestra members over a period of sixteen years. Researchers were able to contact 69 of the original 139 subjects, and 56 of these original subjects agreed to participate in the follow-up study. All of the subjects in the follow-up study were still active orchestra members in Göteborg, Sweden. Data indicated that males from both studies demonstrated a noise notch at 6 and 8 kHz, indicating NIHL; however, when the current audiograms of subjects were compared by age to a nonexposed reference group, researchers found no major reduction in hearing thresholds. All female subjects' audiograms indicated a noise notch at 6 kHz in the left ear in the earlier study, but the follow-up study indicated the same notch in both ears. Based on the data collected from this study the researchers concluded that over the sixteen-year exposure period, orchestra musicians in this study did not demonstrate a progression of hearing loss uncharacteristic of that found in a nonexposed reference group when accounting for the variables age and gender. Additionally, any measured hearing loss found in either study was attributable to other, non-music related issues.

Karlsson, Lundquist, and Olaussen (1983) administered audiometric testing to volunteer subjects ($N = 392$) from five different orchestras in Sweden to determine the risk of hearing loss resulting from a music performance occupation. Data indicated that double bass ($n = 32$), flute ($n = 17$), bassoon ($n = 15$), and percussion ($n = 18$) performers displayed a noise notch at 6 and 8 kHz, which can be defined as noise-induced hearing loss; however, the researchers did not find enough evidence to support that a specific instrument could give rise to any hazardous exposure. The researchers determined that participation in a symphony orchestra does not increase one's risk of hearing loss, and all instruments yield equal exposure. The researchers did acknowledge that although the cohort did not show evidence of NIHL, individual subjects may have sustained NIHL. However, the authors also stated:

> . . . to prove the existence of a relation between playing in an orchestra and hearing impairment it would be necessary to perform a population study clearly stating whether the noise exposure is greater than that accepted for industrial noise (p. 263).

Obeling and Poulsen (1999) studied the potential risk of hearing loss of fifty-seven musicians from four Danish symphony orchestras based on subjects' projected long-term exposure to sound levels resulting from their occupation. Additionally, the researchers administered audiograms to all subjects ($N = 57$). Researchers measured the sound levels during music rehearsals and concerts performed by the subjects with both a Sound Level Meter (SLM) and a noise dosimeter. This information was combined by the researchers with the measured audiograms to project theoretical audiograms. Subjects were separated into groups based on L_{eq}s (i.e., 85 dB, 90 dB, and 95 dB) and were then compared to median hearing levels of a non-exposed reference population. The researchers determined less projected hearing loss than the estimated hearing loss under the same conditions posed by ISO 7029 (i.e., the distribution of median hearing level values for the better ear for an otologically normal population). Although noise dosimeter readings indicated that subjects experienced sound levels ranging from 84.5 dBA to 95.1 dBA, the researchers concluded that musicians in this environment were not at risk of hearing loss.

Musicians require acute hearing sensitivity in the 1 to 4 kHz frequencies during performance and hair cell response to these frequencies can be compromised resulting from NIHL. Gastmer, Pernu, and Chasin (1994) measured the sound levels in a high school music room. Measurements were performed during two instructional periods with both a personal noise dosimeter and an octave band spectrum analysis. The average sound level experienced by the instructor during the two teaching periods was 93.4 dBA and 91.1 dBA, respectively. Octave band spectrum analysis indicated that frequencies in the 250 to 4000 Hz range accounted for a majority of the sound present. The researchers stated that music teachers may be at a greater risk since current regulations on sound exposure are relative to industrial noise, where the same dBA level may include more low frequencies. This possible disparity led the researchers to suggest that further investigation regarding the presence of frequencies during music performance is needed.

Juman, Karmody, and Simeon (2004) conducted a study to determine the difference in the hearing acuity of steel drum band musicians (pannists) and a control group ($N = 59$). The pannists ($n = 29$) were active members of a steelband, and sound-level measurements as well as audiometeric testing were administered during preparation for a national steelband competition. The control group ($n = 30$) was comprised of age-matched volunteers without a history of steel drum experience or hearing problems. The researchers measured sound levels present during consecutive two rehearsals (approximately 6 to 8 hours in duration) using sound pressure level meters situated in eight places around the ensemble. Sound-level measurements ranged from 97.9 dBA to 110.7 dBA during rehearsals. Audiometric data was collected over a period of three days, six weeks after the national competition. Data analysis indicated the at the 2 kHz, 3 kHz, 4 kHz, and 6 kHz frequencies, 35%, 41%, 41%, and 52% of the subjects displayed hearing loss, respectively. In addition, the pannists were found to have significantly worse hearing than the control group at the 2 kHz ($p = 0.02$), 3 kHz, 4 kHz, and 6 kHz (p

= 0.001) frequencies when accounting for presbycusis. When data were analyzed relative to the number of years of participation in the steelband, only those who had been participating for 10 years and greater displayed hearing loss. Twelve of the members had been participants for more than twenty years, of which 75% displayed hearing loss not related to presbycusis.

Cutietta, Kilch, Royse, and Rainbolt (1994) compared the hearing acuity of vocal, high school, and elementary instrumental teacher groups. Subjects ($N = 104$) were volunteer participants and were between the ages of 22 and 62 years, with 73% of subjects between 30 and 49, and 9% were over 50 years old. Fifty-three percent of subjects were either choral or general music teachers, 37% were high school band directors, and the remaining 11% were elementary school instrumental music instructors. Length of teaching service across all subjects ranged from 2 to 34 years with an average of 11.8, 12.6, and 12.4 years for chorus, high school band, and elementary band, respectively. Analysis of subjects' audiograms indicated that 14% indicated a hearing loss due to presbycusis. This finding was found to be greater than the 4-5% of incidence in national surveys with comparable age and gender composition. Nineteen percent of all subjects displayed a noise notch typical of NIHL. High school band directors displayed a steady decrease in hearing acuity by age when compared to hearing loss patterns by age and gender. The researchers suggest that this may support the notion that the natural loss of hearing due to age and gender may be compounded by music teachers ongoing exposure to sound level produced in ensembles. The researchers concluded that music directors should monitor their hearing on a regular basis, as well as implement the use of hearing protection.

Cunningham, Workman, Curk, Hoffman, and Pride (2005) collected data from the Percussive Arts Society International Conferences in 2003 and 2004. Over this period of time three studies were conducted from a sample ($N = 684$) of percussionists relative to: (a) auditory hearing thresholds ($n = 315$), (b) evidence of cochlear damage ($n = 86$), and (c) survey of attitudes and behaviors concerning hearing conservation ($n = 283$). In the first study, the mean pure-tone hearing thresholds of the sample population was 5 - 10 dBA lower than peers of the same age. In the second study, each subject received an otoacoustic emissions test whereby a probe is inserted into the ear canal which measures the cochlea's response to sound stimuli. If no response (i.e., an otoacoustic emission) is measured, hearing loss is expected. Subjects' test results were compared to a control group. The percussion sample had lower emissions at the 4 kHz and 6 kHz in both ears; however, 25% of the percussion sample had no emissions at the 6 kHz level. The final study sought to ascertain general attitude toward hearing protection after subjects were presented with an educational presentation regarding hearing protection devices. Data indicated that 67% of percussionists use hearing protection of some kind during practice, and 56% during performances; 37% reported the use of "industrial-style" hearing protection devices. Additionally, 82% reported that they had not had their hearing checked within the previous year. Cunningham, et al. stated that the data from the survey was discouraging given that subjects had been presented with information relative to the dangers of sound-level exposure.

Conducting Sound-Level Research

Sound-level meters and dosimeters are used for research on sound-level exposure. Sound-level meters measure sound pressure levels and report sound levels in decibels according to the weighted scale options chosen. The A-weighted scale is used most often in the reporting of sound levels experienced by musicians. Readings of a sound-level meter can include minimum, maximum, and average sound pressure level (SPL) experience during a measurement period. Dosimeter measurements can report sound-level information relative to standards such as OSHA or NIOSH. Dosimeters can be used to report the dose percentage, as well as to report a time history of average sound levels over a measurement period. Dosimeters can also be worn by a subject for more accurate readings. In addition to choosing the appropriate instrument to measure sound-level exposures, the duration of exposure and procedures of data collection are variables that warrant proper consideration.

Embleton (1995) issued a report indicating recommendations for noise limits in the workplace. His findings indicated that data on variable sound levels in an environment should not be limited to the sound levels alone, but also should include the duration of quiet periods. Furthermore, Embleton stated that the 3-dB exchange rate (Appendix A) should be accepted, and the 5-dB exchange rate be "firmly rejected" based on the percentage of persons placed at risk (p. 16). Embleton's rejection of the 5-dB exchange is based on allowable hearing loss, as the 3-dB exchange places a smaller percentage of persons at risk than the 5-dB exchange.

Embleton's report also stated that exposure levels for longer work durations should reflect the 3-dB exchange rate, such that a twelve-hour average sound level is not to exceed 83 dBA. Since the exchange rate defines the number of decibels by which the sound level may increase for a halving of exposure time relative to an 8-hour day, the 12-hour sound level is derived conversely so. This report is supported by NIOSH sound-level standards. In addition to the average sound-level exposure, Embleton stated that "impulse" or "peak sound level" should be defined as those sound levels that exceed 140 dB, and should be reported in measurements of sound exposure. When this threshold is exceeded, the sound level is not to be used in the calculation of average sound level. A sound-level threshold of 140 dB suggests that the principle of the equal energy rule (i.e., exchange rate) may not be a valid exchange at higher sound pressure levels (p. 17).

Grayston and Alvord (1993) measured the sound levels in secondary school band rooms to estimate the amount of sound-level exposure band instructors experienced during an 8-hour day. The researchers used a sound level meter set to a mode allowing for the measurements of "projected dose" and "peak dBA." Twenty minute samples from all eight participating schools were taken and analyzed. The average peak across all schools was 118.6 dBA, and ranged from 113.1 dBA to 123.0 dBA. The researchers stated that although 50% of the sample experienced projected doses greater than 100%, this projection overestimates exposure. The overestimation results from applying a 20-minute sample to an 8-hour day, which assumes that the musical activity contained in the sample would occur continuously for 8 hours.

Grayston and Alvord also stated that the occurrence of peak values indicated in their study were pertinent relative to "damage risk criteria" (Kryter, Ward, Miller, & Eldredge, 1966). Kryter, et al. reported a damage risk criteria relative to the occurrence of impact noise over an 8-hour period that would lead to "acceptable" hearing losses of 10 to 20 dB in 50% of the population. The criteria indicated that, over an 8-hour period, permissible occurrences of 145 dB, 140 dB, and 135 dB may occur 10, 100, and 1000 times, respectively.

Clark (1992) posited that the area of occupational noise exposure has extensive research such that a calculation to determine an estimated loss of hearing, accounting for age and gender, based on a single sound-level measurement is available. Estimations on occupational hearing loss are based on an 8-hour day, 5 days a week, and 50 weeks a year (ISO, 1990). Non-occupational noise exposure, according to Clark, does not have sufficient data background to provide similar estimations. Clark therefore states that in the reporting of non-occupational noise exposure, information relative to the pattern of sound-level exposure of the subjects should be collected. It should be noted that occupations relative to music teaching and performance are typically not identified as occupational work environments (NIOSH, 1997).

Mikl (1995) conducted a sound-level study of members of the Australian Opera and Ballet Orchestra over the period of one season from April 1 to October 31, 1992. The researcher believed that more accurate data relative to sound-level exposure of orchestra musicians could be reported if measurement periods extended over a long period of time, accounting for variable exposure between performances. Mikl used sound level meters attached to microphones suspended from the ceiling to measure sound levels. Eight-hour sound-level exposures were determined for each day of the performance season by combining measurements for each of the 14 performances with estimates for sectional rehearsals, sitzprobe (first complete music rehearsal with orchestra and singers), and auditions for the opera *Peter Grimes*. Estimates were derived from the averages for all rehearsals, sitzprobe, and auditions for *Peter Grimes*. Data were compared to the Australian National Occupational Health and Safety Commission standard of an 8-hour work day (85 dBA with a 3-dB exchange). The researcher determined that many of the orchestra musicians experienced sound levels greater than 90 dBA when performing twice daily. Conclusions were that the performance schedule of orchestra musicians in this study exposed subjects to sound levels that placed them at risk for NIHL.

Eaton (2001) measured the sound level exposures of school music teachers (N = 10). Subjects wore dosimeters during a full work day to measure sound-level exposures across all teaching activities. The researcher measured the entire day, in effort to provide a more accurate reading of sound-level exposures throughout the day which included moments of music performance and non-performance (down time) sound levels. Instructional activities were described using a "Teacher's Activity Log" designed by the researcher. The activity log provided a detailed description of specific activities which were then compared to the time history provided by the dosimeter. In the study, Eaton maintained that the difference in amount of hours per workday between music teachers and industrial workers requires the use of a correction formula to compare sound levels of teachers (work year of 40 weeks) to that of the industrial work year of 50 weeks. Results revealed an average sound-level exposure of 86 dBA, which places music teachers at risk for NIHL (based on 85 dBA and a 3 dB exchange).

Sound-Level Measurements in Musical Environments

Royster, Royster, and Killion (1991) conducted a study in which 68 dosimeter samples were taken from the 100-member Chicago Symphony Orchestra under both rehearsal and performance conditions. In addition, the researchers collected audiometeric data for all subjects. Data analysis revealed that 52% of all subjects' audiograms showed noise notches at 3 kHz and 6 kHz, which is consistent with NIHL. Reported average sound levels ranged from 79 dBA to 99 dBA. The projected eight-hour sound-exposure values, based on a 15-hour work week, ranged from 75 dBA to 95 dBA. The researchers determined that subjects' participation in the symphony orchestra contributed to hearing loss defined as NIHL.

Laitinen, Toppila, Olkinuora, and Kuisma (2003) studied the sound-level exposure among Finnish National Opera personnel ($N = 69$) using noise dosimeters both on subjects as well as at fixed points throughout the group. Data were analyzed to determine an annual sound-level exposure based on the rehearsal and performance schedule of the subjects. A total of 87 sound-level measurements were taken for the instrumentalists ($n = 40$) and 66 for the vocalists ($n = 29$) over a period of six group rehearsals and performances. Data indicated that the instrumentalists' average sound-level ranged from 87 dBA to 98 dBA during performances and 86 dBA to 99 dBA during rehearsals. The noise dosimeters were placed in various locations throughout the orchestra, choir, and other personnel. Analysis of dosimeter measurements indicated that rehearsals times were a main source of exposure, primarily in the percussion and woodwind sections. The researchers posited that this was of particular note since a concert venue may only last one to two hours, thus providing more time for hearing recovery; however, typical orchestras rehearse five days a week and for several hours at a time, which may yield less recovery time. Due to the demands of professional musicians, the researchers concluded that the subjects were exposed to sound levels in both rehearsal and performance settings that yielded a high risk of NIHL.

Clark and Luce (1965) reported the sound levels of orchestral instrumentalists performing a chromatic scale with a prescribed dynamic marking. The two dynamic markings used were "*pp*" (i.e., very soft) and "*ff*" (i.e., very loud). The subjects performed the chromatic scale relative to what would be considered a normal condition during an indoor performance. Results indicated that regardless of the dynamic marking, professional musicians almost exclusively performed the higher frequencies louder than the lower frequencies. Although some of the measured variability on sound intensity in this study was attributed to the acoustical properties of the instruments, the subjects' performance of a dynamic marking was found to be subjective. Subjects were found to have displayed a tendency to perform some notated pitches louder than others within the context of a musical performance.

Camp and Horstman (1992) studied the sound-level exposure of orchestra members during rehearsals and performances of Wagner's *Ring Cycle*. The researchers used dosimeters set to OSHA standards of 90 dB with a 5 dB exchange. The dosimeter provided dose percentages and peak (most intense) sound levels as measured over each of the four operas in the *Ring Cycle*. The greatest sound-level recordings were during *Götterdämmerung* which had an average duration of 5 hours and 35 minutes yielding estimated dose percentages of 187.4% (Wagner tuba), 158.4% (horn), 150.2% (trombone), 134.7 % (trumpet), 105.0% (clarinet), 94.5% (tuba), 71.0% (viola), and 41.9% (cello). During the entire performance of *Götterdämmerung*, 62% of the sound-level measurements (66) exceeded 90 dBA. The least intense sound-levels were recorded during *Rheingold* which had an average measurement time of 2 hours and 55 minutes yielding estimated dose percentages of 29.6% (clarinet), 29.1% (horn), 26.9 % (trumpet), 23.5% (viola), 20.7% (timpani), 17.5% (cello), 13.4% (violin I), 12.8% (bass), and 12.5% (cello). These data support that subjects were exposed to sound-levels that exceeded OSHA standards throughout the performance of Wagner's *Ring Cycle*.

Early and Horstman (1996) studied the sound-level exposures of high school and university musicians during practice sessions. Seven different types of musical ensembles were used and labeled as groups. The ensembles were: (a) Group 1 – 25 member percussion ensemble, (b) Group 2 – 6 member soft rock band, (c) Group 3 – 220 member university marching band, (d) Group 4 – 150 member university pep band, (e) Group 5 – 70 member high school band, (f) Group 6 – 69 member high school marching band, and (g) Group 7 – 60 member high school concert band. Practice sessions measured by the researchers lasted one to five hours, depending upon the ensemble. A majority of the sound-levels measured exceeded the Occupational Safety and Health Administration (OSHA) permissible limits of 90 dBA for eight hours of exposure time.

The different acoustical environments of ensembles affected subjects' exposure to sound levels. In one case, a snare drummer from Group 1, practicing for 240 minutes in a small practice room, yielded a projected 8-hour dose percentage of 1,113.28, whereas the largest 8-hour dose percentage of Group 6 (performing outdoors) was the trumpets at 101.8. The researchers concluded that musicians should use hearing protection during rehearsals.

Henoch and Chesky (2000) studied the sound-level exposure of members of a college jazz band ensemble ($N = 18$). Data were collected over three days during the regularly scheduled 50-minute class period with a dosimeter. A total of fifteen different samples were obtained over three rehearsal days. The dose percentages were normalized to a 3-hour and 8-hour time period. A comparison of sound levels experienced by the lead alto saxophone and lead trombone performers across two days revealed little variability and indicated these ensemble members experienced 46% and 49% of their daily dose percentage, respectively, during a 50-minute rehearsal. When sound levels were normalized to a 3-hour time period, 10 of the 15 samples exceed OSHA standards. When data were normalized to an 8-hour time period, allowable limits of all 15 samples exceeded OSHA standards. The researchers concluded that sound levels from successive days were similar, indicating consistent sound-level exposure.

Owens (2003) conducted a studied that analyzed high school band director's exposure to sound pressure levels. His findings indicated that band directors were not exposed to hazardous environments based on OSHA standards of 95 dBA over a four hour period. The average duration of rehearsal time for the subjects was reported as three hours and twenty-eight minutes with an average L_{eq} of 90 dBA. These findings were found to be significantly lower ($p < .01$) than the OSHA criterion standard of 90 dBA over a four hour period. Additionally, all subjects' dose percentages fell below 50% of the maximum allowable dose percentage enforced by OSHA; however, subjects' dose percentages exceeded the maximum allowable dose percentage recommended by NIOSH in six of the ten subjects, with three of those subjects exceeding 200%.

Mace (2005) measured the sound-level exposures of university studio faculty during a typical day of teaching. Sound-level exposures were measured across two days using a personal noise dosimeter and ranged from 69.3 dBA to 93.2 dBA ($N = 37$). For a single day measurement, 35% of the subjects exceeded NIOSH standards for a daily dose; however, over two days 32% of the subjects exceeded this standard. Additionally, 58% of the woodwind, brass, and percussion faculty exceeded NIOSH standards during the measurement period of two days. Eighty-six percent of the activities experienced by the subjects were categorized as individual lesson times and 9% were group (large and/or small ensemble) rehearsals; with 33% and 61% exceeding NIOSH standards, respectively.

Presley (2004) conducted a pilot study describing the sound-level exposures of Drum and Bugle Corps members during a full day rehearsal. Subjects ($N = 32$) wore dosebadges during a twelve-hour rehearsal day. The mean L_{eq} for all subjects was 93.1 dBA, the mean L_{eq} for both the brass ($n = 16$) and percussion ($n = 16$) samples were 90.9 dBA and 95.2 dBA, respectively. Based on ISO standards (85 dBA with a 3 dB exchange for an 8 hour time period) the mean daily dose percentage for all subjects was 1290%, with the highest being 6540% and the lowest 231%. For percussion subjects, the mean dose percentage was 1912.8%, and the mean for brass subjects was 667.7%. These findings indicate that subjects' exposure to sound levels during a full-day of rehearsal excessively exceed ISO standards. The researcher suggested that implementing a hearing conservation program was paramount for all participants.

Summary of Related Literature

The existing research relative to hearing loss found in musicians indicates that the measured hearing loss is or is not a result of fulfilling performance responsibilities. Some studies have posited that the measured hearing loss among subjects was not a result of participation in music-related responsibilities (Kahari et al., 2001a; Kahari et al., 2001b; Karlsson et al., 1983; Obeling & Paulson, 1999). However, there are also studies indicating that musicians are at risk of NIHL as a result of fulfilling music-related responsibilities (Axelsson & Lindgren, 1981; Cutietta et al., 1994; Gastmer et al., 1994; Juman et al., 2004; Kahari et al., 2003). All of these studies based their findings on audiometric data. Clearly the apparent disparity requires more research in the music community to determine the effect of music performance on musicians' hearing acuity.

Due to the limited studies on the topic of sound-level exposures of musicians, only a few provide the most comprehensive research design (Eaton, 2001; Mace, 2005; Mikl, 1995). Although these three studies are the most comprehensive, other studies provide research design parameters that can also be applied in conducting sound-level research.

Embleton (1995) provided several recommended parameters to be considered when conducting sound-level exposure research in variable sound-level environments. Specifically, there are four recommended parameters for sound-level measurements: (a) the inclusion of "quiet times," (b) the use of a 3 dB exchange, (c) a twelve-hour L_{eq} of 83 dBA, and (d) the defining of a peak sound level as one that exceeds 140 dB. Some studies have measured only the duration of music performance, and projected these duration over an eight-hour period. Projecting sound-level exposure implies little to no variability in sound level for the time estimated. In a musical environment it is erroneous to assume that musicians will maintain a single activity over a period of eight or twelve hours. Thus, estimating a small duration of sound-level exposure to an eight- or twelve-hour exposure time can overinflate sound-level exposure estimates by not accounting for quiet time. This finding is supported by Grayston and Alford (1993).

Embleton (1995) also stated that the use of a 3 dB exchange (i.e., equal energy rule) places a smaller population at risk, whereas a 5 dB exchange allows for longer exposure time at higher sound levels, thus increasing risk. The sound-level criterion for duration periods greater than the typical 8-hour workday should also reflect the 3 dB exchange. According to Embleton, longer durations of exposure require a decrease in the average sound level for the measurement period. When applying the 3 dB exchange to a 12-hour day, the average sound level should not exceed 83 dBA. The researcher defined a peak, or impulse, sound level as being those sound levels that exceed a threshold of 140 dB, and should be analyzed outside of the average sound-level calculation. The establishment of a threshold of 140 dB suggests that the principle of the equal energy rule may not be valid at higher sound pressure levels (p. 17).

Grayston and Alford (1993) supported the findings of Kryter, et al. (1966) relative to a damage risk criteria. Kryter, et al. posited a damage risk criteria that allowed for "acceptable" hearing loss of 10 dB to 20 dB in 50% of subjects relative to the frequency of peak, or impulse, sound levels during an 8-hour period. The criteria indicated that impulse sound levels of 145 dB, 140 dB, and 135 dB may occur 10, 100, and 1000 times, respectively, over an 8-hour exposure period. Although a dosimeter calculates a one-minute sound-level average, it does indicate if the threshold of 140 dB had been exceeded. This information, combined with the damage risk criteria, may provide a more accurate measurement of sound-level exposure.

Eaton (2001), Mace (2005), and Mikl (1995) provide the most comprehensive studies in terms of longer measurements. These studies measured full-day exposures relative to subjects' work day. This provided for the possible effect of quiet time on the overall sound-level exposure. As a result, these studies did not overinflate exposure by estimating a small duration to a greater criterion time (i.e., eight hours).

Other research has measured sound levels and determined that various music environments contain potentially damaging sound levels (Camp & Horstman, 1992; Early & Horstman, 1996; Juman et al., 2004; Laitinen et al., 2003; Mace, 2005; Owens, 2003; Presley, 2004; and Royster et al., 1991). These studies measured sound levels and analyzed data under both OSHA and NIOSH criteria and found that many musical environments may place subjects at risk for NIHL.

Restatement of Purpose

No published related literature involving members of Drum and Bugle Corps was identified. The purpose of this study, therefore, was to describe the sound-level exposures of Drum and Bugle Corps members during a typical full-day rehearsal. The researcher determined sound-level exposures of Drum and Bugle Corps members using personal dosimeters. The dosimeters were set to standards of the National Institute for Occupational Safety and Health (NIOSH, 1998). Furthermore, this study collected dosimetric data in an attempt to provide musicians with sufficient and accurate information describing the extent to which they are exposed to sound levels that may place them at risk for NIHL. Specifically, the study was designed to answer the following research questions:

1. What are the average sound levels to which Drum and Bugle Corps members are exposed during a full-day rehearsal?
2. Do Drum and Bugle Corps members experience sound levels that result in dose percentages that meet or exceed standards recommended by the National Institute for Occupational Safety and Health during large ensemble or small ensemble environments during a full-day rehearsal?
3. How do the following variables affect sound-level averages and daily dose percentages:
   a. instrument (i.e., front ensemble, battery percussion, and brass), and
   b. type of rehearsal activity (e.g., full corps rehearsal, small group rehearsal, music rehearsal, etc.)?

CHAPTER III

PROCEDURES

Research supports that musicians may experience sound levels, in both practice and performance environments, that place them at potential risk for noise-induced hearing loss (Axelsson & Lindgren, 1991; Camp & Horstman, 1992; Clark, 1992; Cuietta, Klich, Royse, & Rainbolt, 1994; Early & Horstman, 1996; Eaton, 2001; Henoch & Chesky, 2000; Juman, Karmody, & Simeon, 2004; Kahari, Zachau, Eklof, Sandsjo, & Moller, 2003; Laitinen, Toppila, Olkinuora, & Kuisma, 2003; Mace, 2005; Owens, 2003; Presley, 2004; and Royster, Royster, & Killion, 1991). Conversely, there is research indicating that musicians are not exposed to such hazardous sound-level environments (Kahari, Axelsson, Hellstrom, & Zachau, 2001a; Kahari et al, 2001b; Karlsson, Lundquist, & Olaussen, 1983; Obeling & Poulsen, 1999; Mace, 2005; and Owens, 2003). Existing data relative to musical performances outdoors are limited, and are not clear as to the typical sound levels experienced by members of outdoor performance groups.

The purpose of this study was to describe the sound-level exposures of Drum and Bugle Corps members during a full-day rehearsal. Sound levels were compared to the National Institute for Occupational Safety and Health (NIOSH) standards of 83dB for a 12-hour time period with a 3 dB exchange to determine whether members' sound-level exposures place them at risk for noise-induced hearing loss (NIHL). The procedures of this study was divided into four basic parts: (a) selection of subjects, (b) equipment used,

(c) data collection, and (d) analysis of data. All procedures for this study were approved by the Institutional Review Board at the University of North Carolina at Greensboro (Appendix C).

Selection of Subjects

Subjects for this study were current members of a Drum and Bugle Corps who agreed to volunteer as subjects for the study. Subjects were comprised of members from one corps during the scheduled "Spring-Training" period. During this period of time Drum and Bugle Corps rehearse for up to twelve hours per day for two to three weeks. These volunteers were members of a Drum and Bugle Corps whose director granted consent to the researcher to seek participation by its membership.

Division I Drum and Bugle Corps are those that participate in the Drum Corps International (DCI) summer competitive schedule and maintain an active membership with no more than 135 performers. The Drum and Bugle Corps selected for this study was classified as a Division I Corps by DCI, and was located in a Southeastern state of the United States of America with a total membership of 135 members. Subjects (N = 32) for this study were volunteers and were divided among brass (n = 16), percussion (n = 15), and drum major (n = 1).

Subjects were asked to sign a consent form and were informed that all information collected during the study would remain confidential, and that they were free to withdraw from the study at any time without prejudice (Appendix B). The required completion of the *National Institutes of Health's Human Participants Protection Education for*

Research Teams to conduct research involving human participants was met (Appendix D). Subjects also completed a *Drum and Bugle Corps Member Questionnaire* (Appendix E).

Subjects were instructed on the care of the dosimeter prior to the beginning of the rehearsal, and their responsibilities as participants in the study as outlined in the consent form. After each subject was made aware of their responsibilities, each doseBadge was activated.

Data Collection Instruments and Procedures

Dosimeter

A Cirrus Research doseBadge (CR-100B, dosimeter) was set to NIOSH standards relative to a 12-hour day (i.e., 83 dBA maximum with a 3 dB exchange rate) and used to measure each subject's sound-level exposure (Figure 5). This device was lightweight (1.6 ounces) and wireless, that enabled it to be placed near each subjects' ear. Inside the doseBadge was a rechargeable battery that can power the unit for up to 16 hours, after which time it required a 24-hour recharging period.

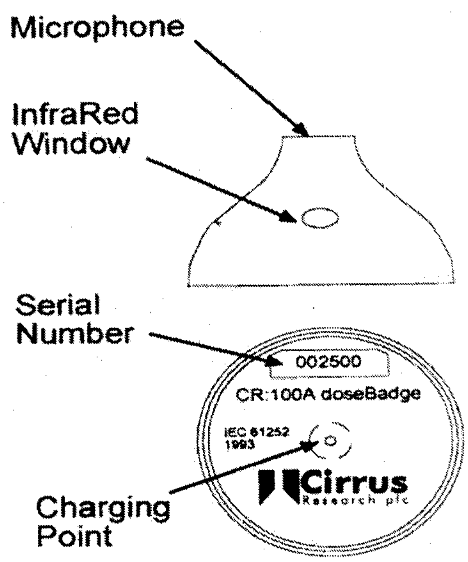

Figure 5. DoseBadge diagram indicating locations of: microphone, infrared window, charging point, and serial number. User manual for the CR:100B doseBadge (2002).

The doseBadge was activated by a reader unit via infrared signals. The reader unit was a handheld device that was used to configure and program the doseBadge. The infrared windows are located on the side of the doseBadge and on the top of the reader unit. Measurement settings for the doseBadge are manipulated using the reader unit keypad controls (Figure 6).

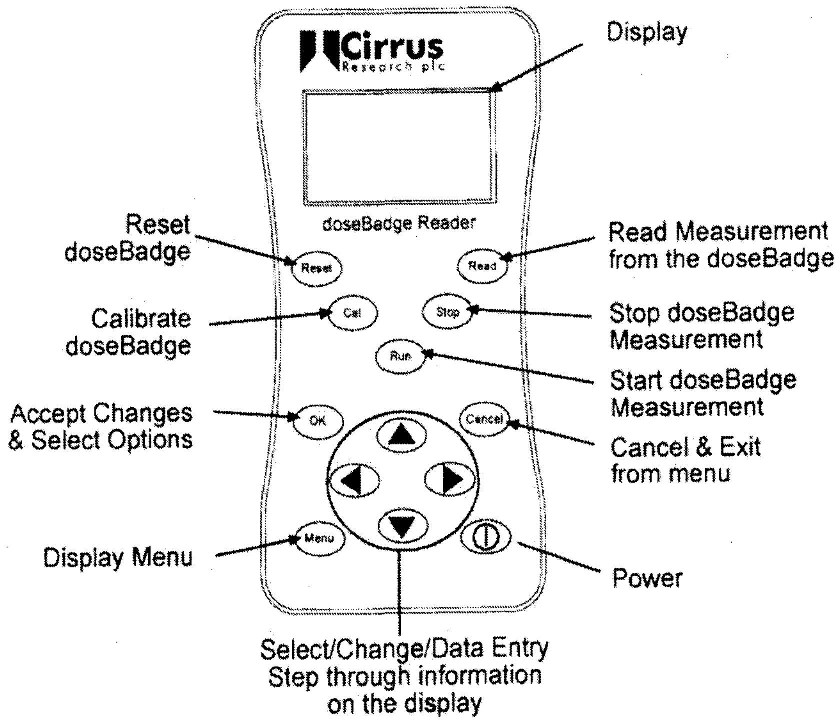

Figure 6. Diagram of the Reader Unit and control buttons (Cirrus Research, 2002).

The researcher attached each doseBadge to the left side of an adjustable athletic visor so as not to exceed four inches from the ear (Yeager & Marsh, 1991). Before the beginning of the rehearsal day, subjects were given a visor with an attached doseBadge that was identified by the serial number located on the doseBadge. The subjects adjusted the visor to fit their head, and the researcher ensured that the doseBadge was properly aligned with the ear. Additionally, the subjects were instructed to not adjust the positioning of the visor (e.g., backwards, bill off-center, etc.), as this would compromise the position of the doseBadge relative to a subject's ear. The researcher also instructed subjects on the proper handling of the device to minimize measurement anomalies. Once the visor was in place and activated, the dosimeter collected data throughout the full day of rehearsal (i.e., 12 hours and 15 minutes). At the conclusion of the rehearsal, subjects returned visors and doseBadges were deactivated by the researcher.

Each dosebagde was connected to the Cirrus RC:100B Reader Unit to download data from the doseBadge to the handheld Reader Unit. Data stored in the Reader Unit was downloaded to a Pentium III Dell Inspiron 5000 computer for analysis. When data had been downloaded from the Reader Unit, the dosimeter was reset and calibrated prior to the next measurement period.

Observation Form

Observational data were collected using the *Observation Form* that was used to describe the various activities of each subject (Appendix F). Data collection took place across two rehearsal days; one day with brass members, and the other with percussionists and the drum major. For observational purposes, the brass subjects were defined operationally as the group of brass instruments made up of the following brass instruments: (a) trumpet, (b) mellophone, (c) euphonium, (d) baritone, and (e) contra. The percussion subjects were divided into two groups labeled battery percussion and front ensemble. The battery percussion group was made up of the marching snare drum, marching bass drum, and marching tenor drum. The front ensemble was comprised of marimba, vibraphone, timpani, and percussion. The term percussion was defined operationally as other percussion instruments in the front ensemble other than those already mentioned (i.e., xylophone, concert bass drum, concert toms, suspended cymbal, gong, and crash cymbals).

The corps schedule for each rehearsal day was identical. The daily schedule was divided into the following activities: (a) full ensemble rehearsal (i.e., all percussion, all brass), (b) small group rehearsal (e.g., baritones, snare drums, bass drum), (c) full corps rehearsal (i.e., all instruments together), (d) drill rehearsal, (e) music rehearsal, and (f) extended breaks (i.e., lunch and dinner). These activities were scheduled separately and also in combination (e.g., battery percussion and music rehearsal, trumpets and music rehearsal, and full corps with drill and music rehearsal). The rehearsal schedule was not altered in any way for this study.

Rehearsal activities occurred on the athletic fields and parking lots of a local high school campus. The campus was framed with a main highway to the west and a dense wooded area along the northern, eastern, and southern perimeters. The campus was on 110 acres of land that included classroom buildings. The corps occupied two baseball fields, a soccer field, three football fields, and a parking lot located on the north side of the campus throughout both rehearsal days. The athletic fields served as rehearsal settings for large group, small group, and full corps rehearsal. As a result of multiple rehearsal areas, a research assistant was used to help collect observational data. The research assistant signed the Research Confidentiality Form required by the University of North Carolina at Greensboro Institutional Review Board process (Appendix G).

During Day 1, rehearsals of brass subjects were in close enough proximity so that one researcher was able to collect observational data on the activities of all sixteen subjects. The research assistant was used this day to become familiarized with the observational form and the process of recording observational data. During Day 2, percussion subjects were divided into two main ensembles: (a) battery percussion (e.g., snare drum, bass drum, etc.), and (b) front ensemble (e.g., marimba, timpani, etc.). These two main groups did not rehearse within proximity of each other, therefore, the researcher collected observational data from the battery and drum major, and the research assistant collected observational data from the front ensemble.

There were many variables throughout the rehearsal day that required documentation. The variables include the aforementioned types of rehearsal activity, scheduled and unscheduled breaks, and the general description of the outdoor environment. Subjects also were identified by instrument type (i.e., trumpet, mellophone, baritone, contra, snare drum, tenor drum, bass drum, vibraphone, marimba, percussion, and timpani). The observational form provided information relative to the musical activities of the subjects, as well as documented periods of breaks.

To acquire information regarding each subject's age, primary and secondary instrument, gender, years of drum corps experience, other non-drum corps ensemble experiences, and known hearing loss, each subject completed a questionnaire (Appendix F). Subjects also were asked to describe any known experiences with loud sounds.

DoseBadge Windshield

The Cirrus Research User Manual suggests that the use of a windshield reduces the effects of excessive air movement and subsequent readings by the doseBadge when measuring in an outdoor environment (Cirrus Research manual, 2002, p. 22). Because all Drum and Bugle Corps rehearsals were spent outdoors, to control for the potential effect of excessive air movement or potential harm to the doseBadge from airborne contaminates, the researcher concluded that use of windshields was necessary. These windshields could be purchased or fabricated. Due to the cost parameters of the current study, the windshields were fabricated for this study.

Windshields were constructed and pilot tested for attenuation. Headliner material used in automobiles to pad and insulate the inside of the roof was purchased from a local fabric store. The material was cut into 1.5" by 1.5" squares. The material had a thickness of .875" that was similar in depth and consistency to the windshield manufactured by Cirrus Research. The material was pilot tested by affixing a cut square of material over a doseBadge and then activating the doseBadge to measure sound levels. The windshields were attached to the microphone housing of the doseBadge with an o-ring (.563" outer diameter by .375" inner diameter by .94"). The o-ring secured the windshield at the microphone housing, and a rubber band was wrapped on top of the windshield and around the bottom of the doseBadge for additional security. The infrared window of the doseBadge was not covered by the windshield to ensure proper connection with the Reader Unit.

In a sound-proof laboratory four dosbadges were used to measure three minutes of an identical sound stimulus under two different conditions: (a) without the researcher-fabricated windshield, and (b) with the researcher-fabricated windshield. At the time of the experiment, only four doseBadges were available. The four doseBadges were placed on an elevated surface in the middle of the laboratory and activated. The music stimulus was the first three minutes of *October*, by Eric Whitacre performed by the University of North Carolina at Greensboro Wind Ensemble in 2002.

The average sound levels (L_{eq}) for the total measured time (three minutes) of each doseBadge according to each condition were compared to determine if there was significant attenuation resulting from the material used as a windshield. A one-way Analysis of Variance (ANOVA) was used to determine whether significant differences existed between the sound-level measurements of the doseBadges. Data yielded no significant difference between the sound level measurements of the four doseBadges either with the windshield or without the windshield ($p > .05$, Table 2).

Table 2
Average Sound Level (L_{eq}) by DoseBadge Measuring An Equivalent Sound Source for Equivalent Durations both With and Without a Windshield.

DoseBadge	L_{eq} With Windshield	L_{eq} Without Windshield
#1	87.4 dBA	87.2 dBA
#2	87.0 dBA	86.8 dBA
#3	85.8 dBA	85.5 dBA
#4	87.3 dBA	87.1 dBA
	$F(3) = .007$	

The data reported in Table 2 revealed that the material used for and the construction of the windshields did not significantly attenuate sound-level measurements ($p > .05$). Because the material tested had similar thickness and consistency to that of a manufactured windshield, the protection of the doseBadge from wind shearing and airborne contaminates was not in question. Based on the results of the test, the researcher used the fabricated windshields to reduce the effect of excessive air movement on sound-level measurements. Additionally, the windshields were used to protect the doseBadges from airborne contaminates that may have damaged the microphone.

Data Analysis

Data from the dosimeter, *Observation Form*, and *Drum Corps Member Questionnaire* were compiled and analyzed using Microsoft Excel® (Microsoft Office, 2003). Data were downloaded from the dosimeter to a computer and analyzed using dBlink® software (Cirrus Research, 2002). The software provided the sound-level exposure data across the following variables: (a) one-minute history, (b) measurement time, (c) dose percentage, (d) L_{eq} (i.e., average sound level), (e) estimated dose percentage, and (f) peak indicators (instantaneous sound levels ≥ 140 dBA).

The projected dose percentage allows for the measurement of a shorter duration (i.e., less than the criterion times of 8 and 12 hours) to be used to estimate sound-level exposure as if the measured sound levels occurred constantly throughout the 8- or 12-hour time period. This calculation is provided as an option on dosimeters for the purposes of projecting invariable sound levels to which workers are exposed during a work day (e.g., computerized machinery in a car manufacturing plant).

Although the sound levels of certain occupations may have little to no variance, musicians experience variance in sound levels largely due to the physical demands involved in musical performances, particularly in a marching environment. Therefore, projection of a musicians' sound-level exposure to an 8- or 12-hour day from measuring a shorter period of rehearsal time would fail to account for all the variance resulting from periods of physical rest needed by the musician. Because Drum and Bugle Corps members experience varying sound levels during full-day rehearsals of all types (e.g., small group, large group, etc.), as well as during extended breaks (e.g., lunch and dinner), the researcher determined measuring the subjects' full-day rehearsal (i.e., 12 hours) to be important. Furthermore, the researcher believed that measuring short periods of time (e.g., one rehearsal activity) and projecting the resultant sound levels as if that single activity were repeated multiple times was unrealistic and inappropriate.

The Early and Horstman study (1996) serves an example of how a projected dose percentage can overinflate the sound-level exposure in an environment with variable sound levels. One of the subjects in the study was measured for four hours and the resultant projected dose percentage for an eight-hour day was 1,113.28%. Henoch and Chesky (2000), reported subjects' projected dose percentages of both a three- and eight-hour day after measuring a 50-minute jazz-band rehearsal. As a result, ten of the fifteen subjects' projected dose percentages exceeded OSHA sound-level requirements. The researchers determined that the use of estimations result in the overestimation of dose percentages, particularly when the measured time is less than half of the criterion time. Additionally, a projected dose percentage also fails to take into account times of rest, or periods of no sound, which are experienced throughout a musicians' or teachers' day.

For this study it should be noted that the full rehearsal time was 12:15 (hrs:mins) for all subjects. The dose percentage of all subjects was estimated to reflect a 12 hour and 15 minutes day. This time was greater than the standard criterion time of twelve hours. Two subjects in this study had a measured time less than twelve hours due to dosimeter malfunction; however, the measurement periods were 11:01 and 9:55 (hrs:mins). The dosimeters in these two cases lost battery charge resulting in the dosimeter shutting down. In these cases, the researcher determined that the estimated dose percentage would not generate enough error to dismiss findings due to the relatively small amount of time missing (59 minutes and two hours and 5 minutes, respectively) to complete the twelve-hour day.

The total run time for all functional dosimeters was greater than the duration of the rehearsal. This was due to starting the dosimeters prior to the beginning of rehearsal and the stopping of the dosimeters after the rehearsal ended. Thus, each subject's time history included approximately sixty more minutes of data that occurred outside of the rehearsal period. The L_{eq} for each subject during the full-day rehearsal period was determined through analysis of the time history using dBlink® software. This analysis included the placement of two markers, one placed at the time indicating the start of the rehearsal and one placed at the time indicating the end of the rehearsal. The dBlink® software provides an L_{eq} "between markers." This L_{eq} was determined to be the average sound level during the full-day rehearsal of 12:15 (hrs:mins). The data provided through this analysis yielded an L_{eq} that was different than the one provided by the dosimeter, since the dosimeter provided data relative to the overall run time. The L_{eq}s relative to the rehearsal period were used to calculate dose percentages

Since the full-day rehearsal period was greater than the criterion time of 12 hours (i.e., 12 hours and 15 minutes), and the L_{eq} for each subject reflected the rehearsal period and not the overall run time of the dosimter, a calculator designed by Associates in Acoustics, Inc. written in Microsoft Excel® was used to estimate noise exposure (available at www.esion.com). Original formulas in the Excel file were created using OSHA standards (i.e., 90 dBA for 8 hours). Formulas were altered such that NIOSH estimates of dose percentage were calculated. The original formula, created in the cell in row 25, column K, was =IF(E25>=80,I25*(100/(480/(2^((E25-90)/5)))),0), where:

(a). E25>=80 is the condition that if the value in column E row 25 is greater than or equal to 80 (dBA) then,
(b). I25*= the value in column I row 25 is the actual duration in minutes,
(c). ((E25-90)/5))= the difference between value in column E row 25 and 90 (the lowest sound level accepted for calculations) divided by 5 (the exchange rate),
(d). 2^= 2 to the power of the quotient of the previous statement,
(e). 480= the dividend to be divided by the product of the previous equation, and
(f). 100= dividend to be divided by the quotient of the previous equation.

This formula calculates the dose percentage according to OSHA standards. Because some average sound levels were lower than 80 dBA, the value was changed to 60 when calculating dose percentages according to NIOSH. To calculate the dose percentage according to NIOSH standards, values in the formula were altered resulting in the following formula, =IF(E25>=60,I25*(100/(720/(2^((E25-83)/3)))),0), where 60 represented the lowest sound level accepted for calculations, 83 represented the dBA level recommended for a 12-hour day, and 3 represented the exchange rate. Use of the calculator designed in Excel allowed for all calculations to be estimated using a consistent source.

The L_{eq} as measured by the dosimeter was entered into the cell in row 25, column E. The criterion time of 720 minutes (twelve hours) was entered in the cell in row 25, column H and the measured period (in minutes) was entered in the cell in row 25, column I. The estimated dose percentage is calculated in the cell in row 25, column K.

Each doseBadge contains an internal clock that was synchronized prior to activation with the time pieces used by the researcher and research assistant to record observation data. As rehearsal events occurred, the researchers indicated the time of the event on the *Observation Form*. The recorded times were used to identify times and durations of rehearsal activities along the time history report provided by the doseBadge.

The time history was analyzed with the *Observation Form* to determine L_{eq} for each rehearsal activity throughout the day. The time history analysis was accomplished by opening the dBlink® software and each subject's file. Once the subject's file was opened in dBlink®, the time history was viewed. The time history graph places the time along the y-axis and the sound level on the x-axis. Two cursors on either side of the time history graph were placed at two points along the x-axis of the graph that corresponded to the beginning and ending of a rehearsal activity, as recorded in the *Observation Form*. Once the cursors were placed the dBlink® software provided the average sound level "between the cursors." The derived value from this procedure produced the L_{eq} for a specific rehearsal activity. Data from each subjects' time history were analyzed and represented in tables categorizing time durations measured, rehearsal activity, number of subjects, average sound-level exposure per activity and instrument, and daily noise dose.

Peak sound levels were indicated along the time history graph by a vertical red line. This mark indicated that the sound-level threshold of 140 dBA was exceeded at some point during the minute. Sound levels exceeding 140 dB were not used by the doseBadge in calculating average sound levels. Research supported that sound levels exceeding 140 dB may not be valid under the equal energy rule. Additionally, the damage risk criteria reported by Kryter, Ward, Miller, and Eldredge (1966) indicated allowances of sound level occurrences of 145 dB, 140 dB, and 135 dB over an eight-hour period. Therefore, peak sound levels were calculated for frequency of occurrence and by instrument relative to the damage risk criteria. The recording of impulse sound levels also was due to the characteristically high occurrences of sound-level exposures greater than 140 dB found in battery percussion readings (Presley, 2004).

Exploratory data included the reconstruction of each subjects' time history to reflect intermittent use of four hearing protection devices (HPD). These were constructed in order to provide possible solutions to the excessive sound-levels experienced by Drum and Bugle Corps members. The four different HPDs had noise reduction ratings (NRR) of 15, 20, 25, and 30 dB. Hypothesized time histories were constructed by subtracting the attenuation effect of four different HPDs during specified rehearsal times in the Excel spreadsheet. The hypothesized time histories were then converted into a Notepad file and analyzed through dBlink®. The dBlink® software provided an L_{eq} for the full-day rehearsal reflecting the intermittent HPD use which was then entered into the cell in row 25, column E of the Excel estimate calculator designed by Associates in Acoustics, Inc. The estimate calculator provided a dose percentage based on the L_{eq} provided by the time history.

CHAPTER IV

RESULTS

The purpose of this study was to describe sound-level exposures of Drum and Bugle Corps members during a full-day rehearsal. For purposes of this study, sound-level averages were based on a criterion time of twelve hours and an average sound-level of 83 dBA with a 3 dB exchange. Using a personal noise dosimeter, sound-level exposures were measured during a full-day rehearsal (i.e., twelve hours). Sound-level exposures were expressed in decibels as L_{eq}, indicating an average sound level during a rehearsal day. The L_{eq} value combined with the measured time were used to calculate the daily sound dose percentage. These data were used to answer the following questions:

1. What were the average sound levels to which Drum and Bugle Corps members were exposed during a full day of rehearsal?
2. Did Drum and Bugle Corps members experience sound levels that resulted in dose percentages that met or exceeded standards recommended by the National Institute for Occupational Safety and Health during large ensemble or small ensemble environments during a full day of rehearsal?
3. How did the following variables affect sound-level averages and daily dose percentages:
   a. instrument (i.e., front ensemble, battery percussion, and brass), and
   b. type of rehearsal activity (e.g., full corps rehearsal, small group rehearsal, and music rehearsal, etc.)?

Description of Subjects

All subjects were members of a Drum and Bugle Corps located in a Southeastern state of the United States of America. During Summer 2005, the membership enrollment for the corps was 135, which included 68 brass, 17 battery percussion, and 10 front ensemble members. The battery percussion section was comprised of marching snare drum, bass drum, and tenor drum. The front ensemble percussion section was comprised of the marimba, vibraphone, timpani, and auxiliary percussion instruments (e.g., xylophone, concert bass drum, suspended cymbals, concert toms, etc.). Sound-level data were collected over two days during the month of June 2005 (i.e., one day for brass samples and one day for percussion samples).

Of the 95 brass and percussion members, 32 agreed to serve as subjects. The 32 subjects represented the following instruments: 16 brass members (4 trumpets, 4 mellophones, 2 euphoniums, 2 baritones, and 4 contras), 15 percussion members (4 snare drums, 2 tenor drum, 2 bass drums, 2 front ensemble percussionists, 3 vibraphones, 1 marimba, and 1 timpani), and one subject was the Drum Major for the Drum and Bugle Corps. The two front ensemble percussionists performed on auxiliary percussion instruments and were labeled as "percussion" (e.g., xylophone, concert bass drum, suspended cymbals, concert toms, etc.).

Prior to use, the Cirrus Research RC:100B Reader Unit was used to reset and clear the memory of each dosimeter, as well as to calibrate the dosimeters to 1000 Hz at 114 dB. The dosimeter was activated prior to the beginning of the rehearsal time for each subject. To collect observational data for each rehearsal activity, the researcher completed an observation form addressing the following variables: (a) the beginning and ending time of each rehearsal activity, (b) instruments observed, (c) individual, small group, or large group activity, and (d) music rehearsal, drill rehearsal, or both.

Each subject wore a Cirrus Research CR:100B doseBadge set to standards recommended by NIOSH (i.e., twelve-hour L_{eq} of 83 dBA with a 3 dB exchange). Prior to the beginning of each rehearsal, the researcher informed the subjects of the parameters of the study, and specifically, the guidelines for wearing the athletic visor. The dosimeter was placed on an athletic visor within four inches of each subject's ear to collect sound levels experienced throughout the measurement period. The visor was worn by each subject without removal throughout the rehearsal day. Furthermore, the subjects were instructed that if any problems were to occur, or if there were any questions during the measurement period relative to the parameters of the study, the researcher would be present throughout the rehearsal day to answer questions and assist with research-related issues. During both measurement days, no subjects reported any problems or questions relative to the wearing of the athletic visor, or the parameters of the study.

Questionnaire

A questionnaire was completed by each subject prior to the beginning of each rehearsal that provided a general descriptions of the 32 subjects (e.g., gender, number of years in Drum and Bugle Corps, number of years in other performance groups). Subjects ($N = 32$) were males ($n = 26$) and females ($n = 6$) and ranged in drum corps experience from 1 to 6 years, with a mean of 2.3 years. Table 3 shows subjects' gender, instrument played, and average years of drum corps experience.

Table 3
Description of Subjects' Instrument, Gender, and Average Years of Experience in a Drum and Bugle Corps (DBC)

Instrument	Gender		DBC Years of Experience	
	Male $n = 24$	Female $n = 6$	Mean	Range
Trumpet	3	1	3.50	3.00
Mellophone	2	2	1.50	1.00
Baritone	2	0	3.00	2.00
Euphonium	2	0	2.50	3.00
Contra	4	0	1.50	3.00
Snare Drum	3	1	3.00	4.00
Tenor Drum	2	0	1.50	1.00
Bass Drum	2	0	2.50	1.00
Vibraphone	3	0	2.50	2.00
Marimba	0	1	3.00	0.00
Timpani	0	1	2.00	0.00
Auxiliary Percussion	2	0	2.50	1.00
Drum Major	1	0	3.00	0.00

The brass subjects accounted for 24% of the total brass members in the corps. The battery percussion and front ensemble subjects accounted for 47% and 70% of total members, respectively. Additionally, 72% ($n = 23$) of all subjects had greater than two years of experience as a member of a Drum and Bugle Corps.

Subjects also were asked to respond to items relative to group performance experiences, hearing loss, and other types of exposure to loud sounds. Specifically, the questionnaire asked for subjects' number of years of experience in the following categories: (a) Drum and Bugle Corps, (b) high school marching band, (c) college marching band, (d) high school indoor/winter drumline, (e) college indoor/winter drumline, (f) high school percussion ensemble (non-marching), (g) college percussion ensemble (non-marching), (h) jazz band, (i) private lessons, (j) other small group (subject specified), and (k) other group (subject specified).

Group Performance Experience

The data presented in Table 4 indicate the group performance categories and the average years of experience by brass and percussion subjects. Although not a group performance experience, the "Private Lessons" category was included because this activity was indicated by both brass and percussion subjects, and was experienced by more than half of the subjects.

Table 4
Group Performance Categories and Average Years of Experience.

Category	Percentage of Subjects	Average Years of Experience
Drum and Bugle Corps	100%	2.30
High School Marching Band	94%	4.00
College Marching Band	47%	1.57
Jazz Band	59%	2.23
Private Lessons	63%	4.51

All subject responses reported in Table 4, 97% ($n = 31$) performed in high school and/or college marching band in addition to their participation in the Drum and Bugle Corps activity. Typically, high school and college marching band activities occurred during the fall season; these activities follow the summer season of the Drum and Bugle Corps. Groups mentioned in Table 4, outside of the Drum and Bugle Corps, may not rehearse with a twelve-hour day; however, they may use similar rehearsal activities and rehearsal activity durations that comprised the Drum and Bugle Corps' twelve-hour day. For example, although high school and college marching band members may not experience 12-hour rehearsals, they may experience small group, large group, and full ensemble rehearsal activities similar to those reported in this study. Jazz bands typically maintain schedules throughout the year and can be both a fall and spring activity. Private lessons can occur independent of time of year, and can take place throughout the year. Subjects' activities in these performance groups indicated a pattern of sound-level exposure over the course of a calendar year.

Percussion subjects (n = 15) indicated involvement in a variety of percussion-specific categories (i.e., indoor/winter drumline and percussion ensemble). Typical indoor/winter drumlines perform indoors in a large ensemble practice room, auditorium, or gymnasium. A percussion ensemble typically performs in a large ensemble rehearsal room or auditorium. Table 5 provides data representing percussion subjects' experience with percussion-specific performance groups.

Table 5
Percussion-Specific Group Performance Categories

Percussion-Specific Category	Percentage of Percussion Subjects Involved	Average Years of Experience
High School Indoor/Winter Drumline	60%	1.78
College Indoor/Winter Drumline	47%	1.71
High School Percussion Ensemble*	73%	3.20
College Percussion Ensemble*	67%	2.20

* non-marching

Typically, indoor/winter drumlines takes place during the winter time following the fall season of performing programs that include marching and music. A typical percussion ensemble that does not march may rehearse throughout the fall, winter, and spring seasons. Of all percussion subjects, 87% (n = 13) performed in both high school and/or college marching band and high school/college indoor drumline and/or high school/college percussion ensemble (non-marching), in addition to participating in Drum and Bugle Corps activities. Subject involvement in these additional percussion performance groups, in addition to the music groups mentioned in Table 4, substantiated a pattern of sound-level exposure for percussionists over a calendar year.

Subjects were asked to specify any small group or other group not listed on the questionnaire with which they had previous experience. Table 6 provides subject specified categories of performance group, the number of subjects who participated, and the years of experience with the group across all subjects.

Table 6
Subject Specified Categories of Group Performance, Number of Subjects, and Average Years of Experience

Category	Number of Subjects	Average Years of Experience
Rock Band	4	2.60
Chamber/Small Brass	4	2.25
Church Band	2	2.00
Steel Drum Band	2	2.00
Symphony	1	6.00
Symphonic Band	1	7.00
Choir	1	6.00

Continued

Table 6 (continued)
Subject Specified Categories of Group Performance, Number of Subjects, and Average Years of Experience

Category	Number of Subjects	Average Years of Experience
Wind Ensemble	1	7.00
Piano Ensemble	1	10.00
Pep Band	1	5.00

The subject-specified groups provided in Table 6 were reported by 13 different subjects. Five of these subjects indicated participation in two or more of these groups. Participation in these groups was in addition to participation with the Drum and Bugle Corps, high school/college marching bands, jazz band, private lessons, and various percussion ensemble activities, and indicated a high level of participation in group performance activities throughout the year by the reported subjects.

Data analysis relative to subject participation in various group activities indicated that these subjects were exposed to sound levels in various musical environments for the majority of the calendar year. Although participation in these activities throughout the year is not considered to be an occupation, these data supported that a pattern of excessive sound-level exposure may similarly exist as found in performing non-music job-related activities that are regulated by OSHA.

Hearing Loss or Hearing Problems

The questionnaire asked subjects to respond to the following question. “Do you have hearing loss or hearing problems? If yes, please describe.” Of the 32 subjects, eight indicated that they had hearing loss or a hearing problem. Table 7 provides subjects’ instrument and description of hearing loss or hearing problem.

Table 7
Subject Description of Hearing Loss or Problem.

Instrument	Description
Euphonium	I can't hear as well as I could before I started drum corps.
Contra	Busted right ear drum earlier this year.
Snare Drum	Hearing loss in both ears - very slight.
Bass Drum	My left ear is weaker than my right. I think it started with the drum set, having a large China cymbal on the left.
Bass Drum	Some instances of ringing in the ear; not dependent on situation.
Vibraphone	Some high pitched ringing in my ears at times, randomly.
Percussion (Front Ensemble)	Maybe some trouble hearing sometimes; may or may not be actual hearing loss.
Percussion (Front Ensemble)	A little in my right ear.

Hearing thresholds were not measured in this study, therefore, the accuracy of subject's statements relative to hearing loss were not determined. However, two subjects did report a ringing sensation in their ears that is indicative of tinnitus. The two subjects who reported tinnitus were percussion subjects.

Loud Sounds

In the questionnaire, subjects were asked to respond to the following statement: "Please describe any very loud sounds you have experienced during your life (e.g., gun shots, machines, position in musical environments, etc.)." Table 8 contains the 12 categories of loud sounds reported by subjects and the frequency with which each category was reported. A horizontal line separates the seven music-related categories of loud sounds from the five non-music-related categories.

Table 8
Subjects' Reports of Loud Sounds Experienced, Categorized by Type of Loud Sound and Number of Times Reported

Type of Loud Sound	Number of Times Reported
Drumline	8
Drum Corps	7
Rock Concerts	7
Metronome	5
Marching Bands	3
Indoor Percussion Ensemble	2
Drum Set	1
Gun Shots/Cannon	15
Airplanes/Jets	4
Machinery/ Manufacturing Plant	2
Race Cars	1
Fireworks	1

Subjects reported many sources of loud sounds including music and non-music-related sounds. Eighty-four percent ($n = 27$) of subjects reported experience with loud sounds, 13% ($n = 4$) provided no answer, and 3% ($n = 1$) answered "all of the above." Music-related sounds comprised 59% ($n = 33$) of all reported loud sounds and nonmusic-related sounds comprised 41% ($n = 23$) of all loud sounds. "Drumline" was indicated most frequently as a source of loud sounds, and 75% ($n = 6$) of these responses were from percussion subjects. Subjects reported "metronome" as a source of loud sounds and this is attributed to the amplification of an electronic metronome during rehearsal. Specifically, the technique of amplifying a metronome during outdoor rehearsals was common during subjects' full-day rehearsal. Of all non-music related sounds, 65% of subjects reported exposure to gun shots and/or cannons that can produce sound levels possibly resulting in acoustic trauma.

Overview of Data Analysis Procedure

Results of sound-level measurements, sound exposure, and completed observation forms provided data that were analyzed across the following variables: (a) duration of rehearsal activities, (b) type of rehearsal activity, (c) the average sound level during rehearsal activities (L_{eq}), (d) duration of entire measurement period, (e) the average sound level for the entire measurement period (L_{eq}), and (f) the sound dose percentage based on standards accepted by the National Institutes of Safety and Health (NIOSH). To perform the data analysis, sound-level data were downloaded from the dosimeters into the Cirrus RB:100 Reader Unit. Using a Windows-based personal computer, data for individual measurement periods were downloaded from the Reader Unit to the computer and accessed via software written for the doseBadge dosimeter system (i.e., dBlink®). The data extracted from each doseBadge file, relative to NIOSH standards, were: (a) average sound-level (L_{eq}), (b) dose percentage, (c) time history, and (c) peak intensity levels.

For this study the full-day rehearsal time was 12:15 (hrs:mins) for all subjects. This time exceeded the standard criterion time of twelve hours; therefore, the dose percentage was estimated to reflect a 12-hour day. Subject's L_{eq}s for the rehearsal period were determined through analysis using dBlink® software. The dBlink® software provided calculations of the L_{eq} "between cursors," and this L_{eq} was determined to reflect the average sound level of the full-day rehearsal period and not the overall run time of the dosimeter.

Subject's dose percentages were calculated using a calculator designed by Associates in Acoustics, Inc. written in Microsoft® Excel to estimate noise exposure. Average sound level and duration of exposure for each subject was inserted into the Excel calculator to calculate dose percentage relative to the rehearsal period.

Average Sound-Level Exposure

Drum and Bugle Corps members in this study experienced a 12:15 (hrs:mins) rehearsal day, which included several music performance activities, as well as lunch and dinner breaks. This study measured variables that describe members' sound-level exposure relative to a full-day rehearsal. Specifically, the study was designed to examine average sound levels (L_{eq}) to which Drum and Bugle Corps members were exposed to during a full-day rehearsal.

Table 9 contains data describing subject's instrument, average sound levels during the full-rehearsal day, and whether the average sound level exceeded NIOSH standards for a twelve-hour day (i.e., 83 dBA, 3 dB exchange). In the table, values for subject's average sound-level exposure (L_{eq}) represent the entire rehearsal day. Two subjects had measurement times less than the rehearsal day due to doseBadge malfunction. In these two cases the battery expired prior to the end of the rehearsal resulting in the doseBadge shutting off. The rehearsal time period for all other subjects was 12:15 (hrs:mins).

Table 9
Subject's Instrument, Average Sound Level (L_{eq}), Measurement Duration, and Whether L_{eq} Exceeded NIOSH Standards for a 12-hour Day (Exceeds 83 dBA)

Instrument	L_{eq}	Measurement Duration	Exceeds 83 dBA
Trumpet 1	89.9 dBA	735 minutes	YES
Trumpet 2	92.9 dBA	735 minutes	YES
Trumpet 3	92.8 dBA	735 minutes	YES
Trumpet 4	92.4 dBA	735 minutes	YES
Mellophone 1	90.6 dBA	735 minutes	YES
Mellophone 2	91.0 dBA	735 minutes	YES
Mellophone 3	90.6 dBA	735 minutes	YES
Mellophone 4	92.0 dBA	735 minutes	YES
Euphonium 1	88.9 dBA	735 minutes	YES
Euphonium 2	**89.6 dBA**	**577 minutes**	**YES**
Baritone 1	94.3 dBA	735 minutes	YES
Baritone 2	92.9 dBA	735 minutes	YES
Contra 1	90.9 dBA	735 minutes	YES
Contra 2	89.7 dBA	735 minutes	YES
Contra 3	90.3 dBA	735 minutes	YES
Contra 4	90.9 dBA	735 minutes	YES
Snare Drum 1	102.3 dBA	735 minutes	YES
Snare Drum 2	102.6 dBA	735 minutes	YES
Snare Drum 3	**103.1 dBA**	**634 minutes**	**YES**
Snare Drum 4	100.2 dBA	735 minutes	YES
Tenor Drum 1	99.4 dBA	735 minutes	YES
Tenor Drum 2	98.9 dBA	735 minutes	YES
Bass Drum 1	99.8 dBA	735 minutes	YES
Bass Drum 2	94.4 dBA	735 minutes	YES
Percussion 1	93.8 dBA	735 minutes	YES

Continued

Table 9 (Continued)
Subject's Instrument, Average Sound Level (L_{eq}), Measurement Duration, and Whether L_{eq} Exceeded NIOSH Standards for a 12-hour Day (Exceeds 83 dBA)

Instrument	L_{eq}	Measurement Duration	Exceeds 83 dBA
Percussion 2	93.8 dBA	735 minutes	YES
Vibraphone 1	94.0 dBA	735 minutes	YES
Vibraphone 2	96.9 dBA	735 minutes	YES
Vibraphone 3	92.5 dBA	735 minutes	YES
Marimba	93.6 dBA	735 minutes	YES
Timpani	93.4 dBA	735 minutes	YES
Drum Major	88.4 dBA	735 minutes	YES

Note: Subjects ($n = 2$) in bold print indicate measurement times less than the rehearsal time of 12:15 (hrs:mins) resulting from doseBadge malfunction.

As reported in Table 9, all subjects experienced an average sound level that exceeded the NIOSH standard for a twelve-hour day (i.e., 83 dB). The lowest L_{eq} was experienced by the Drum Major (88.4 dBA), and the greatest L_{eq} was experienced by Snare Drum 3 (103.1 dBA). It should be noted that the Snare Drum 3's L_{eq} resulting from a measurement time of 634 minutes, does not include the final hour of rehearsal. This subject's L_{eq} could have been greater than measured as the missing time was not an extended break, but additional music performance time. The same is true for Euphonium 2. All three snare drummers experienced an average sound level greater than 100.0 dBA. Of interest to the researcher was the finding that subjects Percussion 1 and 2 from the front ensemble, Mellophones 1 and 3, and Contras 1 and 4 experienced identical L_{eq}s of 93.8 dBA, 90.6 dBA, and 90.9 dBA, respectively. This could be attributable to the lack of variance of rehearsal activities within these instrument groups.

Dose Percentages

In addition to determining subject's L_{eq}, this study analyzed each subject's dose percentage during the entire rehearsal day of 12:15 (hrs:mins). Dose percentages were derived from L_{eq} and duration of exposure to L_{eq}. A daily dose percentage that exceeds 100% was considered placing subjects at risk for NIHL (NIOSH, 1998). Did Drum and Bugle Corps members experience sound levels that resulted in dose percentages that met or exceeded the permissible standards recommended by NIOSH during large-group and small-group environments throughout a full-day rehearsal? Table 10 provides information of subjects' instrument and dose percentage. The estimated dose percentage for all subjects reflected a twelve-hour and fifteen minute day and were calculated using the Excel calculator.

Table 10
Subject's Instrument and Dose Percentage.

Instrument	Dose Percentage
Trumpet 1	502.72%
Trumpet 2	1005.43%
Trumpet 3	982.47%
Trumpet 4	895.74%
Mellophone 1	590.97%
Mellophone 2	648.19%
Mellophone 3	590.97%
Mellophone 4	816.67%
Euphonium 1	399.01%
Euphonium 2	368.22%
Baritone 1	1389.42%
Baritone 2	895.74%

Continued

Table 10 (Continued)
Subject's Instrument and Dose Percentage.

Instrument	Dose Percentage
Contra 1	633.38%
Contra 2	480.02%
Contra 3	551.39%
Contra 4	633.38%
Snare Drum 1	8822.29%
Snare Drum 2	9455.49%
Snare Drum 3	9154.99%
Snare Drum 4	5319.92%
Tenor Drum 1	4422.12%
Tenor Drum 2	3939.66%
Bass Drum 1	4850.29%
Bass Drum 2	1392.88%
Percussion 1	1212.57%
Percussion 2	1212.57%
Vibraphone 1	1269.92%
Vibraphone 2	2481.83%
Vibraphone 3	897.97%
Marimba	1157.82%
Timpani	1105.53%
Drum Major	348.22%

As reported in Table 10, every subject exceeded 100% of their daily dose during the full-day rehearsal that included large-group and small-group rehearsal environments. The dose percentage was calculated based on the duration of exposure to the L_{eq}, therefore, the subjects who experienced the highest L_{eq} subsequently experienced the highest dose percentage. However, Snare Drum 3, who experienced the highest L_{eq}

(103.1 dBA), had a smaller dose percentage (9154.99%) than Snare Drum 2, who experienced an L_{eq} of 102.6 dBA, but experienced a dose percentage of 9455.49%. The difference was be attributed to the measurement duration. Snare Drum 3 experienced an L_{eq} of 103.1 dBA over 634 minutes, and Snare Drum 2 experienced an L_{eq} of 102.6 over 735 minutes. Although Snare Drum 2 had a lower L_{eq} than Snare Drum 3, Snare Drum 2 duration of exposure was greater by 101 minutes. Two of the brass subjects (Trumpet 2 and Baritone 1) experienced a dose percentage greater than 1000%; however, only one percussion subject (Vibraphone 3) experienced a dose percentage less than 1000%. Data reported in Table 10 demonstrated that percussion subjects experienced the highest dose percentages across all subjects.

Surprisingly, the Drum Major experienced the lowest dose percentage, primarily since the Drum Major is often positioned in front of the corps. This could have resulted from one or both of the following: (a) the Drum Major had more administrative duties throughout the day that did not involve music exposure, and (b) when the Drum Major was positioned in front of the corps, it was on an elevated podium (approximately nine feet high) approximately 10 to 15 feet away from the corps.

Variables Affecting Sound-Level Averages and Dose Percentages

This study measured the sound-level exposure of various instruments within a Drum and Bugle Corps. In addition, the corps experienced various rehearsal settings throughout the rehearsal day (i.e., full corps, large group, and small group). These settings involved music rehearsal and/or marching rehearsal activities. The combination of subject's instrument and rehearsal activity variables were analyzed in this study. Specifically, how do the following variables affect sound-level averages and daily dose percentages: (a) instrument (e.g., trumpet, baritone, snare drum, timpani, etc.), and (b) rehearsal activity (e.g., full corps rehearsal, small group rehearsal, music rehearsal, marching rehearsal, extended breaks)?

In an effort to address the effect of the aforementioned variables on subjects' sound-level exposure, sound-level averages for both the subjects and each rehearsal activity were determined using dBlink® software. The *Observation Form* was used to identify points along the time history indicating the time when each rehearsal activity took place. Detailed descriptions of each subject's sound-level average per rehearsal activity throughout the entire rehearsal day are provided in Appendix H.

Instrument

Instrument families for this study were brass and percussion. Although the key of a particular brass instrument can vary from corps to corps, for this study brass instruments were defined operationally as: (a) trumpet, (b) mellophone, (c) baritone, (d) euphonium, and (e) contra (tuba). These brass instruments provided a sample of instruments in the soprano, alto, tenor, and bass voices for the Drum and Bugle Corps. Additionally, the percussion instruments used in this study were defined operationally as: (a) snare drum, (b) tenor drum, (c) bass drum, (d) vibraphone, (e) marimba, (f) timpani, and (g) percussion. For this study, the term "percussion" was used to indentify the auxiliary percussion instruments used in the front ensemble (e.g., xylophone, suspended cymbals, concert bass drum, gong, etc.). The Drum Major subject for the study did not play an instrument, but stood on a 9-foot portable podium approximately 15-feet from the sideline of the rehearsal field.

Table 11 contains data describing instrument, number of subjects per instrument, average sound levels during a full-rehearsal day. In the table, values of average sound-level exposure (L_{eq}) represented the entire rehearsal day. Additionally, the L_{eq}s were averaged arithmetically by instrument to provide average sound levels by instrument.

Table 11

Instrument, Number of Subjects per Instrument (n), and Average Sound-Level (L_{eq}).

Instrument	*n*	L_{eq}
Trumpet	4	92.00 dBA
Mellophone	4	90.85 dBA
Euphonium	2	89.25 dBA
Baritone	2	93.60 dBA
Contra	4	90.45 dBA
Snare Drum	4	102.05 dBA
Tenor Drum	2	99.65 dBA
Bass Drum	2	97.10 dBA
Percussion	2	93.80 dBA
Vibraphone	3	94.47 dBA
Marimba	1	93.60 dBA
Drum Major	1	88.40 dBA

Data provided in Table 11 demonstrated that the highest L_{eq}s across all subjects were found with the percussion instruments, with the snare drum, tenor drum, and bass drum subjects (i.e., the battery) experiencing the highest L_{eq}. This finding could be a result of the physical characteristics of the instruments. For example, the brass-instrument sound comes out of the bell of the instrument and directed away from the performer's ear. Percussion instruments, however, produce sounds that are not directed away from the performer.

Dose percentages were analyzed per instrument group to determine whether the instrument effected the dose percentages. Average dose percentages by instrument were calculated arithmetically. Table 12 provides the instrument, number of subjects per instrument, mean dose percentage by instrument, and the range of the percentages.

Table 12
Instrument, Number of Subjects per Instrument (n), and Average Dose Percentage Based on a 12-hour Day (Average Dose Percentage), and Range

Instrument	*n*	Average Dose Percentage	Range
Trumpet	4	846.59%	502.71
Mellophone	4	661.70%	225.70
Euphonium	2	383.62%	30.79
Baritone	2	1142.58%	493.68
Contra	4	574.54%	153.36
Snare Drum	4	8188.17%	4135.57
Tenor Drum	2	4180.89%	482.46
Bass Drum	2	3121.59%	3457.41
Percussion	2	1212.57%	0
Vibraphone	3	1549.91%	1583.86
Marimba	1	1157.82%	0
Timpani	1	1105.53%	0
Drum Major	1	348.22%	0

As reported in Table 12, all subjects experienced dose percentages exceeding standards recommended by NIOSH for a twelve-hour day. The dose percentage calculation is based on the L_{eq}, therefore, subjects with the highest L_{eq} also experienced the highest dose percentage. The highest of these dose percentages were found among snare drum subjects (8188.17%) and the lowest was experienced by the Drum Major (348.22%). Snare drum subjects ($n = 4$) experienced an average dose percentage (8188.17%) that was almost two times greater than the average dose percentage found for the tenor drums (4180.89%); they produced the second highest average across all instruments. Average dose percentages for each of the battery percussion instruments (i.e., snare drum, tenor drum, bass drum) was found to be greater than double the average dose percentage of any other instrument.

Data from Table 12 also demonstrated that all subjects experienced dose percentages exceeded the permissible standards recommended by NIOSH during a full-day rehearsal as measured by instrument group. Battery percussion subjects ($n = 8$) were found to experience the greatest dose percentages of all subjects, and all percussion subjects (i.e., battery and front ensemble) experienced a dose percentage greater than 1000%. These are similar to the L_{eq} findings reported in Table 9 where the battery percussion subjects were found to have experienced the highest average sound levels across all subjects. Of the brass subjects, only the baritone subjects experienced an average dose percentage greater than 1000%.

Of the instruments with more than two subjects, the range of dose percentages was smallest (153.36%) for the contras and largest for the snare drum (4135.57%). The variance in range for the snare drums was attributed to the placements of the subjects within the group. Three of the subjects were positioned such that another snare drummer was on the subject's left and right side, while one snare drum subject was positioned such that another snare drummer was positioned to the subject's right only. The dosimeter was adjacent to subject's left ear.

Rehearsal Activities

During the data collection, 356 rehearsal activities were observed and measured. Each rehearsal activities was categorized as either small group, large group, or full corps rehearsal. Small group rehearsals were defined operationally as a division among the instrument family (e.g., trumpets, mellophones, battery, etc.). Additionally, this category was used to define additional divisions within the percussion family (i.e., snare drum, bass drum, and tenor drum). Large group activities were those activities that included an entire instrument family (i.e., all brass and all percussion). The full corps activities included both the brass and percussion families during a rehearsal. Each rehearsal activity included music performance or marching, or both. Marching rehearsal activities involved little to no instrumental music performance for the brass subjects; however, there were periods of singing combined with marching. All rehearsal activities by the percussion family included music performance. Extended breaks were defined operationally as lunch and dinner breaks during the rehearsal day.

The durations of each activity were calculated for each subject to determine how the full rehearsal day was divided. The *Observation Form* provided the occurrence and duration of each rehearsal activity. Table 13 provides data describing the type of rehearsal activity, the total number of occurrences of each rehearsal activity, the total number of minutes, the mean duration, and standard deviation for all rehearsal activities across both days of data collection.

Table 13
Total Number of Occurrences (Total), Total Minutes, Mean, and Standard Deviation for all Rehearsal Activities.

Rehearsal Activity	Total	Total (in minutes)	Mean (in minutes)	Standard Deviation
Small Group	8	424	53.00	41.09
Large Group	6	297	49.50	30.45
Full Corps	5	550	110.00	59.07
Extended Breaks	4	199	49.75	12.09

Data reported in Table 13 revealed that the mean duration for full corps rehearsals was the greatest across all activities. The greatest number of rehearsal activity occurrence was found in the small group rehearsal activity. With the exception of extended breaks, all rehearsal activities displayed large variance from the mean. This finding was attributed to individual rehearsal activity durations. The full-day rehearsal was comprised of several activities throughout the day; some were greater in duration than others.

Data were further analyzed across subjects to determine the occurrence of L_{eq}s exceeding 83 dBA relative to each rehearsal activity. Table 14 contains descriptive data relative to all measured rehearsal activities. The column labeled "Category" contains the rehearsal activities subjugated by instrument family. The column labeled "Total In Category" contains the total number of occurrences for each rehearsal activity across all categories (rows). Small group, large group, full corps, and extended break categories occurred 121, 95, 78, and 62 times across all subjects, respectively. The column labeled

"% of Rehearsal Time" contains the percentage of the full day rehearsal time allotted to each category. The columns labeled "Rehearsal Activities Exceeding 83 dBA" and "% of Rehearsal Activities Exceeding 83 dBA" contain the number and percent of rehearsal activities in each category, respectively, that exceeded an sound-level average of 83 dBA. Due to the variance in the Drum Majors' rehearsal activities relative to the other subjects, the aforementioned information was not provided in Table 14. Horizontal lines separate rehearsal activities within the table.

Table 14
Rehearsal Activities by Category, Total Number of Occurrences by Subject (Total in Catergory), Percentage (%) of Rehearsal Time, L_{eq}s Exceeded 83 dBA, and Percentage of L_{eq}s Exceeding 83 dBA

Category	Total in Category	% of Rehearsal Time	L_{eq}s Exceeding 83 dBA	% of L_{eq}s Exceeding 83 dBA
Small Group	121	29%	100	83%
Brass	16	7%	14	88%
Percussion	105	51%	86	82%
Large Group	95	20%	28	30%
Brass	80	29%	14	18%
Percussion	15	11%	14	93%
Full Corps	78	37%	68	87%
Brass	48	49%	38	79%
Percussion	30	25%	30	100%
Extended Breaks	62	14%	0	0%
Brass	32	15%	0	0%
Percussion	30	13%	0	0%

As reported in Table 14, most (37%) of the rehearsal time of the Drum and Bugle Corps members were categorized as full corps, and 87% of the full corps rehearsal time produced L_{eq}s greater than 83 dBA across all subjects. Although brass subjects experienced a large group rehearsal setting 29% of the rehearsal time, only 18% of these activities yielded L_{eq}s greater than 83 dBA. Additionally, percussion subjects experienced a small group rehearsal activity 51% of the time, and 82% of this rehearsal time produced L_{eq}s greater than 83 dBA.

Data collection for percussion subjects occurred on a day where 75% of the rehearsal activities throughout the full-day rehearsal was spent without brass subjects. However, 100% of the time spent with the brass (i.e., full corps rehearsal activities) yielded an L_{eq} greater than the criterion of 83 dBA. Additionally, brass subjects experienced full corps rehearsal activities 49% during the full-day rehearsal with a mean duration of 121 minutes. During this time 79% the brass subjects experienced L_{eq}s greater than 83 dBA. These findings showed that full corps rehearsal activities contribute a large amount of sound-level exposure to subjects.

To conclude each rehearsal day, the full corps performed the program that was presented throughout the summer of competition. The objective of the rehearsal day was to isolate specific issues through various rehearsal activities relative to the physical and musical demands of the competitive program. Data relative to full corps rehearsal activities was determined to be a large source of sound-level exposure. Therefore, the performance of the competitive program by the full corps was analyzed to determine sound-level exposure.

Table 15 provides descriptive data relative to the instrument, number of subjects per instrument, and average sound level by instrument during the twelve minute performance of the competitive program. The average sound level for each instrument was averaged arithmetically since the time measurements were of equal durations.

Table 15
Instrument, Number of Subjects, Average Sound Level (L_{eq}), and Standard Deviation During Program Performance

Instrument	Number of Subjects	L_{eq}	Standard Deviation
Trumpet	3	99.3 dBA	0.89
Mellophone	4	98.2 dBA	0.75
Euphonium	1	99.3 dBA	0.00
Baritone	2	98.9 dBA	1.62
Contra	4	96.4 dBA	0.72
Brass Average		*98.1 dBA*	*1.56*
Snare Drum	3	107.0 dBA	1.16
Tenor Drum	2	103.8 dBA	0.56
Bass Drum	2	101.1 dBA	4.45
Percussion	2	103.0 dBA	0.98
Vibraphone	3	104.0 dBA	2.65
Marimba	1	101.2 dBA	0.00
Timpani	1	101.0 dBA	0.00
Percussion Average		*103.6 dBA*	*2.75*
Drum Major	1	94.2 dBA	0.00
Average for All		*100.6 dBA*	*3.71*

During the performance of the program, two dosimeters had expired batteries and ceased measurement and were excluded from Table 15. This occurred in the euphonium and snare drum sections. Data provided in Table 15 reveal that the L_{eq} for all percussion subjects during the twelve-minute performance was greater than 100.0 dBA. As previously reported, NIOSH sound-level standards allow only a 15-minute exposure time to sound levels of 100.0 dBA, and a 7.5-minute exposure time to sound levels of 103 dBA. All brass subjects' L_{eq}s fell within NIOSH sound-level requirements during the performance. However, L_{eq}s for all percussion subjects was 103.6 dBA for a duration of 12 minutes, exceeding recommendations. These data demonstrated that the performance of the competitive program may contribute to the sound-level exposure of percussionists.

Of interest to the researcher was the occurrence of peak sound levels (i.e., impact noise), particularly for the percussion subjects. As previously indicated, percussion subjects in this study experienced the greatest sound-level exposure. Rehearsal activities were determined to affect sound-level exposure; however, the discrepancy between brass and percussion sound-level exposures perhaps was the result of instrument design. Percussion instruments are not designed to direct sound, unlike a brass instrument where the sound directly comes from the bell. Analysis of impact noise across percussion subjects was analyzed to determine whether instrument design affected sound-level exposures.

A peak level threshold of 140 dB is the factory setting on the Cirrus Research 100B doseBadge. In the time history report a "P" appears in the cell next to the minute sound-level average where the threshold has been exceeded. Although it cannot be determined how many times during a specific minute the threshold was exceeded, the duration of the peak level, or what the sound level is, the frequency of occurrence indicates at least one moment of impact sound.

The battery percussion subjects' data, in particular, yielded a very high number of peak indications (1341, $n = 8$) during the measured rehearsal time when compared to brass (19, $n = 16$) and front ensemble (98, $n = 7$) subjects. Table 16 represents data relative to battery percussion subjects' instrument, rehearsal time in minutes, peak indicators, and the percentage of indications over the rehearsal period. The time represents only the time subjects were involved in a rehearsal activity and does not include extended breaks (i.e., lunch and dinner).

Table 16
Battery Percussion Subjects' Instrument, Rehearsal Time, Peak Indicators, and Percentage of Rehearsal Time.

Instrument	Rehearsal Time	Peak Indicators	Percentage of Rehearsal Time
Snare Drum 1	643	196	31%
Snare Drum 2	643	288	45%
Snare Drum 3	**504**	**193**	**38%**
Snare Drum 4	643	252	39%
Tenor Drum 1	643	89	14%
Tenor Drum 2	643	89	14%
Bass Drum 1	643	220	34%
Bass Drum 2	643	14	2%

Note: Snare Drum 3 in bold print indicate measurement times less than the rehearsal time of 12:15 (hrs:mins) resulting from doseBadge malfunction.

Data in Table 16 indicate the minimum number of times that sound levels exceeded 140 dB (i.e., impact noise). The occurrence of impact noise among battery percussion subjects is notably greater across snare drum subjects. This could be attributable to the physical design of the instrument as the marching snare drums used by subjects in this study were comprised of a reinforced shell which can support greater surface tension on the top head, which is made of Kevlar®. The top head on the snare drum is made of Kevlar® brand fibers, which can withstand considerable stress. It is possible that impact noise among marching snare drum subjects could be attributable to the design and materials that comprise the instrument. Although the other battery percussion subjects experienced a great amount of impact noise during the rehearsal day, these values were found to be less than those found among snare drum subjects. One bass drum subject experience impact noise that exceeded one of the snare drum subjects. This could be the result of placement within the group during rehearsal as this bass drum was next to the snare drum section during group rehearsals. It should be noted that three of the battery percussion subjects reported hearing loss or hearing problems of some type, and one indicated the occurrence of ringing in the ear, or tinnitus.

Exploratory Data Analysis

Due to the high dose percentages and average sound levels reported in this study, the researcher sought to investigate the possible effects of subjects' use of a hearing protection device (HPD) during the rehearsal day. There are several HPDs commercially available with various idiosyncracies; however, the most pertinent information regarding all HPDs is the noise reduction rating (NRR). Hearing protection devices that have a NRR of 15 (NRR-15) indicates that, when worn properly, sound levels are attenuated by

15 dB, a NRR of 20 (NRR-20) indicates sound-level attenuation by 20 dB. Commercially available HPDs have a NRR-15, -20, -25, and -30.

The researcher constructed a time history of estimated exposure to sound levels for all subjects under the following hypothetical situations: (a) use of an HPD with a NRR-15 during specified times of the rehearsal day, (b) use of an HPD with a NRR-20 during specified times of the rehearsal day, (c) use of an HPD with a NRR-25 during specified times of the rehearsal day, and (d) use of an HPD with a NRR-30 during specified times of the rehearsal day. The specific rehearsal activities chosen by the researcher were based on duration of exposure. For brass subjects, full corps and large group activities were chosen that accounted for 79% of the rehearsal day (i.e., 577 minutes). For percussion subjects, small group and full corps rehearsal activities were chosen that accounted for 76% of the rehearsal day (i.e., 559 minutes). The purpose of this data analysis was exploratory and designed to provide possible solutions for Drum and Bugle Corps members' sound-level exposures that exceed recommended standards.

To determine a hypothetical time history, the reduction rating of each HPD was subtracted from the average sound levels provided in each subjects' time history according to the selected rehearsal activities. The new time history represented the effect of HPD use during the specified times (intermittent use). These files were then opened in the dBlink® software was used to analyze these HPD-modified data files to determine the L_{eq} for the entire day.

Brass Subjects

Data presented in Figure 7 indicate the estimated L_{eq}s for all brass subjects based on the intermittent use of HPDs with a NRR-15 and a NRR-20 across large group and full corps rehearsal activities throughout a rehearsal day of 12:15 (hrs:mins). Subjects with L_{eq}s equal to, or less than 83 dBA are considered *not* to be at risk for NIHL.

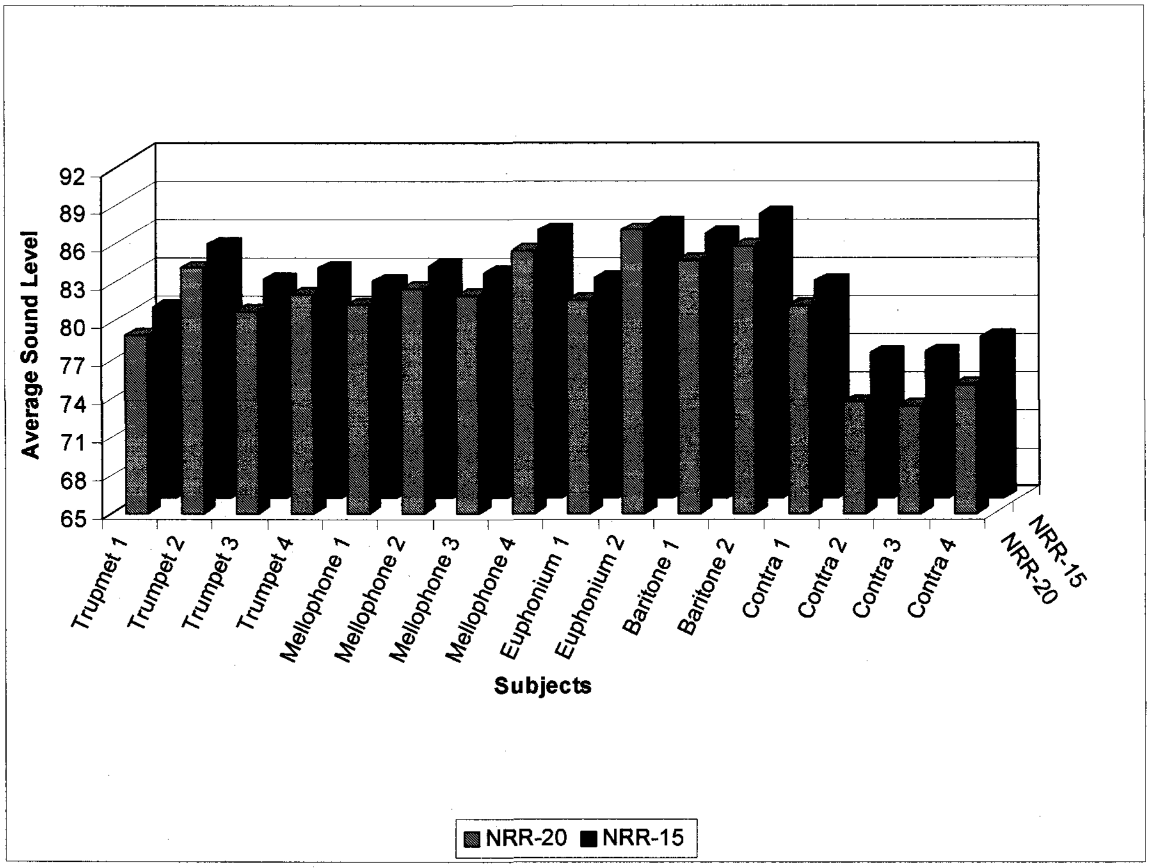

Figure 7. Estimated Average Sound Level for Brass Subjects Based on Intermittent use of HPDs with a Noise reduction rating (NRR) of 15 and 20

Data from Figure 7 demonstrated that, if used during large group and full corps rehearsal, an HPD with a NRR-15 and a NRR-20 can reduce the average sound level exposure across all subjects. Eleven (69%) brass subjects' L_{eq} fell beneath the 83 dBA level with use of an HPD with a NRR-15. As previously reported, all brass subjects experienced L_{eq}s greater than 83 dBA without use of any type of Hearing protection device.

Application of the NRR-15 and the NRR-20 did not reduce all brass subjects' L_{eq} to 83 dBA or less. Therefore, the calculations of the NRR-25 and the NRR-30 were applied to the five brass subjects who were still exceeding NIOSH sound-level standards. Table 17 presents data used in Graph 1, with additional data reflecting the applications of the NRR-25 and the NRR-30. Subject's L_{eq}s that were found to be within sound-level standards were not calculated at subsequent levels of HPD use.

Table 17

Average Sound Level by Subject, True L_{eq}, L_{eq} With a NRR-15 (NRR-15), L_{eq} With a NRR-20 (NRR-20), L_{eq} With a NRR-25 (NRR-25), and L_{eq} With a NRR-30 (NRR-30)

Subject	True L_{eq}	NRR-15	NRR-20	NRR-25	NRR-30
Trumpet 1	89.9 dBA	**80.0 dBA**	–	–	–
Trumpet 2	92.9 dBA	85.0 dBA	84.4 dBA	84.2 dBA	84.1 dBA
Trumpet 3	92.8 dBA	**82.2 dBA**	–	–	–
Trumpet 4	92.4 dBA	83.1 dBA	**82.3 dBA**	–	–
Mellophone 1	90.6 dBA	**82.1 dBA**	–	–	–
Mellophone 2	91.0 dBA	83.3 dBA	**82.8 dBA**	–	–
Mellophone 3	90.6 dBA	**82.7 dBA**	–	–	–
Mellophone 4	92.0 dBA	86.1 dBA	85.8 dBA	85.7 dBA	85.6 dBA
Euphonium 1	88.9 dBA	**82.3 dBA**	–	–	–
Euphonium 2	89.6 dBA	87.4 dBA	87.4 dBA	87.3 dBA	87.3 dBA
Baritone 1	94.3 dBA	85.8 dBA	85.0 dBA	84.8 dBA	84.7 dBA
Baritone 2	92.9 dBA	86.4 dBA	86.1 dBA	86.0 dBA	85.9 dBA
Contra 1	90.9 dBA	**82.1 dBA**	–	–	–

Continued

Table 17 (continued)
Average Sound Level by Subject, True L_{eq}, L_{eq} With a NRR-15 (NRR-15), L_{eq} With a NRR-20 (NRR-20), L_{eq} With a NRR-25 (NRR-25), and L_{eq} With a NRR-30 (NRR-30)

Subject	True L_{eq}	NRR-15	NRR-20	NRR-25	NRR-30
Contra 2	89.7 dBA	**76.4 dBA**	–	–	–
Contra 3	90.3 dBA	**76.5 dBA**	–	–	–
Contra 4	90.9 dBA	**77.7 dBA**	–	–	–

Note: L_{eq}s equal to, or less than 83 dBA are marked in bold.

Data presented in Table 17 illustrate the possible effect of the use of four types of hearing protection devices across all brass subjects. With the use of an HPD with a NRR-15, 66% of brass subjects' L_{eq}s would be equal to or less than 83 dBA; with an NRR-20 this percentage of desired attenuation increased to 69%. Estimations revealed that all contra subjects met NIOSH standards with use of a NRR-15. Further application of the NRR-25 and NRR-30 to subjects exceeding 83 dBA indicated a diminishing effect. The five brass subjects' (Trumpet 2, Mellophone 4, Euphonium 2, Baritone 1, and Baritone 2) maintained L_{eq}s above the criteria, and the NRR-25 and NRR-30 only reduced sound-level averages by .01-.02 dBA. This could be attributed to the sound-levels from the rehearsal activities not selected for hypothetical HPD test for these specific subjects.

For the five brass subjects the researcher then computed another time history that reflected further HPD testing; however, for this calculation an HPD with a NRR-30 was applied to all rehearsal activities (extended use), excluding extended breaks. This time history reflected HPD use for 628 minutes of the rehearsal day. Additionally, this hypothetical time history was applied only to the five brass subjects with L_{eq}s greater than 83 dBA. Table 18 provides data relative to the five brass subjects' Leqs based on use of an HPD with a NRR-30 for extended use, which excluded extended breaks (i.e., lunch, and dinner).

Table 18
Subjects' L_{eq} Reflecting Extended Use of HPD with a NRR-30 (Extended Use - NRR-30)

Subject	Extended Use - NRR-30
Trumpet 2	**82.9 dBA**
Mellophone 4	**67.3 dBA**
Euphonium 2	84.0 dBA
Baritone 1	**67.9 dBA**
Barintone 2	**81.0 dBA**

Note: L_{eq}s equal to, or less than 83 dBA are marked in bold print.

Data presented in Table 18 demonstrated that extended use of an HPD with a NRR-30 would provide the protection needed from sound-level exposures in all but one subject (i.e., Euphonium 2). With the application of several hypothetical time histories, including various HPDs with intermittent and extended uses, all brass subjects, except Euphonium 2, fell within NIOSH standards. Euphonium 2 data could be attributable to the doseBadge malfunction, which resulted in less measurement time. Of the missing 158 minutes from Euphonium 2's full-day rehearsal, none of this time included an extended break. In addition, Euphonium 2's missing 158 minutes were among the 628 minutes selected for HPD use across all subjects. As a result, other brass subjects' had a greater number of data points along the time history where the attenuation effects of an HPD could take place. Thus the increased number (158) of effected L_{eq}s from all other brass subjects allowed for a greater reduction in average sound level.

Percussion Subjects

The aforementioned data analysis relative to hypothetical time histories was applied to the percussion subjects. The rehearsal activities selected for the percussion subjects were small group and full corps rehearsal activities. These activities accounted for 559 minutes (76%) of the full-day rehearsal. Initial calculations of time histories to reflect use of an HPD with a NRR-15 and a NRR-20 indicated that none of the percussion subject's L_{eq}s would fall within sound-level recommendations. Additional estimates across all percussion subjects based on HPDs with a NRR-25 and a NRR-30 also were calculated. As with the brass subjects, the projected effects of HPDs with a NRR-25 and a NRR-30 yielded little variance. The percussion L_{eq}s measured in this study and the L_{eq}s representing use of an HPD with a NRR-30 during selected rehearsal activities are presented in Figure 8.

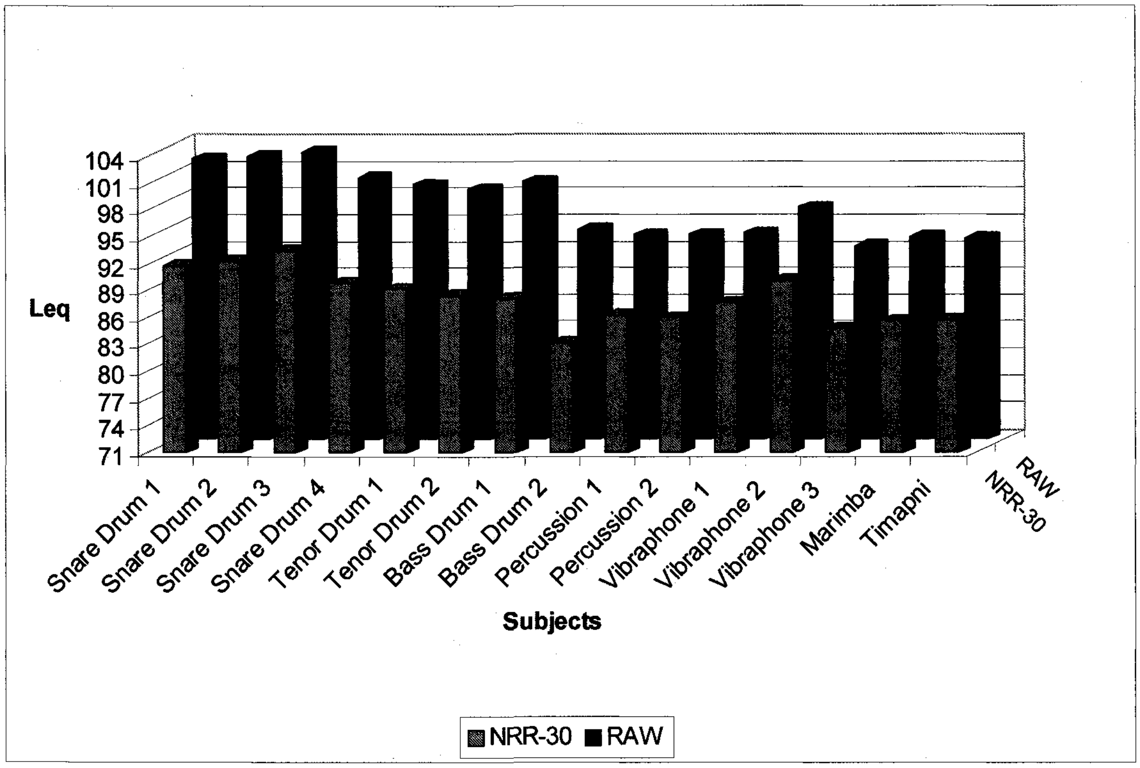

Figure 8. Percussion Subjects' L_{eq} Measurement for Full-Day Rehearsal (RAW), and L_{eq} Reflecting Intermittent Use of HPD With a NRR-30 (NRR-30).

Data presented in Figure 8 demonstrated that although HPD use had an effect on sound-level averages, none of the percussion subjects L_{eq}s fell within NIOSH standards. After determining that none of the hypothesized HPD usage would satisfy NIOSH sound-level standards, the researcher calculated a new hypothesized time history. Similarly to the brass subjects, the newly designed time history reflected use of an HPD with a NRR-30 over all rehearsal activities, excluding extended breaks (i.e., lunch and dinner). The estimated use of an HPD in the new time history accounted for 643 minutes (87%) of the full-day rehearsal. Table 19 provides data describing subject, L_{eq} reflecting use of an HPD with a NRR-30 across 76% of the full-day rehearsal (intermittent use), and reflecting the use of an HPD with a NRR-30 across 87% (extended use) of the full-day rehearsal.

Table 19
Percussion Subjects' L_{eq} With Intermittent Use of HPD With a NRR-30 (Intermittent Use - NRR-30), and L_{eq} With Extended Use of HPD With a NRR-30 (Extended Use - NRR-30).

Subject	L_{eq} With Intermittent Use - NRR-30	L_{eq} With Extended Use - NRR-30
Snare Drum 1	91.8 dBA	79.9 dBA
Snare Drum 2	92.4 dBA	81.9 dBA
Snare Drum 3	93.5 dBA	78.1 dBA
Snare Drum 4	89.9 dBA	71.9 dBA
Tenor Drum 1	89.2 dBA	70.9 dBA
Tenor Drum 2	88.4 dBA	70.5 dBA
Bass Drum 1	88.1 dBA	77.0 dBA
Bass Drum 2	83.2 dBA	74.1 dBA
Percussion 1	86.2 dBA	68.1 dBA
Percussion 2	86.0 dBA	68.0 dBA
Vibraphone 1	87.7 dBA	67.4 dBA
Vibraphone 2	90.1 dBA	69.2 dBA
Vibraphone 3	84.8 dBA	70.5 dBA
Marimba	85.6 dBA	68.0 dBA
Timpani	85.7 dBA	71.1 dBA

Data from Table 19 revealed that all percussion subjects would meet NIOSH sound-level criteria if an HPD with a NRR-30 was used for all rehearsal activities during a full-day rehearsal. Extended usage of the NRR-30 over the rehearsal day demonstrated notably greater protection from sound-level exposure, when compared to intermittent use. These findings further indicate that although initial measurements yielded egregious sound-level exposure, the situation is not without a plausible solution. In addition, these estimates indicate that average sound levels could be as low as 15.6 dBA below NIOSH standrads.

Data analysis for both brass and percussion subjects indicate that estimated L_{eq}s based on hypothetical HPD uses (i.e., intermittent use, extended use) of various types (i.e., NRR-15, NRR-20, NRR-25, NRR-30) can reduce sound-level exposure to levels that meet NIOSH standards. For all percussion subjects, a more aggressive use of an HPD with a NRR-30 is required to limit the exposure to high sound levels. For most of the brass subjects (69%), an intermittent use of HPDs with a NRR-15, -20, -25, and -30 would reduce sound-level exposure to levels that meet NIOSH standards; the remaining subjects would require a more aggressive use.

Summary

Thirty-two members of a Drum and Bugle Corps served as the subjects of this research study designed tp provide a descriptive analysis of sound-level exposures during a full-day rehearsal. Of the 32 subjects, 16 played the following brass instruments: (a) trumpet (n = 4), (b) mellophone (n = 4), (c) euphonium (n = 2), (d) baritone (n = 2), and (e) contra (n = 4). Fifteen subjects performed the following percussion instruments: (a) snare drum (n = 4), (b) tenor drum (n = 2), (c) bass drum (n = 2), (d) front ensemble percussion (n = 2), (e) vibraphone (n = 3), (f) marimba (n = 1), and (g) timpani (n = 1). One subject was the Drum Major. Across all subjects, 72% (n = 23) had more than two years of experience with a Drum and Bugle Corps.

Ninety-seven percent of all subjects reported additional group performance experiences with high school and/or college marching band, both of which begin approximately when the Drum and Bugle Corps activity ends. Although these additional group performance settings may not rehearse for twelve hours a day, the rehearsal activities throughout the twelve-hour day may be similar to the rehearsal activities experienced in high school and/or college marching band rehearsals. This information helps to establish a pattern of sound-level exposure over a calendar year.

Percussion subjects indicated additional experiences in percussion specific performance groups. Thirteen (87%) percussion subjects indicated performance in high school and/or college marching band in addition to performance with high school/college marching indoor/winter drumline, and/or high school/college percussion ensemble. These additional activities typically occur during the fall, winter, and spring seasons. For percussion subjects, this also establishes a pattern for sound-level exposure relative to participation in these groups over the course of a calendar year.

Twenty-five percent ($n = 8$) of all subjects reported a hearing loss or hearing problem of some type; three of whom indicated a ringing sensation in the ear, or tinnitus. When asked to describe experiences with any loud sounds, subjects provided 12 different categories of loud-sound exposure. Seven of the twelve categories were music-related. Drumline, Drum Corps, and Rock Concerts were reported as sources of loud sounds 8, 7, and 7 times, respectively. Of the non-music related categories, Gunshot/Cannon was reported as a source of loud sound exposure 15 times.

Daily sound-level averages were measured by a personal noise dosimeter attached to an athletic visor which was worn by all subjects throughout the rehearsal day. Dosimeters were started prior to the beginning of the rehearsal and stopped after the conclusion of the rehearsal day. The duration of the full-day rehearsal was 12:15 (hrs:mins); however, the total run time for each dosimeter exceeded this time. The dosimeter software (dBlink®) and Excel sound-level calculator were used to determine daily sound-level exposures and sound-dose percentages based on NIOSH standards for a twelve-hour day (i.e., 83 dBA, with 3 dB exchange).

Data analysis relative to average sound-level exposure indicated that 100% of all subjects in this study experienced an average sound-level (L_{eq}) greater than 83 dBA for the entire rehearsal day. The lowest L_{eq} was experienced by the Drum Major (88.4 dBA), and the greatest L_{eq} was experienced by Snare Drum 3 (103.1 dBA). All four snare drum subjects experienced an L_{eq} greater than 100.0 dBA. Subsequently, data analysis further indicated that 100% of all subjects experience a sound-dose percentage greater than 100%. Two of the brass subjects (Trumpet 2 and Baritone 1) experience a dose percentage greater than 1000%; however, only one percussion subject (Vibraphone 3) experienced a dose percentage less than 1000%. The greatest dose percentage was found with Snare Drum 2 (9455.49%) and the lowest was found with the Drum Major (348.22%).

The full-day rehearsal was divided into several rehearsal activities. These rehearsal activities were categorized as small group, large group, full corps, and extended break rehearsal activities. To determine whether specific rehearsal activities had an effect on average sound-level exposure for the entire rehearsal day, L_{eq}s for each subject over the durations of each activity were calculated.

The researcher found that 87% of all subjects experienced an L_{eq} exceeding 83 dBA during full corps rehearsal activities. This rehearsal activity was the most common rehearsal activity during the full-day rehearsal (37% of the rehearsal day), and had a mean duration of 110 minutes. Data collection for the percussion samples occurred on a day where 75% of the rehearsal activities throughout the full-day rehearsal was spent without the brass subjects. However, 100% of the time spent with the brass (i.e., full corps rehearsal activities) yielded an L_{eq} greater than the criterion of 83 dBA. Additionally, brass subjects experienced full corps rehearsal activities 49% during the full-day rehearsal with a mean duration of 121 minutes. During this time 79% the brass subjects experienced Leqs greater than 83 dBA. These findings indicate that full corps rehearsal activities contribute a large amount of sound-level exposure to subjects.

During small group rehearsal activities, the second most common rehearsal activity (29% of the rehearsal day) and with a mean duration of 53 minutes, 82% of percussion subjects and 88% of the brass subjects experienced L_{eq}s exceeding 83 dBA. Large group rehearsal activities had a mean duration of 50 minutes and comprised 20% of the rehearsal day. During these activities 18% of the brass subjects and 93% of the percussion subjects exceeded 83 dBA. However, the extended break (i.e., lunch and dinner) comprised 20% of the rehearsal day, during which time no subjects experienced an L_{eq} greater exceeding 83 dBA. These data indicate that the rehearsal activity has an effect on sound-level exposures.

The performance of the competitive program, which concludes the full-day rehearsal, was measured to determine the L_{eq} for all subjects during this performance (twelve minutes in duration). Issues relative to the performance of this program are objectives of all the rehearsal activities that occur throughout the full-day rehearsal. This performance will also occur several times throughout the summer of competitive performances. As previously reported, NIOSH sound-level standards allow a 15-minute exposure time for sound levels of 100.0 dBA, and a 7.5-minute exposure time for sound levels of 103 dBA. All brass subjects' L_{eq}s fell within NIOSH sound-level requirements during the performance. However, L_{eq}s for all percussion subjects was 103.6 dBA for a duration of 12 minutes, exceeding recommendations. These data indicate that the performance of the competitive program greatly contributes to the sound-level exposure of percussionists.

The occurrence of impact noise (i.e., sound levels greater than 140 dBA) were analyzed due to the frequency of occurrence across percussion samples. The battery percussion subjects' data, in particular, yielded a very high number of peak indications (1341, $n = 8$) during the measured rehearsal time when compared to brass (19, $n = 16$) and front ensemble (98, $n = 7$) subjects. Each of the four snare drum subjects experienced impact noise, at least 31%, 45%, 38%, and 39% of the rehearsal time. This could be attributable to the design of the marching snare drum. The snare drum shell is reinforced, which allows for greater surface tension to be placed on the top drum head. To accommodate the tension allowance from the shell, Kevlar® brand fiber drum heads are used. These fibers are very strong and can endure tremendous force. As a result, the sound-level produced from striking the snare drum may be higher than those found from striking another percussion instrument. The occurrence of impact noise dose suggest that a snare drummer may be more susceptible to higher sound-level exposures.

Exploratory data analysis included the hypothetical application of hearing protection devices (HPD) over specified rehearsal activities to reduce the sound-level exposures of subjects as measured in this study. The specific rehearsal activities chosen by the researcher were based on duration of exposure. For brass subjects, full corps and large group activities were chosen, which accounted for 79% of the rehearsal day; for percussion subjects, small group and full corps rehearsal activities were chosen, which accounted for 76% of the rehearsal day. The purpose of this data analysis was to provide possible solutions to Drum and Bugle Corps members' sound-level exposures that exceed recommended standards.

Data analysis indicated that intermittent use of an HPD with a NRR-15 and NRR-20 would reduce 69% of brass subjects' L_{eq} to a level that is equal to, or less than, 83 dBA. Intermittent use of an HPD with a NRR-25 and NRR-30 were applied to the brass subjects that were still above sound-level standards. Use of HPDs with NRR-25 and NRR-30 has little effect on subjects' L_{eq}; therefore, another time history was constructed to reflect extended use of an NRR-30. With the extended use of an HPD with a NRR-30, 94% of brass subjects would meet NIOSH sound-level standards.

The percussion sample was also analyzed under the intermittent use of HPDs with a NRR-15, -20, -25, -30. Results indicated that non of the percussion subjects' L_{eq}s would meet NIOSH standards under the conditions of intermittent use. An extended use of an HPD with a NRR-30 was calculated across all percussion subjects, this was similar to the extended use calculations implemented in the brass time histories. The extended use calculation estimated sound-level exposure based on use of an HPD with a NRR-30 during 87% of the full-day rehearsal (643 minutes). Results from the extended use hypothesis indicated that all percussion subjects' L_{eq}s would meet NIOSH standards. Although aggressive, this does provide a possible solution to the excessive exposure to sound levels found among the percussion subjects. The ecological validity of wearing any type of HPD for 9 to 10 hours a day may be suspect; however, subject's exposure to sound-levels in this study revealed that an aggressive plan of use may be the only solution.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to describe the sound-level exposures of Drum and Bugle Corps members during a full-day rehearsal. Sound-level exposures were measured using a personal noise dosimeter. Sound-level exposures were used to calculate the daily dose percentages experienced by Drum and Bugle Corps members during a rehearsal day of 12:15 (hrs:mins). Dose percentages were reported according to standards recommended by the National Institute of Safety and Health (NIOSH). Recommended standards for a 12-hour day suggest a sound-level average (L_{eq}) of 83 dBA with a 3 dB exchange rate. In the current study, a full-day rehearsal for all subjects was 12:15 (hrs:mins). Data analysis relative to sound-level exposures were grouped by the following variables: (a) rehearsal activity (i.e., small group, large group, full-corps, and extended breaks), and (b) instrument (e.g., brass and percussion, trumpet and snare drum). The research questions of the study were as follows:

1. What are the average sound levels to which Drum and Bugle Corps members are exposed during a full day of rehearsal?
2. Do Drum and Bugle Corps members experience sound levels that result in dose percentages that meet or exceed standards recommended by the National Institute for Occupational Safety and Health (NIOSH) during large ensemble or small ensemble environments during a full day of rehearsal?

3. How do the following variables affect sound-level averages and daily dose percentages:
   a. instrument (i.e., front ensemble, battery percussion, and brass), and
   b. type of rehearsal activity (e.g., full corps rehearsal, small group rehearsal, and music rehearsal)?

Summary

Subjects ($N = 32$) were members of a Drum and Bugle Corps selected as a sample of convenience located in a southeastern state of the United States of America. Participants volunteered to be subjects and were members of the brass ($n = 16$) and percussion sections ($n = 15$). One subject was the Drum Major of the corps and did not perform with a musical instrument. Sound-level measurements were taken on two separate days, one for both the percussion and Drum Major subjects, and the other for the brass subjects. During the measured rehearsal days, each subject was provided with a personal dosimeter (Cirrus CR-100B doseBadge) that was attached to an athletic visor. The athletic visor, with the attached dosimeter, was worn by all subjects without removal throughout the rehearsal day.

Each subject completed a *Drum Corps Members Questionnaire* prior to the beginning of the rehearsal day. Additionally, the researcher and an assistant, completed an *Observation Form* that documented the time and type of rehearsal activity experienced by the subjects throughout the rehearsal days. Data analysis by each subject, as well as by groups according to instrument family (i.e., brass and percussion) and specific instrument (e.g., trumpet, mellophone, snare drum, marimba) were conducted.

Seventy-two percent ($n = 23$) of all subjects reported greater than two years of experience as a member of a Drum and Bugle Corps. Additionally, 97% ($n = 31$) performed in a high school and/or college marching band in addition to their participation in the Drum and Bugle Corps activity. Typically, high school and college marching band activities occur during the fall season that follows the summer season of activities by the Drum and Bugle Corps. Participation in these activities indicated a pattern of sound-level exposure for subjects over a calendar year.

Of all percussion subjects, 87% ($n = 13$) performed in both high school and/or college marching band and high school/college indoor drumline and/or high school/college percussion ensemble (non-marching) in addition to participating in the Drum and Bugle Corps activity. Involvement in these additional percussion performance groups help to substantiate a pattern of sound-level exposure for percussionists over a calendar year.

Activity in the aforementioned performance groups revealed a pattern of participation in similar group settings. When the summer months of drum corps end, the fall marching band season for high school and college begins. Brass subjects may be exposed to high sound levels as a result of their participation in these groups which can span the course of six months. Percussion subjects indicated participation in percussion performance groups that occur during the winter and spring times, in addition to their participation in high school or college marching band. For percussion subjects, participation in percussion-related performance groups may occur over the course of 10 to 11 months. This type of participation indicates a highly active pattern of exposure to percussion-induced sound levels. Sound levels produced by percussion instruments in this study were considered hazardous to the preservation of percussionists' hearing acuity.

Subjects also reported many sources of loud sounds including music and nonmusic-related sounds. Eighty-four percent (*n* = 27) of subjects reported experience with loud sounds, 3% (*n* = 1) answered "all of the above, and 13% (*n* = 4) provided no answer. Music-related sounds comprised 59% (*n* = 33) of all reported loud sounds and nonmusic-related sounds comprised 41% (*n* = 23) of all loud sounds. "Drumline" was indicated most frequently as a source of loud sounds, and 75% (*n* = 6) of these responses were from percussion subjects. Subjects reported "metronome" as a source of loud sounds, and this is attributed to the amplification of an electronic metronome during rehearsal. Specifically, the amplification of a metronome during outdoor rehearsals was common during the subjects' full-day rehearsal. Of all non-music related sounds, 65% of subjects reported exposure to gun shots and/or cannons which can produce sound levels that result in acoustic trauma.

As reported by subjects, music-related events were determined to be a major source of "very loud sounds." Additionally, "Drumline" was the most frequently indicated source of loud sound exposure, and six of these responses came from percussion subjects. This finding indicated that subjects who participate in music-related events, do so knowing that these activities contain loud sounds. When participating in an activity that even subjectively contains loud sounds, one should seek to protect the hearing organ during such exposure.

Results demonstrated that daily L_{eq}s ranged from 88.4 dBA to 103.1 dBA across all subjects. All subjects' L_{eq} were above the criteria level of 83 dBA for a 12-hour day during the full-day rehearsal. Estimations of subjects' daily dose percentage also indicated that all subjects experienced dose percentages greater than 100%. The lowest dose percentage was found with the Drum Major subject (348.22%), and the highest was 9455.49% found in the snare drum section.

Data analysis by specific instrument revealed that snare drum subjects ($n = 4$) experienced the highest average sound-levels by group (102.05 dBA), the lowest L_{eq} among instruments was found in the contra section (90.45 dBA, $n = 4$). Estimations of dose percentages were averaged by group and indicated that the greatest average dose percentage was found with the snare drum section (8188.17%). The lowest average dose percentage by group was found with the euphonium section (383.62%). All percussion instruments had a dose percentage greater than 1000.00%, and only one brass instrument had an average dose percentage greater than 1000.00% (Baritone 1, 1142.58%). Additionally, average dose percentages by instrument for all battery percussion subjects (i.e., snare drum, tenor drum, bass drum) was found to be greater than double the average dose percentage of any other instrument.

Battery percussion subjects in this study experienced greater sound levels than other percussion and brass subjects; however, no subject in this study experienced safe sound levels. The highest dose percentage across all subjects was found with Snare Drum 2 (9455.49%). This dose percentage is almost 100 times greater than the recommended daily dose percentage. Only one percussion subject (Vibraphone 3) experienced a dose percentage less than 1000%. The percussion instruments in this Drum and Bugle Corps were the same types of percussion instruments found in many high school and college marching bands. These percussion instruments, including the battery instruments (i.e., snare drum, tenor drum, and bass drum) were similar to those found in an indoor marching/winter drumline, which was an activity experienced by most of the percussion subjects in this study. Sound levels resulting from outdoor performance on the battery percussion instruments by subjects in this study possibly were similar to, if not greater than, the sound levels found in a rehearsal for an indoor marching/winter drumline. Therefore, based upon the pattern of exposure to percussion performance groups during a calendar year indicated by the subjects in this study, the L_{eq}s measured in this study possibly were experienced consistently throughout a calendar year while participating in percussion performance groups with similar instrumentation. The sound-level exposure combined with the extended pattern of exposure suggested that percussionists who participated in the current study require an aggressive plan of hearing protection use.

Sound-level averages for each subject across all rehearsal activities were calculated and analyzed. Four categories of rehearsal activities were identified: (a) small group, (b) large group, (c) full corps, and (d) extended breaks. These activities accounted for 29%, 20%, 37%, and 14% of all subject's full-day rehearsal day, respectively. The average duration for each activity was as follows: (a) small group – 53.00 minutes, (b) large group – 49.50 minutes, (c) full corps – 110.00 minutes, and (d) extended breaks – 49.75 minutes.

For all small group activities, 82% (n = 105) of the percussion and 88% (n = 16) of the brass subjects experienced an L_{eq} that exceeded 83 dBA; this activity accounted for 7% and 51% of all brass and percussion subjects' full-day rehearsal time, respectively. The large group rehearsal activity was experienced 29% of the time by brass subjects and 11% of the time by percussion subjects. The percentage of brass subjects' L_{eq} that exceeded 83 dBA was expected to be greater than the L_{eq} found in the small group rehearsal activity because of the greater number of participants in large group rehearsal activities,. However, only 18% (n = 80) of the large group rehearsal activities experienced by the brass subjects yielded an L_{eq} that exceeded 83 dBA, while 88% (n = 16) of the small group rehearsal activities yielded an L_{eq} that exceeded 83 dBA.

Full corps rehearsal activities accounted for 49% and 25% of brass and percussion full-day rehearsal, respectively. During the full corps rehearsal activity 79% (n = 78) of the brass subjects and 100% (n = 30) of the percussion subjects experienced an L_{eq} that exceeded 83 dBA. When compared to brass subjects' L_{eq} from small group, large group, and full corps rehearsal settings, it appeared that the addition of percussion instruments during full corps rehearsals affected brass subject's L_{eq}. The extended breaks (i.e., lunch and dinner) accounted for 14% of the full-day rehearsal time across all subjects during which time there were no L_{eq}s that exceeded 83 dBA.

The sound-level average experienced by all subjects during the twelve minute performance of the competitive program also were calculated. The competitive program was performed as a result of competitive performances scheduled throughout the summer. The L_{eq} for all brass and percussion subjects was 98.3 dBA and 103.8 dBA, respectively.

The Drum Major's L_{eq} during the performance was 94.2 dBA. The highest L_{eq} by instrument was experienced by the snare drum subjects (107 dBA, $n = 4$), and the lowest was experienced by the contras (96.4, $n = 4$). All percussion instruments (i.e., snare drum, tenor drum, bass drum, percussion, vibraphone, marimba, and timpani) experienced an L_{eq} greater than 100 dBA during performance of the competitive program.

Although a twelve-hour rehearsal day is common for this population during the time of year that data were collected, the remaining months of Drum and Bugle Corps activity are comprised of shorter rehearsals (i.e., rehearsals less than twelve hours). The shorter rehearsals that occur during the remaining months of the summer are similar in duration to the small group, large group, and full corps rehearsal activities that took place throughout the full-day rehearsal in this study. These durations and resultant L_{eq}s may be of interest to the Drum and Bugle Corps community relative to subjects' cumulative sound-level exposure throughout the summer, as well as to populations outside of this community.

The individual rehearsal activity durations in this study are common to other outdoor marching groups beyond this population (i.e., high school marching band and college marching band). During high school and college marching band rehearsals several small group, large group, and full-ensemble rehearsal activities can take place over a single rehearsal. The findings relative to subjects' L_{eq} found in this study may therefore be similar to those found in high school and/or college marching bands. These findings are relevant to subjects in this study, as participation in other performance groups was very high. When the Drum and Bugle Corps activity ends for these subjects, they may very well enter into a marching band situation that yields similar sound-level exposures.

The number of impact noise moments (i.e., sound levels that exceed 140 dBA) experienced by all subjects was calculated. Battery percussion subjects experienced the highest occurrence of impact noise during rehearsal activities. Particularly, snare drum subjects ($n = 4$) experienced the most occurrences of impact noise, or peaks, with all four subjects experiencing greater than 193 moments of peaks during the measurement time. These data were further analyzed to determine what percentage of the total rehearsal time yielded a peak level indicator. Four snare drum subjects experienced a peak level at least once during 32%, 48%, 38%, and 42% of the rehearsal time of 643 minutes (excluding extended breaks). These occurrences were attributed to the physical design of the instrument. The marching snare drums used by subjects in this study were comprised of a reinforced shell that support increased surface tension on the top head that is made of Kevlar®. The top head on the snare drum was made of Kevlar® brand fibers that can withstand considerable stress and possibly produce moments of peak sound level when struck. Thus, experience of impact noise among marching snare drum subjects could be attributed to the design and materials that comprised the instrument. Tenor drum subjects ($n = 2$) experienced peak levels 15% of the time, and the two bass drum subjects experienced peak levels 35% and 2% of the time.

Although it is unknown exactly how many impact moments occurred over the duration of the rehearsal day for each battery percussion subject, each peak moment potentially could induce acoustic trauma. With this in mind, the possible effects of a single subject experiencing anywhere from 193–288 minimum impact moments over 643 minutes warrants attention. Particularly when the snare drum instrument is considered, other percussion groups may use a marching snare drum indoors. Although beyond the scope of this study, yet suggested by the data is that the possible effects of a marching snare drum instrument indoors may yield a dangerous sound-level environment. Moreover, this study indicated that percussion subjects, and especially snare drum subjects, may require a hearing conservation plan to reduce the possible long-term effects of this type of exposure.

A time history of estimated exposure to sound levels was constructed for all subjects within the following hypothetical situations which included a hearing protection device (HPD) with four different noise reduction ratings (NRR): (a) use of an HPD with a NRR-15 during specified times of the rehearsal day, (b) use of an HPD with a NRR-20 during specified times of the rehearsal day, (c) use of an HPD with a NRR-25 during specified times of the rehearsal day, and (d) use of an HPD with a NRR-30 during specified times of the rehearsal day. The purpose of this data analysis was to provide possible solutions to Drum and Bugle Corps members' sound-level exposures that exceed recommended standards. For brass subjects, full corps and large group activities were chosen, which accounted for 79% of the rehearsal day (i.e., 577 minutes). For percussion subjects, small group and full corps rehearsal activities were chosen, which accounted for 76% of the rehearsal day (i.e., 559 minutes).

Intermittent use of an HPD with a NRR-15 indicated that 66% of brass subject's L_{eq} would be equal to, or less than 83 dBA; with an NRR-20 this increased to 69%.

Estimations indicated that all of the contra subjects would meet NIOSH standards with use of a NRR-15. Further application of the intermittent uses of the NRR-25 and NRR-30 to subjects exceeding 83 dBA indicated a diminishing effect. Five brass subjects' (Trumpet 2, Mellophone 4, Euphonium 2, Baritone 1, and Baritone 2) maintained an L_{eq} above the criteria, and the NRR-25 and NRR-30 only reduced L_{eq}s by .01-.02 dBA.

An extended use of an HPD with a NRR-30 was applied to the aforementioned brass subjects. Extended use was defined as use of an HPD for all rehearsal activities, excluding extended breaks. Data analysis relative to the extended use of an HPD with a NRR-30 indicated that adequate protection (i.e., L_{eq} equal to, or less than 83 dBA) would be experienced from sound-level exposures in all but one subject (i.e., Euphonium 2). With the application of several hypothetical time histories, including various HPDs with intermittent and extended uses, all brass subjects, except Euphonium 2, fell within NIOSH standards.

The rehearsal activities selected for the percussion subjects were small group and full corps rehearsal activities. These activities accounted for a total of 559 minutes (76%) of the full-day rehearsal. Initial calculations of time histories to reflect intermittent use of an HPD with a NRR-15 and a NRR-20 indicated that none of the percussion subject's L_{eq} would fall within sound-level recommendations. Additional estimates across all percussion subjects based on HPDs with a NRR-25 and a NRR-30 also failed to provide proper protection (i.e., L_{eq} equal to, or less than 83 dBA).

An extended use calculation was applied to all percussion subjects that implied use of an HPD with a NRR-30 for 87% (i.e., all rehearsal activities excluding extended breaks) of the rehearsal day. Data constructed under these parameters demonstrated that all percussion subjects' L_{eq} may be expected to fall below 83 dBA for the twelve-hour rehearsal.

Perceptions on the use of hearing protection may vary, although the protection afforded by their use cannot be understated. During the course of this study, members in the corps were observed, during small breaks (i.e., less than 5 minutes), reapplying sun-block lotion; this observation was noticed throughout the day. Undoubtedly this was to curb the effects of long-term exposure to sunlight. The use of this type of protection allows for all people, not only Drum and Bugle Corps members, to remain for long periods of time outdoors without any long-term effects. The medical community has maintained that long-term, unprotected exposure to sunlight can cause skin cancer. Although there is great risk, the use of protection (i.e., sun-block) reduces this risk. The protection affords people the opportunity to enjoy outdoor recreation activities without the effects of long-term exposure. The use of hearing protection devices by Drum and Bugle Corps members can be applied the same manner, or approach. Participation in an activity that is meaningful and enjoyable may be done so without any long-term effects with the use of hearing protection.

Information regarding the sound-level exposure of Drum and Bugle Corps members should be made known to this community of musicians. This information also should include a plan for hearing preservation so the activity can continue to be enjoyed by thousands of people each summer without the effects of long-term exposure. This study has indicated that the use of a hearing protection device can diminish sound-level averages below the allowable NIOSH standards for a twelve-hour day.

Limitations of the Study

Due to the lack of current and comparative published research on sound-level exposures in the area of Drum and Bugle Corps members, it is important to examine the limitations of this study. All subjects were instructed in the care of the dosimeters. Specifically, participants were instructed to avoid physical contact with the dosimeter (e.g., tapping the windshield). Some of the brass subjects' time history indicated isolated moments of inconsistent sound-level averages. These inconsistencies seemed to be the result of accidental contact with the microphone cover throughout the rehearsal day. The frequency of these occurrences did not seem to affect dose percentages.

Subject responses across the Drum and Bugle Corps Members' Questionnaire proved to lack clarity. For example, when subjects were asked to report any known hearing loss or hearing problems some subject's responses were generally vague and nondescript. A possible solution may be to suggest answers to help subjects properly identify known hearing problems (e.g., ringing in the ears, audiometric test results, etc.). In addition, the questionnaire should have asked subjects to report on the use, if any, of a hearing protection device during Drum and Bugle Corps rehearsals. These two revisions to the questionnaire may allow for greater clarity in subject's responses.

Drum and Bugle Corps are not abundantly available for study. All Drum and Bugle Corps experience a highly detailed schedule during the twelve-hour rehearsal day period (i.e., the weeks of spring training). Because these full-day rehearsals occur over a period of two to three weeks, scheduling often is problematic, particularly due to the fact that after a twelve-hour run time the doseBadges need a full 24-hours to recharge. Additionally, the nature of this research (i.e., measuring the sound-level exposures of Drum and Bugle Corps Members) could be interpreted as leading to information detrimental to the activity of Drum and Bugle Corps. Therefore, finding a willing Drum and Bugle Corps is difficult and limiting.

The hearing threshold of subjects was not measured in this study. Measurement of hearing thresholds before and after a full-day rehearsal, in addition to the data collected, would provide the necessary data to analyze the effects of a full-day of Drum and Bugle Corps rehearsals and resulting sound exposures on subjects' hearing acuity. Scheduling and personnel to provide this type of measurement were not available for this study.

The Cirrus doseBadge personal dosimeter system is relatively new and not without technical problems. Over the days of data collection, two of the doseBadges malfunctioned resulting in the final hours of the rehearsals not being recorded. Data from other subjects did not suggest that the incomplete readings would have yielded different results; therefore, the data were analyzed as collected. Additionally, the software interface can be ambiguous. When downloading data from the doseBadge to a computer the file management capabilities can be confusing, which may lead to inaccurately naming and saving files.

Recommendations for Future Research

Replication of this study will provide an increased sample size of Drum and Bugle Corps members. An increased sample size may provide more data relative to the specific variables (i.e., instrument and rehearsal activity) present in a full-day rehearsal. The possibility exists that other Drum and Bugle Corps members experience substantially greater or lesser daily sound-level exposure than subjects of this study. Replicating this study with different Drum and Bugle Corps may provide information to support the present findings.

Future research should allow for additional days of sound-level measurements during full-day rehearsals. Increased days would provide additional data to estimate a typical day's exposure under the "Spring Training" conditions. Furthermore, extended research can include days during the competitive season that are different from days measured in this study. As mentioned before, a measurement of hearing thresholds before and after a rehearsal will provide valuable insight to the effects of sound-level exposure on Drum and Bugle Corps members. Periodic measurements of hearing thresholds of the same subjects over the course of the summer, however, would provide the necessary data to analyze the effects of a summer of Drum and Bugle Corps activity and resulting sound exposures on subjects' hearing acuity.

Research involving the use of HPDs and resultant effects on sound-level exposures also is needed. Attitudes of musicians towards HPDs needs to be further documented to determine an effective way to implement a plan for use. In addition, research involving the effects of HPD use on musicians hearing acuity in the music community is an emerging field. Hearing protection device manufacturers also may increase their efforts to provide the best protection from sound-level exposure, particularly with percussion performers.

Specifically, research in the area of percussion sound-level exposure requires additional attention. As found in this study, percussionists are subjected to extremely high sound levels, including many moments of impact noise (i.e., sound levels greater than 140 dBA). Hearing health education among the percussion community is paramount for those who are involved in the teaching and performing of percussion ensembles, indoor/winter drumlines, high school and college marching bands, and Drum and Bugle Corps. Recent research in this area suggests that most percussionists do not use hearing protection of any kind during rehearsal and/or performances (Cunningham, Workman, Curk, Hoffman, & Pride, 2005). This research, combined with findings of the current study, reveal that percussionists need to develop a proactive, health-conscious awareness of the sound-level environments and their possible effects.

The most valuable type of research relative to the sound-level exposures of Drum and Bugle Corp members may require a longitudinal research design, incorporating other group performance experiences to create a timeline of exposure for subjects involved in various musical activities across a calendar year. Since both outdoor and indoor performance groups tend to occur along a seasonal time frame, connecting sound-level exposures and hearing thresholds across a year of activity could provide a strong foundation for the development hearing health among musicians within this population.

The intent of any research in this area serves the purpose of improving the activity experienced by musicians. Although information relative to other health-related issues are generally well-known by the population at large (e.g., sun-block to reduce the risk of long-term exposure to sunlight), musicians' health is an emerging concern within the field of music education and music performance and is relatively unknown. As a result, many musicians are unaware of both the potential risks involved in music performance settings, and the effects of hearing protection.

Participation in the Drum and Bugle Corps activity has provided hundreds of thousands of people across four decades excellent music performances and instruction, as well as meaningful and valuable experiences. Information provided in this study seeks to maintain the future of this activity by describing health-related issues and possible solutions to the potentially damaging effects resulting from participation. Knowledge gained from this research may be invaluable to musicians' understanding the importance of preventing hearing loss among all musicians. Results of the current study and future studies may provide musicians with the foundation to make informed decisions regarding the advantage in using hearing protection.

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APPENDIX A

GLOSSARY OF TERMS

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Acoustic Trauma - A single incident which produces an abrupt hearing loss. Welding sparks (near to the ear drum), blows to the head, and blast noise are examples of events capable of producing acoustic trauma (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Criterion Level (CL) - In dB, the normalized eight hour average weighted sound-level that corresponds to the maximum permitted daily exposure, or 100% noise dose (Cirrus Research User Manual, 2002, p. 49).

Criterion Time (CT) - The time, in hours, used in the calculation of the dose percentage measurement parameter (Cirrus Research User Manual, 2002, p. 49).

Decibel (dB) - The unit used to express the intensity of sound. The decibel was named after Alexander Graham Bell. The decibel scale is a logarithmic scale in which 0 dB approximates the threshold of hearing in the mid frequencies for young adults and in which the threshold of discomfort is between 85 and 95 dB SPL and the threshold for pain is between 120 and 140 dB SPL (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html). The equation is ten times the logarithm of the ratio of two intensities, two powers, or two energies. A Decibel expresses how many units one intensity or amplitude is above or below another intensity or amplitude, therefore the decibel is ultimately a relative term and not an absolute (Yost, 2000, p. 28).

Dosimeter - When applied to noise, refers to an instrument that measure sound levels over a specified interval, stores the measures, and calculates the sound as a function of sound level and sound duration and describes the results in terms of: (a) dose, (b) time-weighted average, (c) peak level, (d) equivalent sound level, and (e) sound exposure level (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Equal Energy Rule - An increment of decibels that requires the halving of exposure time, or a decrease in decibels that requires the doubling of exposure time (example: a 3 dB exchange rate requires that noise exposure time be halved for each 3 dB increase in noise level) (NIOSH, 1998, p. xiii).

Equivalent continuous sound-level (L_{eq}) - The level which if maintained constant for the same period as the measurement would contain the same amount of energy as the varying noise level (Cirrus Research User Manual, 2002, p. 47).

Frequency - The number of cycles completed per second by a sinusoid, and expressed as Hz (Yost, 2000, p. 13).

Hertz (Hz) - The unit of measurement for audio frequencies. The frequency range for human hearing lies between 20 Hz and approximately 20,000 Hz. The sensitivity of the human ear drops off sharply below about 500 Hz and above 4,000 Hz (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Intensity - An objective measurement of a physical property, namely the amount of power. Often expressed in power units per unit area such as watts per square meter (Radocy & Boyle, 1988, p. 52).

Loudness - A subjective perception of the magnitude or strength or a sound (Radocy & Boyle, 1988, p. 52).

Noise - Although musical sound are not considered noise, for the purposes of this study and related literature, sound-level exposure with music as the stimulus will be measured as a possible source of NIHL.

Noise Dose - The noise exposure expressed as a percentage of the allowable daily exposure. For OSHA, a 100% dose would equal an 8-hour exposure to a continuous 90 dBA noise; a 50% dose would equal an 8-hour exposure to an 85 dBA noise or a 4-hour exposure to a 90 dBA noise. If 85 dBA is the maximum permissible level, then an 8-hour exposure to a continuous 85 dBA noise would equal a 100% dose. If a 3 dB exchange rate is used in conjunction with an 85 dBA maximum permissible level, a 50% dose would equal a 2-hour exposure to 88 dBA or an 8-hour exposure to 82 dBA (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Noise-induced Hearing Loss (NIHL) - Changes in normal auditory function that occur as a consequence of long term exposure to hazardous sound levels. This type of hearing loss is classified as sensorineural hearing loss (Yost, 2000, p. 253; National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Peak - The maximum value reached by the sound pressure at any instant during a measurement period. The CR:100B dosebadge measures the Peak level, and records if the level has exceeded the present Peak Threshold which is set, as default to 140 dB(C) (Cirrus Research User Manual, 2002, p. 49).

Presbycusis - The gradual increase in hearing loss that is attributable to the effects of again, and not related to medical causes or noise exposure (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Sensorineural Hearing Loss - A hearing loss resulting from damage to the inner ear from any source, including noise (National Institutes of Occupational Safety and

Health, http://www.cdc.gov/niosh/hpterms.html).

SPL (Sound Pressure Level) - A measure of the ratio of the pressure of a sound wave relative to a reference sound pressure. Sound pressure level in decibels is typically referenced to 20 mPa (i.e., micro-pascals). When used alone, (e.g., 90 dB SPL) a given decibel level implies an unweighted sound pressure level (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Threshold Shift - Audimetric monitoring programs will encounter two types of changes in hearing sensitivity: (a) permanent threshold shift (PTS), and (b) temporary threshold shift (TTS). As the names imply, any change in hearing sensitivity which is persistent is considered PTS. Persistence may be assumed if the change is observed on a 30-day follow-up exam. Exposure to loud noise may cause a temporary shift in hearing sensitivity (i.e., a TTS) that may persist for 14 hours (or even longer in cases where the exposure duration exceeded 12 to 16 hours). Hearing health professionals need to recognize that not all threshold shifts represents decreased sensitivity, and not all temporary or permanent threshold shifts are due to noise exposure (National Institutes of Occupational Safety and Health, http://www.cdc.gov/niosh/hpterms.html).

Weighted measurements - One of two weighting curves applied to measures of sound levels to account for perceived "loudness," each weighting curves is based on the Fletcher and Munson equal loudness curves. **A-weighting**: A unit representing the sound level measurement with the A-weighting network on a sound-level meter (reference of 40 dB SPL with 1000 Hz reference tone). **C-weighting**: A unit representing the sound level measurement with the C-weighting network on a sound-level meter (reference of 90 dB SPL with 1000 Hz reference tone) (NIOSH, 1998, p. xii).

APPENDIX B

PERMISSION TO REPRINT MATERIALS

ELSEVIER Our ref: PresleyUNCNM4-05
Date: April 26, 2005

Douglas Presley
dlpresley@triad.rr.com

Dear Mr. Presley:

PUBLICATION DETAILS: Two diagrams from Patton: MOSBY'S HANDBOOK OF ANATOMY AND PHYSIOLOGY, © 2000 Mosby

As per your letter dated April 21, 2005, we hereby grant you permission to reprint the aforementioned material at no charge in your thesis subject to the following conditions:

1. If any part of the material to be used (for example, figures) has appeared in our publication with credit or acknowledgement to another source, permission must also be sought from that source. If such permission is not obtained then that material may not be included in your publication/copies.

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Yours sincerely,
Nicole McIntyre
for Elsevier

The Hope for Hearing Foundation

To: Doug Presley, dlpresle@uncg.edu
Date: May 5, 2004

Dear Doug,

Those were commissioned by me and are my property. They will eventually go into a book that has been in process for a couple of years. Hope for Hearing Foundation would be happy to give you permission to use them in your dissertation. If you would just cite the Hope for Hearing Foundation, that would be fine.

Sincerely,

Christine Coleman, M. A.

Executive Director

Hope for Hearing Foundation
5855 Green Valley Circle, Suite 305
Culver City CA 90230
(310)410-0900 fax (310)410-0080
email: director@hope4hearing.org
website: www.hope4hearing.org

APPENDIX C

INSTITUTIONAL REVIEW BOARD APPROVAL

5/4/2005

THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

MAY 2 4 2005

IRB File NUM:

045264

TITLE: A Descriptive Study on the Sound Level Exposures of Drum and Bugle Corps Members During T

PI: Presley,Douglas **DEPT:** MUS

CO_PIS:

FACULTY SPONSOR: Sink,Patricia

Action Taken:

_____ eXempt from Full Review

__✓__ Expedited Review

_____ Full IRB Review

Disposition of Application:

__✓__ Approved

_____ Disapproved

MODIFICATIONS AND COMMENTS:

[signature]
IRB Chair/Designee

APPROVAL DATE*: 5/23/05

EXPIRATION DATE*: 5/23/06

*Approval of Research is for up to **ONE** year only. If your research extends beyond one year, the project must be reviewed before the expiration date prior to continuation.

N:\RSS\apps\uncg\DATA\ORC\facesheet.rpt

Review Checklist
Applications for the Use of Human Participants in Research

Directions: Faculty members should complete this checklist before submitting an application for their own research and when signing off as faculty sponsors for student research. **Attach 2 copies of the proposal.**

Name of researcher: Douglas Presley
Date of Submission:

Name of faculty (sponsor): Patricia Sink
Projected data of first data collection: 5/20/05

Review Criteria	Check (√) by Faculty	Check (√) by IRB Rep.
Part A is complete and investigators have attached evidence of training in the use of human participants.	√	
Part B: The investigator has answered questions 1 - 6 on separate paper.	√	
1. **Goals for the project** are clearly stated and suggest the need for human participa consent. (Please note that information collected solely for instructional purposes does not require IRB approval).	√	
2. The protocol states:		
a. data gathering procedures and tools (copies attached to the application)	√	
b. data recording procedures	√	
c. the number of participants and justification, procedures for selecting particip	√	
d. the length of time for procedures	√	
e. relationship between the researcher, participants, and participating institutions/agencies	√	
f. any need for deception or less than full disclosure (if appropriate)	NA	
g. what students not participating will do (if data collection occurs in a class)	NA	
h. approval from any agencies has been obtained (copy of letter/s attached)	NA	
i. how consent will be obtained and indicates that participants will receive a cop the consent document/s.	√	
3. The proposal describes the benefits to individual participants and society.	√	
4. Concerning risks, the protocol states:		
a. risks to subjects and precautions taken to minimize them	√	
b. how confidentiality of data will be maintained	√	
c. how long data will be kept and how they will be eventually destroyed	√	
d. the level of risk for participants (none, minimal, more than minimal)	√	
5. The proposal describes the participant population and justifies any decisio exclude persons on the basis of gender, race, or ethnicity.	√	
6. Materials to be used in recruiting participants are attached to the proposal	√	
7. Conflict of Interest question answered "N/A," "NO" or "Yes"		
If Conflict of Interest answered "Yes" a Potential Conflict of Interest in Resea form is attached.	NO	
8. Either "No use of PHI from CE" is indicated or "Use of PHI from CE" is indicated.		
If "Use of PHI from CE" indicated, an Application to Use PHI in Research is a If waiver is requested, UNCG Request for Waiver of Authorization form is a	NO	
9. Signed Confidentiality Agreements attached		
Part C: The consent form (long form or short form with oral presentation) incl		
a. clear explanation of the purpose and procedures to be used	√	
b. description of benefits to individuals and/or society	√	

c. risks of participation (if more than minimal include a statement regarding compensation/treatment/direction to contact Eric Allen.)	√	
d. opportunity to ask questions and withdraw without penalty.	√	
e. amount of time required for participation	√	
f. how confidentiality will be maintained and eventual disposal of data	√	
g. researcher's name and phone number for questions about the research	√	
h. Eric Allen's name and his phone number for questions about rights human participants	√	
i. place for the signature of a witness to the oral presentation (when short form i	√	
j. Separate form for assent of minors (if applicable)	√	

THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

Instructions for Completing the Application for the Use of Human Participants in Research

All research with human participants conducted by students, faculty, or staff at UNCG must be reviewed initially by a member of the University's Institutional Review Board, whether or not requests for outside funding are involved. To initiate this review, the investigator/project director must complete this application and submit it to the IRB member in his/her college/school/department. The IRB member determines the category of review appropriate for the study and forwards it to the Office of Research Compliance. The University IRB meets if full committee review is necessary. Criteria for exempt, expedited, and full committee review are available at: <http://www.ohrp.osophs.dhhs.gov/polasur.htm>.

Please submit **the original and one copy** of this human participants application at least one month prior to the date you wish to initiate data collection. (You are advised to keep a copy for your records also.) **YOU MAY NOT COLLECT DATA PRIOR TO RECEIVING AN APPROVAL FORM FROM THE IRB.**

Faculty members will be informed by the IRB regarding the disposition of their applications and those of students they are sponsoring. Students do not receive direct notification of IRB disposition of proposals. Any changes in research protocol that affect human participants must be approved by the IRB prior to implementation unless the changes are necessary to eliminate apparent immediate hazards to the participant. Any unanticipated problems involving risks to participants or others must be promptly reported to the IRB.

COMPLETE PART A (ON THIS PAGE) AND NUMBERS 1-6 ON PAGE 3. ATTACH THE APPROPRIATE CONSENT FORM INFORMATION. BE SURE TO SIGN THIS APPLICATION ON PAGE 3.

Part A

Date: 5/18/04

Project Title: A DESCRIPTIVE STUDY ON THE SOUND LEVEL EXPOSURES OF DRUM AND BUGLE CORPS MEMBERS DURING TYPICAL FULL-DAY REHEARSALS

Principal Investigator(s): Douglas Presley

Email Address of Principal Investigator: dlpresley@triad.rr.com

Phone Number of Principal Investigator: 336-334-5435

Address of Principal Investigator: UNCG School of Music
P.O. Box 26167
UNC Greensboro
Greensboro, N. C., 27402-6167

Relationship to the University (specify): Faculty ☐ Student √ Other ☐

If student, name of faculty sponsor: Patricia Sink

Faculty sponsor's email address: psink@triad.rr.com

School/College: University of North Carolina at Greenboro Department: School of Music

Funding Agency/Sponsor (if applicable):

Projected data collection dates*: From 5/20/05 To 6/18/05

Have the investigators attached certificates of completion of training in the use of humans in research? y

* Beginning date should be at least 1 month after submission of IRB application. Data collection cannot begin before IRB approval is received.

THIS PAGE IS FOR IRB USE ONLY

(IRB Representative: Indicate appropriate category of review: exempt, expedited, or full review. Note: the standard requirements for informed consent apply regardless of the type of review utilized by the IRB.)

Part B - Exempt

This proposed research is judged to be exempt from full committee review because it falls in one or more of the following categories (see 45 CFR 46, June 18, 1991, p. 5). Check all that apply:

_1. 46.101 (b)(1)
_ 2. 46.101 (b)(2)
_ 3. 46.101 (b)(3)
_ 4. 46.101 (b)(4)
_ 5. 46.101 (b)(5)
_ 6. 46.101 (b)(6)

Part C - Expedited or Full Review

This proposed project has been reviewed and was found to require:

____ Expedited Review (63 FR 60364-60367, November 9, 1998)

Expedited category. Check all that apply:

____1. (a)
____1. (b)
____2. (a)
____2. (b)
____3.
____4.
____5.
____6.
____7.
____8. (a)
____8. (b)
____8. (c)
____9.

____ Full IRB Review. Please explain: ______________________________

I certify that this project has been reviewed by me as an IRB member and that the research was not proposed by me or by a student working under my supervision.

______________________________ ______
IRB Signature Date

____
Print Name

Dept. /School

Send this application package to: IRB, Office of Research Compliance, 204 Foust Building, The Campus.

Part D - IRB Action

__ Exempt Review (Date: / /)

__ Expedited Review (Date: / /)

__ Full Review (Date: / /)

Comments:

________________________________ _____

IRB Chairperson ORC Representative

RESPOND TO NUMBERS 1 THROUGH 6 ON SEPARATE PAPER. SUBMIT NO MORE THAN 3 PAGES FOR YOUR ANSWERS. Supporting materials (e.g. letters and consent forms) should be attached.

1. BRIEF STATEMENT OF PROJECT GOALS

2. PROTOCOL: Procedures: what will be done? How long will subjects require to complete procedures?
   - Name and description of data gathering tool (if not well known, attach a copy)
   - How will data be recorded? (audiotapes, videotapes, written records)
   - Number of participants, respondents, or participants. From where will participants be obtained?
   - What, if any, relationship exists between the researcher and the participants, and between the researcher and agencies (e.g., schools, hospitals) participating in data collection? (Example: Is researcher employed at the agency?)
   - Any special situations (Example: Deception used because full disclosure prior to procedure would bias data.)
   - If data collection is done in class, explain what students who do not participate will be doing.
   - Attach statement of approval from any agencies (e.g., schools, hospitals) that will be involved with recruitment of participants or data collection.

3. BENEFITS: Describe the benefits to individual participants and to society.

4. RISKS: Describe the risks to the participants and precautions that will be taken to minimize them. This includes physical, psychological, and sociological risks.
   - How will confidentiality of data be maintained? Attach signed confidentiality agreements (form attached) for members of research team who will have access to personal data on human research participants.
   - Final disposition of data (What will be done with questionnaires, inventories, videotapes, and/or audiotapes? How long will they be stored, and how will they be destroyed?)
   - How would you describe the level of risk for participants taking part in this project?

√ No risks ☐ Minimal risks ☐ More than minimal risks

5. POPULATION: Briefly describe your participant population. Will you exclude persons on the basis of gender, race, color, or any other demographic characteristic? If so, justify.

6. PARTICIPANT CONSENT: Describe how and where participants will be informed of their rights and how informed consent will be obtained and documented. Attach a copy of consent form, oral presentation (if used), and any materials to be used in recruitment (e.g. fliers, advertisements). *See next page for details on content of Consent Forms.*

Note: Signed consent forms must be retained in a secure location, for a minimum of three (3) years, after completion and available for IRB review.

7. CONFLICT OF INTEREST: At any time will any members of the research team or their immediate family members have financial interest in, receive personal compensation from, or hold a position in an industry sponsoring this study, or otherwise have potential conflict of interest regarding conduct of this study?

☐ **N/A no industry sponsors** **√ NO** ☐ **YES** **If yes, attach Potential Conflict of Interest in Research form.**

8. PHI: Personally identifiable health information (PHI) is defined by HIPAA to include data on a person's physical or mental heath, health care, or payment for health care. As part of this study, will you obtain PHI from a hospital, health care provider, or other HIPAA-defined Covered Entity? (If unsure, read the Application to Use PHI in Research.)

√ NO ☐ YES If yes, attach the Application to Use PHI in Research (available from ORC website.)

I certify that the statements made herein are accurate and complete. I agree to inform the Board in writing of any emergent problems or proposed procedural changes. Should changes be made, I further agree not to proceed with the research until the Board has reviewed and approved the changes that I propose to make in the protocol.

____

Principal Investigator Date

____

Faculty Sponsor (for student investigators) Date

CONSENT FORMS

Read very carefully.

1. Consent forms must be written in simple language that is understandable to the participants. A reading level of 4-7th grade is recommended for most populations.

2. Consent forms should NOT be written in the first person (e.g. they should NOT say "I understand the procedures and risks and agree to participate in this study...."). Sections of the consent form may be in the third person (e.g, "Subjects in this study will be interviewed.....") and the actual agreements to participate should be in the second person (e.g., "By signing this consent form, you are agreeing that you understand the procedures and risks..."). (See attached sample consent forms.)

3. When research involves minors or those who are not legally competent, informed consent must be obtained from the parent or guardian and, in some cases, assent obtained from the participant.

4. A copy of the consent form must be provided to each participant and a signed copy retained by the principal investigator. EXCEPTION: A letter containing all aspects of informed consent may be used for data collected by mailed survey. Participants need not sign a consent form since returning the questionnaire is implied consent.

5. Consent may be obtained through either the Long Form or the Short Form with Oral Presentation. Research design dictates which form is appropriate for a given study. Either format must ensure that participants are apprised of all aspects of informed consent (see list below).

ASPECTS OF INFORMED CONSENT (required in all studies)

1. Explanation of research purpose and procedures (including participant selection)
2. Benefits
3. Risks (if study poses more than minimal risk, must include statement regarding compensation/treatment for injury, and directions to contact Mr. Eric Allen at (336) 256-1482 about any research-related injuries)
4. The opportunity to withdraw without penalty
5. The opportunity to ask questions
6. The amount of time required of the participants
7. Confidentiality of data and final disposition of data
8. Phone number and name for questions on research
9. Phone number and name to ask about the rights of research participants (Mr. Eric Allen at 336-256-1482)

A. Long Form: The long form must be used when research procedures are complicated or when the researcher will have no direct contact with the participants. Information should be included in the spaces provided on the form. N/A should be inserted for sections not applicable to a specific study. **THE FORM MAY BE REVISED BUT MUST INCLUDE ALL ASPECTS OF INFORMED CONSENT** (see list above). Some research requires that other information be included in the consent document. Your IRB representative will inform you if additional information is needed for your study.

B. Short Form with Oral Presentation: A short form with an oral presentation may be used when procedures are rather simple and when the researcher will have direct contact with the participants. The oral presentation must include the aspects of informed consent. A witness unaffiliated with the study must sign the oral presentation. The witness can be a subject or a family member, but NOT a member of the research team.

Oral Presentation must include:

1. Explanation of research purpose and procedures (including participant selection)
2. Benefits
3. Risks (if study poses more than minimal risk, must include statement regarding compensation/treatment for injury, and directions to contact Mr. Eric Allen at (336) 256-1482 about any research-related injuries)
4. The opportunity to withdraw without penalty
5. The opportunity to ask questions
6. The amount of time required of the participants
7. Confidentiality of data and final disposition of data

The oral presentation does not require the participants' signatures but must include the date on which it was read to participants.

IF AN ORAL PRESENTATION IS PLANNED, INCLUDE THE CONTENT OF THE PRESENTATION ON THE FORM.

Sample consent forms appear on the following pages. **Attach only the forms that you plan to use.** For special situations in obtaining consent, please see your IRB representative or call the Office of Research Compliance.

THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

CONSENT TO ACT AS A HUMAN PARTICIPANT: LONG FORM

Project Title: AN ANALYSIS OF THE SOUND-LEVEL EXPOSURES OF DRUM AND BUGLE CORPS MEMBERS DURING A FULL-DAY REHEARSAL

Principal Investigator: Doug Presley (336-334-5435, or dlpresley@triad.rr.com)

Project Director: Dr. Patricia E. Sink (336-334-5469, or psink@triad.rr.com)

Participant's Name: ______________________________
Print Name

DESCRIPTION AND EXPLANATION OF PROCEDURES

The purpose of this study is to describe Drum Corps members' sound level exposures during typical full-day rehearsals. A Cirrus dosbadge (CR-100B) will be used to measure your sound level exposures across two rehearsal days. According to research, two rehearsal days are necessary to provide sufficient sound level exposure data to derive a musicians' typical day. As currently planned, data collection for measuring sound level exposures will occur over the course of two days, separated by one day for battery recharging. Upon completion of each data collection day you will return the dosebadge for downloading the data, recalibrating, and recharging. Please be assured that the data recorded via the dosebadge is only sound levels and not the language, nor musical content of your rehearsals and/or meetings. To insure that the data collection procedure using the dosebadge is accurate and consistent, you will be instructed to: (a) place the visor with the attached dosebadge securely on your head, (b) keep the visor on throughout the entire day, (c) if, in the event of rain, place the provided protective covering over the dosebadge immediately, and (d) return the dosebadge to the researcher at the conclusion of the rehearsal. In addition to measuring sound level exposures, you will complete a brief *Drum Corps Member Questionnaire*, and the assistant researchers will complete a description of the environments in which you rehearse. At any time, you may withdraw from this study by notifying the Primary Investigator. In such case, all your recorded data to the point of withdrawal will be destroyed.

RISKS, DISCOMFORTS, AND CONFIDENTIALITY

There are no risks associated with this study. All collected data will be identified by your subject number only, with the exception of the *Drum Corps Member Questionnaire*. On the questionnaire, you are requested to provide your name, instrument, other group performance memberships, and years of Drum Corps experience. The confidentiality of the dosebadge readings, questionnaire, and observational data will be protected. Your name and other forms of identification will not be associated with data entered on the computer for analysis.

BENEFITS

Upon completion of the data collection phase of the study you will be given a visor, t-shirt, and compact disk recording of the UNCG Wind Ensemble to keep. Beyond these tangible benefits to you, results of this study are intended to produce reliable information related to the sound levels exposures of musicians.

CONSENT

By signing this consent form, you agree that you understand the procedures and benefits involved in this research. You are free to refuse to participate or to withdraw your consent in this research study at any time without penalty or prejudice; your participation is entirely voluntary. Your privacy will be protected because you will not be identified by name as a participant in this project. The research and consent form have been approved by the University of North Carolina at Greensboro Institutional Review Board, which ensures that research involving people follows federal regulations. Questions regarding your rights as a participant in this project can be answered by calling Eric Allen of the UNCG Office of Sponsored Programs (336-256-1482). Specific questions regarding the research study can be answered by calling the Principal Investigator, Doug Presley (336-334-3589), or the Project Director, Patricia Sink (336-334-5469). All data collected form this study will be kept and maintained for future reference for twenty calendar years from the collection date; at the conclusion of this time all data will be destroyed. Any new information that develops during the project will be provided to you if the information might affect your willingness to continue participation in the project.

By signing this form, you are agreeing to participate in the described research study. Thank you so much for your valuable and worthwhile participation in this project.

Sincerely,

Doug Presley,
Principal Investigator

Patricia E. Sink,
Project Director

____ ________________

Participant's Signature of Consent Date

APPENDIX D

NATIONAL INSTITUTES OF HEALTH CERTIFICATE

Human Participant Protections Education for Research Teams

Completion Certificate

This is to certify that

Douglas Presley

has completed the **Human Participants Protection Education for Research Teams** online course, sponsored by the National Institutes of Health (NIH), on 05/24/2004.

This course included the following:

- key historical events and current issues that impact guidelines and legislation on human participant protection in research.
- ethical principles and guidelines that should assist in resolving the ethical issues inherent in the conduct of research with human participants.
- the use of key ethical principles and federal regulations to protect human participants at various stages in the research process.
- a description of guidelines for the protection of special populations in research.
- a definition of informed consent and components necessary for a valid consent.
- a description of the role of the IRB in the research process.
- the roles, responsibilities, and interactions of federal agencies, institutions, and researchers in conducting research with human participants.

National Institutes of Health

http://www.nih.gov

APPENDIX E

DRUM CORPS MEMBER QUESTIONNAIRE

SOUND-LEVEL EXPOSURE STUDY:
DRUM CORPS MEMBER QUESTIONNAIRE

DCM#:____________________ DATE:____________________

Corps Member's Name: ____

Corps Member's Instrument:____

Age:____________________ Gender:____________________

1. Total years experience in Drum Corps activity (including current):__________________

2. Other types of group performance experience (check all that apply):

____High School Marching Band	Number of years ____
____College Marching Band	Number of years ____
____High School Indoor/Winter Drumline	Number of years ____
____High School Percussion ensemble (non-marching)	Number of years ____
____College Percussion ensemble (non-marching)	Number of years ____
____Jazz Band	Number of years ____
____Private lessons	Number of years ____
____Other small ensemble (please specify):	
__________________________	Number of years ____
__________________________	Number of years ____
____Other group (please specify):	
__________________________	Number of years ____
__________________________	Number of years ____

3. Primary instrument:__________________

4. Secondary instrument:_________________

5. Do you have haring loss or hearing problems (i.e., ringing sound in ears, difficulty hearing)?______If yes, please describe:

____

____

____

6. Please describe any very loud sounds that you have experienced during your life (e.g., gun shots, heavy machinery, concerts, etc.):

____

____

____

APPENDIX F

OBSERVATION FORM

SOUND-LEVEL EXPOSURE STUDY: DRUM CORPS MEMBER OBSERVATION FORM

DCM#:____________________ Date:____________________ Day#:_______

Type of instrumental group (please check one response listed below):

Battery Percussion Rehearsal:_____ Front Ensemble Rehearsal:_____
High Brass Rehearsal:_____ Middle Brass Rehearsal:_____
Low Brass Rehearsal:_____

Activity observation codes (to be used to indicate specific activity throughout the rehearsal day):

"FE" - Full Ensemble "SG" - Small Groups "FC" - Full Corps
"DR" - Drill "MU" - Music "O" - Other (explain)
"BR <5" - Break for less than 5 minutes (restroom, water, etc.)
"BR >5" - Break for less than 5 minutes (restroom, water, etc.)

TIME	**OBSERVATION OF REHEARSAL ACTIVITY**

(use the back of this sheet if necessary)

APPENDIX G

RESEARCHER CONFIDENTIALITY

THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

RESEARCH CONFIDENTIALITY AGREEMENT
FOR RESEARCH INVOLVING HUMAN SUBJECTS

I, ______________________________ **(print name)**, have agreed to serve as an observer and a data collection assistant for the research project entitled, *A descriptive study of sound level exposures of drum and bugle corps members during a typical full-day rehearsal.*

I agree not to discuss or disclose any of the content or personal information contained within the data, tapes, transcriptions or other research records with anyone other than the Principal Investigator, Doug Presley, and the Project Director, Patricia Sink. I agree to maintain confidentiality at all times and to abide by the UNCG Policy and Procedure for Ethics in Research and the UNCG Policy on the Protection of Human Subjects in Research.

____ ________________

Signature of Observer and Data-Collector Assistant Date

Principal Investigator: Doug Presley (336-334-3589, dlpresley@triad.rr.com)

Project Director: Patricia Sink (336-334-5469, psink@triad.rr.com)

APPENDIX H

SUBJECTS' DETAILED TIME HISTORY REPORT

Brass Subjects' Detailed Time History Report

Instrument: Trumpet 1

Dose Percentage: 502.72%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	67.7 dBA
Full Corps, marching	182	8%	79.6 dBA
Extended Break, lunch	64	0%	70.0 dBA
Large Group, music (warm-up)	29	7%	79.4 dBA
Small Group, music	51	65%	89.9 dBA
Large Group, music	41	64%	92.3 dBA
Large Group, marching and music	91	56%	91.9 dBA
Extended Break, Dinner	43	0%	72.9 dBA
Large Group, music	18	44%	86.2 dBA
Full Corps, marching and music, w/out pit	107	52%	93.3 dBA
Full Corps, marching and music, w/ pit	75	67%	92.9 dBA
TOTALS	735	33%	89.9 dBA

Instrument: Trumpet 2

Dose Percentage: 1005.43%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	66.7 dBA
Full Corps, marching	182	28%	84.8 dBA
Extended Break, lunch	64	5%	93.5 dBA

Large Group, music (warm-up)	29	10%	80.4 dBA
Small Group, music	51	57%	89.8 dBA
Large Group, music	41	68%	96.0 dBA
Large Group, marching and music	91	56%	94.8 dBA
Extended Break, Dinner	43	2%	75.0 dBA
Large Group, music	18	5%	78.4 dBA
Full Corps, marching and music, w/out pit	107	49%	95.5 dBA
Full Corps, marching and music, w/ pit	75	72%	95.8 dBA
TOTALS	735	37%	92.9 dBA

Instrument: Trumpet 3

Dose Percentage: 982.47%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	69.4 dBA
Full Corps, marching	182	32%	84.7 dBA
Extended Break, lunch	64	2%	73.8 dBA
Large Group, music (warm-up)	29	10%	79.7 dBA
Small Group, music	51	59%	91.7 dBA
Large Group, music	41	71%	96.0 dBA
Large Group, marching and music	91	54%	95.5 dBA
Extended Break, Dinner	43	0%	73.7 dBA
Large Group, music	18	28%	84.6 dBA
Full Corps, marching and music, w/out pit	107	50%	96.4 dBA
Full Corps, marching and music, w/ pit	75	48%	96.4 dBA
TOTALS	735	36%	92.8 dBA

Instrument: Trumpet 4

Dose Percentage: 895.74%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	67.6 dBA
Full Corps, marching	182	28%	83.8 dBA
Extended Break, lunch	64	2%	72.7 dBA
Large Group, music (warm-up)	29	17%	83.2 dBA
Small Group, music	51	47%	93.3 dBA
Large Group, music	41	73%	96.4 dBA
Large Group, marching and music	91	52%	94.0 dBA
Extended Break, Dinner	43	2%	75.6 dBA
Large Group, music	18	44%	86.7 dBA
Full Corps, marching and music, w/out pit	107	53%	94.7 dBA
Full Corps, marching and music, w/ pit	75	57%	96.8 dBA
TOTALS	735	36%	92.4 dBA

Instrument: Mellophone 1

Dose Percentage: 590.97%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	65.2 dBA
Full Corps, marching	182	6%	78.1 dBA
Extended Break, lunch	64	0%	61.8 dBA
Large Group, music (warm-up)	29	7%	78.8 dBA
Small Group, music	51	63%	92.7 dBA

Large Group, music	41	76%	96.4 dBA
Large Group, marching and music	91	62%	91.8 dBA
Extended Break, Dinner	43	0%	70.3 dBA
Large Group, music	18	44%	86.5 dBA
Full Corps, marching and music, w/out pit	107	49%	92.9 dBA
Full Corps, marching and music, w/ pit	75	68%	94.2 dBA
TOTALS	735	33%	90.6 dBA

Instrument: Mellophone 2

Dose Percentage: 648.19%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	63.5 dBA
Full Corps, marching	182	4%	78.2 dBA
Extended Break, lunch	64	0%	70.0 dBA
Large Group, music (warm-up)	29	7%	79.2 dBA
Small Group, music	51	65%	94.1 dBA
Large Group, music	41	71%	98.0 dBA
Large Group, marching and music	91	57%	91.1 dBA
Extended Break, Dinner	43	2%	78.0 dBA
Large Group, music	18	39%	85.6 dBA
Full Corps, marching and music, w/out pit	107	49%	92.2 dBA
Full Corps, marching and music, w/ pit	75	64%	94.3 dBA
TOTALS	735	32%	91.0 dBA

Instrument: Mellophone 3

Dose Percentage: 590.97%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	64.5 dBA
Full Corps, marching	182	9%	79.5 dBA
Extended Break, lunch	64	0%	67.9 dBA
Large Group, music (warm-up)	29	4%	80.2 dBA
Small Group, music	51	67%	93.5 dBA
Large Group, music	41	71%	95.7 dBA
Large Group, marching and music	91	54%	91.8 dBA
Extended Break, Dinner	43	0%	68.8 dBA
Large Group, music	18	39%	86.4 dBA
Full Corps, marching and music, w/out pit	107	50%	91.9 dBA
Full Corps, marching and music, w/ pit	75	67%	93.5 dBA
TOTALS	735	33%	90.6 dBA

Instrument: Mellophone 4

Dose Percentage: 816.67%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	70.0 dBA
Full Corps, marching	182	4%	77.5 dBA
Extended Break, lunch	64	3%	75.5 dBA
Large Group, music (warm-up)	29	7%	77.7 dBA
Small Group, music	51	47%	97.2 dBA

Large Group, music	41	71%	97.8 dBA
Large Group, marching and music	91	62%	92.8 dBA
Extended Break, Dinner	43	2%	71.0 dBA
Large Group, music	18	6%	77.3 dBA
Full Corps, marching and music, w/out pit	107	51%	94.0 dBA
Full Corps, marching and music, w/ pit	75	71%	94.3 dBA
TOTALS	735	31%	92.0 dBA

Instrument: Euphonium 1

Dose Percentage: 399.01%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	65.0 dBA
Full Corps, marching	182	6%	78.4 dBA
Extended Break, lunch	64	0%	62.4 dBA
Large Group, music (warm-up)	29	7%	78.9 dBA
Small Group, music	51	63%	93.3 dBA
Large Group, music	41	63%	93.0 dBA
Large Group, marching and music	91	51%	87.2 dBA
Extended Break, Dinner	43	2%	75.4 dBA
Large Group, music	18	0%	74.9 dBA
Full Corps, marching and music, w/out pit	107	62%	89.7 dBA
Full Corps, marching and music, w/ pit	75	68%	94.5 dBA
TOTALS	735	32%	88.9 dBA

Instrument: Euphonium 2

Dose Percentage: 368.22%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	66.3 dBA
Full Corps, marching	182	23%	83.4 dBA
Extended Break, lunch	64	8%	93.4 dBA
Large Group, music (warm-up)	29	3%	74.9 dBA
Small Group, music	51	69%	95.4 dBA
Large Group, music	41	66%	93.1 dBA
Large Group, marching and music	91	58%	89.1 dBA
Extended Break, Dinner	43	2%	76.7 dBA
Large Group, music	18	39%	86.0 dBA
Full Corps, marching and music, w/out pit	**24**	**47%**	**87.1 dBA**
Full Corps, marching and music, w/ pit	**0**	**0%**	**-----**
TOTALS	577	31%	89.6 dBA

Note: The activities marked in bold indicates when the doseBadge malfunction occurred for this subject resulting in incomplete data.

Instrument: Baritone 1

Dose Percentage: 1389.42%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	64.4 dBA
Full Corps, marching	182	5%	80.0 dBA
Extended Break, lunch	64	3%	74.4 dBA
Large Group, music (warm-up)	29	10%	84.4 dBA

Small Group, music	51	61%	96.3 dBA
Large Group, music	41	68%	97.9 dBA
Large Group, marching and music	91	59%	96.4 dBA
Extended Break, Dinner	43	7%	72.5 dBA
Large Group, music	18	44%	88.3 dBA
Full Corps, marching and music, w/out pit	107	65%	97.6 dBA
Full Corps, marching and music, w/ pit	75	65%	98.0 dBA
TOTALS	735	35%	94.3 dBA

Instrument: Baritone 2

Dose Percentage: 895.74%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	70.5 dBA
Full Corps, marching	182	16%	84.6 dBA
Extended Break, lunch	64	3%	78.5 dBA
Large Group, music (warm-up)	29	10%	83.1 dBA
Small Group, music	51	67%	95.9 dBA
Large Group, music	41	63%	97.9 dBA
Large Group, marching and music	91	67%	94.4 dBA
Extended Break, Dinner	43	23%	93.1 dBA
Large Group, music	18	56%	89.4 dBA
Full Corps, marching and music, w/out pit	107	59%	94.9 dBA
Full Corps, marching and music, w/ pit	75	76%	94.7 dBA
TOTALS	735	40%	92.9 dBA

Instrument: Contra 1

Dose Percentage: 633.38%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	69.3 dBA
Full Corps, marching	182	26%	85.2 dBA
Extended Break, lunch	64	1%	90.3 dBA
Large Group, music (warm-up)	29	10%	81.0 dBA
Small Group, music	51	53%	86.0 dBA
Large Group, music	41	61%	91.2 dBA
Large Group, marching and music	91	67%	93.7 dBA
Extended Break, Dinner	43	7%	79.8 dBA
Large Group, music	18	33%	85.9 dBA
Full Corps, marching and music, w/out	107	62%	95.0 dBA
Full Corps, marching and music, w/ pit	75	65%	93.0 dBA
TOTALS	735	39%	90.9 dBA

Instrument: Contra 2

Dose Percentage: 480.02%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	66.5 dBA
Full Corps, marching	182	13%	79.8 dBA
Extended Break, lunch	64	0%	70.7 dBA
Large Group, music (warm-up)	29	3%	76.1 dBA
Small Group, music	51	18%	82.3 dBA

Large Group, music	41	61%	90.1 dBA
Large Group, marching and music	91	85%	93.1 dBA
Extended Break, Dinner	43	5%	75.8 dBA
Large Group, music	18	11%	78.9 dBA
Full Corps, marching and music, w/out pit	107	56%	95.0 dBA
Full Corps, marching and music, w/ pit	75	65%	90.6 dBA
TOTALS	735	30%	89.7 dBA

Instrument: Contra 3

Dose Percentage: 551.39%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	71.5 dBA
Full Corps, marching	182	14%	81.6 dBA
Extended Break, lunch	64	0%	69.9 dBA
Large Group, music (warm-up)	29	14%	79.2 dBA
Small Group, music	51	20%	81.6 dBA
Large Group, music	41	73%	90.9 dBA
Large Group, marching and music	91	65%	93.6 dBA
Extended Break, Dinner	43	0%	72.8 dBA
Large Group, music	18	33%	86.9 dBA
Full Corps, marching and music, w/out pit	107	52%	95.1 dBA
Full Corps, marching and music, w/ pit	75	68%	92.3 dBA
TOTALS	735	33%	90.3 dBA

Instrument: Contra 4

Dose Percentage: 633.38%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Large Group, marching	34	0%	63.5 dBA
Full Corps, marching	182	23%	84.0 dBA
Extended Break, lunch	64	0%	69.7 dBA
Large Group, music (warm-up)	29	7%	79.9 dBA
Small Group, music	51	41%	84.3 dBA
Large Group, music	41	64%	91.1 dBA
Large Group, marching and music	91	66%	94.4 dBA
Extended Break, Dinner	43	0%	73.5 dBA
Large Group, music	18	33%	83.8 dBA
Full Corps, marching and music, w/out	107	55%	95.3 dBA
Full Corps, marching and music, w/ pit	75	67%	93.4 dBA
TOTALS	735	36%	90.9 dBA

Percussion Subjects' Time History Report

Instrument: Snare Drum 1

Dose Percentage: 8822.29%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	66%	103.4 dBA
Small Group, marching and music	133	62%	98.3 dBA
Small Group, by instrument	28	93%	105.3 dBA
Small Group, all battery	19	95%	108.3 dBA
Extended Break, Lunch	55	13%	89.0 dBA
Small Group, by instrument	97	78%	105.0 dBA
Large Group	84	89%	101.2 dBA
Full Corps, music	34	59%	104.1 dBA
Extended Break, Dinner	37	3%	76.8 dBA
Small Group, by instrument	29	72%	90.0 dBA
Small Group, all battery	20	90%	106.0 dBA
Full Corps, marching and music	152	57%	103.1 dBA
TOTALS	735	63%	102.3 dBA

Instrument: Snare Drum 2

Dose Percentage: 9455.49%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	60%	104.0 dBA

Small Group, marching and music	133	53%	97.7 dBA
Small Group, by instrument	28	93%	106.8 dBA
Small Group, all battery	19	90%	110.1 dBA
Extended Break, Lunch	55	13%	92.0 dBA
Small Group, by instrument	97	71%	104.7 dBA
Large Group	84	88%	101.7 dBA
Full Corps, music	34	68%	103.9 dBA
Extended Break, Dinner	37	0%	76.3 dBA
Small Group, by instrument	29	70%	101.8 dBA
Small Group, all battery	20	90%	106.8 dBA
Full Corps, marching and music	152	57%	102.8 dBA
TOTALS	735	60%	102.6 dBA

Instrument: Snare Drum 3

Dose Percentage: 9154.99%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	68%	104.0 dBA
Small Group, marching and music	133	14%	88.9 dBA
Small Group, by instrument	28	96%	108.3 dBA
Small Group, all battery	19	95%	111.2 dBA
Extended Break, Lunch	55	7%	86.8 dBA
Small Group, by instrument	97	71%	105.3 dBA
Large Group	84	88%	102.4 dBA
Full Corps, music	34	68%	104.2 dBA
Extended Break, Dinner	37	0%	75.3 dBA
Small Group, by instrument	29	55%	103.6 dBA

Small Group, all battery	20	100%	107.1 dBA
Full Corps, marching and music	**51**	**49%**	**103.1 dBA**
TOTALS	624	52%	103.1 dBA

Note: The doseBadge malfunctioned during that rehearsal activity for the day resulting in an incomplete reading.

Instrument: Snare Drum 4

Dose Percentage: 5319.92%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	62%	101.3 dBA
Small Group, marching and music	133	59%	96.2 dBA
Small Group, by instrument	28	93%	103.9 dBA
Small Group, all battery	19	90%	107.2 dBA
Extended Break, Lunch	55	9%	90.1 dBA
Small Group, by instrument	97	70%	102.0 dBA
Large Group	84	85%	99.0 dBA
Full Corps, music	34	62%	102.9 dBA
Extended Break, Dinner	37	0%	72.7 dBA
Small Group, by instrument	29	55%	99.7 dBA
Small Group, all battery	20	95%	103.0 dBA
Full Corps, marching and music	152	59%	100.9 dBA
TOTALS	735	60%	100.2 dBA

Instrument: Tenor Drum 1

Dose Percentage: 4422.12%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	47%	99.7 dBA
Small Group, marching and music	133	53%	95.2 dBA
Small Group, by instrument	28	96%	101.8 dBA
Small Group, all battery	19	95%	108 dBA
Extended Break, Lunch	55	9%	90.8 dBA
Small Group, by instrument	97	75%	101.0 dBA
Large Group	84	89%	98.2 dBA
Full Corps, music	34	62%	102.0 dBA
Extended Break, Dinner	37	0%	74.2 dBA
Small Group, by instrument	29	72%	98.0 dBA
Small Group, all battery	20	85%	103.0 dBA
Full Corps, marching and music	152	55%	99.6 dBA
TOTALS	735	59%	99.4 dBA

Instrument: Tenor Drum 2

Dose Percentage: 3939.66%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	49%	99.7 dBA
Small Group, marching and music	133	53%	95.0 dBA
Small Group, by instrument	28	93%	102.7 dBA
Small Group, all battery	19	100%	106.5 dBA

Extended Break, Lunch	55	13%	90.5 dBA
Small Group, by instrument	97	78%	100.9 dBA
Large Group	84	87%	97.3 dBA
Full Corps, music	34	62%	101.9 dBA
Extended Break, Dinner	37	0%	74.8 dBA
Small Group, by instrument	29	79%	98.6 dBA
Small Group, all battery	20	90%	102.8 dBA
Full Corps, marching and music	152	63%	99.1 dBA
TOTALS	735	62%	98.9 dBA

Instrument: Bass Drum 1

Dose Percentage: 4850.29%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	64%	100.6 dBA
Small Group, marching and music	133	54%	94.4 dBA
Small Group, by instrument	28	36%	82.9 dBA
Small Group, all battery	19	95%	108.2 dBA
Extended Break, Lunch	55	1%	94.1 dBA
Small Group, by instrument	97	72%	102.3 dBA
Large Group	84	87%	97.5 dBA
Full Corps, music	34	62%	101.5 dBA
Extended Break, Dinner	37	14%	84.1 dBA
Small Group, by instrument	29	79%	103.4 dBA
Small Group, all battery	20	90%	103.6 dBA
Full Corps, marching and music	152	56%	99.6 dBA
TOTALS	735	58%	99.8 dBA

Instrument: Bass Drum 2

Dose Percentage: 1392.88%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group, all battery	47	40%	93.5 dBA
Small Group, marching and music	133	33%	88.1 dBA
Small Group, by instrument	28	11%	80.6 dBA
Small Group, all battery	19	95%	103.9 dBA
Extended Break, Lunch	55	2%	89.7 dBA
Small Group, by instrument	97	77%	97.3 dBA
Large Group	84	69%	91.6 dBA
Full Corps, music	34	62%	98.2 dBA
Extended Break, Dinner	37	16%	89.5 dBA
Small Group, by instrument	29	79%	95.6 dBA
Small Group, all battery	20	90%	97.5 dBA
Full Corps, marching and music	152	51%	94.1 dBA
TOTALS	735	49%	94.4 dBA

Instrument: Front Ensemble Percussion 1

Dose Percentage: 1212.57%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	49%	87.8 dBA
Extended Break, Lunch	62	2%	75.4 dBA
Small Group	97	54%	93.3 dBA
Large Group	84	99%	95.6 dBA

Small Group	35	71%	90.4 dBA
Extended Break, Dinner	37	0%	72.9 dBA
Small Group	21	29%	85.3 dBA
Large Group, w/ brass, no battery	32	53%	87.6 dBA
Full Corps	152	61%	98.6 dBA
TOTALS	735	52%	93.8 dBA

Instrument: Front Ensemble Percussion 2

Dose Percentage: 1212.57%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	61%	90.2 dBA
Extended Break, Lunch	62	2%	73.6 dBA
Small Group	97	64%	92.8 dBA
Large Group	84	89%	95.4 dBA
Small Group	35	77%	90.4 dBA
Extended Break, Dinner	37	0%	72.2 dBA
Small Group	21	29%	85.4 dBA
Large Group, w/ brass, no battery	32	56%	87.8 dBA
Full Corps	152	63%	98.3 dBA
TOTALS	735	57%	93.8 dBA

Instrument: Vibraphone 1

Dose Percentage: 1269.92%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	48%	88.3 dBA
Extended Break, Lunch	62	3%	72.2 dBA
Small Group	97	42%	90.2 dBA
Large Group	84	91%	97.1 dBA
Small Group	35	74%	89.2 dBA
Extended Break, Dinner	37	0%	69.4 dBA
Small Group	21	5%	81.0 dBA
Large Group, w/ brass, no battery	32	50%	87.2 dBA
Full Corps	152	63%	98.7 dBA
TOTALS	735	49%	94.0 dBA

Instrument: Vibraphone 2

Dose Percentage: 2481.83%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	49%	88.8 dBA
Extended Break, Lunch	62	2%	71.7 dBA
Small Group	97	44%	91.9 dBA
Large Group	84	91%	99.5 dBA
Small Group	35	66%	89.7 dBA
Extended Break, Dinner	37	0%	72.1 dBA
Small Group	21	38%	84.8 dBA

Large Group, w/ brass, no battery	32	47%	87.8 dBA
Full Corps	152	61%	102.2 dBA
TOTALS	735	50%	96.9 dBA

Instrument: Vibraphone 3

Dose Percentage: 897.97%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	42%	86.6 dBA
Extended Break, Lunch	62	2%	73.6 dBA
Small Group	97	49%	89.3 dBA
Large Group	84	93%	94.1 dBA
Small Group	35	63%	89.1 dBA
Extended Break, Dinner	37	3%	80.5 dBA
Small Group	21	24%	82.3 dBA
Large Group, w/ brass, no battery	32	34%	84.2 dBA
Full Corps	152	61%	97.6 dBA
TOTALS	735	48%	92.5 dBA

Instrument: Marimba

Dose Percentage: 1157.82%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	47%	87.4 dBA
Extended Break, Lunch	62	2%	72.4 dBA

Small Group	97	53%	92.0 dBA
Large Group	84	85%	95.0 dBA
Small Group	35	74%	94.3 dBA
Extended Break, Dinner	37	0%	71.3 dBA
Small Group	21	38%	82.4 dBA
Large Group, w/ brass, no battery	32	41%	86.7 dBA
Full Corps	152	60%	98.4 dBA
TOTALS	735	49%	93.6 dBA

Instrument: Timpani

Dose Percentage: 1105.53%

Detailed Time History Report

Activity	Duration (minutes)	% of L_{eq} Exceeding 83.5 dBA	L_{eq} for Rehearsal Activity
Small Group	215	32%	92.9 dBA
Extended Break, Lunch	62	8%	80.1 dBA
Small Group	97	51%	91.3 dBA
Large Group	84	85%	95.0 dBA
Small Group	35	63%	85.0 dBA
Extended Break, Dinner	37	0%	76.9 dBA
Small Group	21	29%	83.2 dBA
Large Group, w/ brass, no battery	32	25%	83.4 dBA
Full Corps	152	61%	97.2 dBA
TOTALS	735	44%	93.4 dBA