Schools of music and conservatories and hearing loss prevention

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Abstract

Music students are not being taught that music is a sound source capable of harming hearing. Ensemble directors of public school and college bands, orchestras, and choirs, are unaware and unprepared to recognize and manage risk from excessive sound exposures. Schools of music and conservatories around the world, and the organizations that accredit them, need to embrace the idea that schools of music are best suited to facilitate change, conduct research, create and impart knowledge, institute competency, and most importantly, cultivate a culture of responsibility and accountability throughout the music discipline. By drawing attention to actions pursued at and through the College of Music at the University of North Texas, the purpose of this paper is to encourage change and to assist others in efforts to reach the best conditions for preventing irreversible hearing disorders associated with music.

Key Words: Earplugs; musicians; music; college; students

Introduction

Music helps celebrate and preserve our cultural heritages while allowing us to explore the realms of expression and imagination. Professional organizations like the National Association for Music Education (MENC) advocate that every young American be guaranteed the opportunity to learn music and to share in musical experiences (MENC, 2010). The credo of the Association of European Conservatories, a European cultural and educational network with more than 273 member institutions for professional music training in 55 countries, declares the importance of music in all levels of education in our society, ranging from early childhood to higher education and lifelong learning (AEC, 2000). In support of music education worldwide, the International Society for Music Education (ISME) maintains that access for all people to music learning opportunities and to participate actively in various aspects of music is essential for the wellbeing of the individual and society (ISME, 2006). These goals have resulted in educational opportunities designed to shape the musical comprehension for a vast number of people.

In order to preserve and advance this rich heritage, professional associations impose stringent training requirements for those seeking to become music professionals. In the United States, over 600 schools of music are accredited by the National Association of Schools of Music (NASM) which was founded in 1924 for the purpose of developing and maintaining basic threshold standards for the granting of degrees and other credentials (NASM, 2003). Annually, NASM accredited schools of music serve about 100,000 young adults. Curricular structures within these schools of music are based on accreditation standards and are designed to ensure the development of a range of knowledge, skills, and competencies expected of the music professional. Through a peer review process of accreditation that uses national standards to characterize basic requirements and conditions for the study of music, the standards have a definitive impact on curriculum and subsequent knowledge base of students educated by...
With a lack of knowledge and skills to deal with these issues, trained music professionals are unlikely to recognize hazardous conditions, speak up about safety, teach this concern to others, or to engage in preventative and protective behaviors. Adding to this dilemma, the technical means to measure and understand risk levels from musical activities are underdeveloped. And in the event that sound levels produced during educational activities are known to be risky, evidenced-based solutions for intervention are largely absent. Some educators may assume that adjustment to the intensity levels produced during ensemble-based instructional activities compromises the effectiveness of the educational experience. In my view, this ongoing scenario is unacceptable.

To address these deficiencies, schools of music and conservatories around the world, and the organizations that accredit them, need to embrace the idea that schools of music are best suited to facilitate change, conduct research, create and impart knowledge, institute competency, and most importantly, cultivate a culture of responsibility and accountability throughout the music discipline (Chesky et al, 2008). By drawing attention to actions pursued at and through the College of Music (COM) at the University of North Texas (UNT), the purpose of this paper is to encourage change and to assist others in their own efforts to reach the best conditions for preventing irreversible hearing disorders associated with music.

### The health promotion in schools of music project (HPSM)

Several grant applications were written in 2003 that stressed the need to prevent performance injuries in NASM schools of music. Funding was secured from the National Endowment for the Arts, the Grammy Foundation, and others to develop the health promotion in schools of music (HPSM) project (HPSM, 2005). By design, this project integrated consensus building activities for five working groups of experts, a three-day national conference, and a specific goal of disseminating recommendations to NASM. After extensive debate and review, HPSM recommendations were disseminated in 2006 to NASM board of directors, local chairs/deans of all NASM schools of music across the United States and then published as a special article in the Medical Problems of Performing Artists journal (Chesky et al, 2006). HPSM recommendations included the following declarations and recommendations. (pp. 142–143)

- **Performance injuries are preventable.** A holistic approach that encourages wellness and personal responsibility is necessary for prevention. Schools of music should focus on prevention education in addition to supporting efforts directed at treating diseases once they have occurred.

- **Schools of music do influence student behaviors through factors such as collective values, beliefs, and actions.** These factors need to be considered and modified as crucial first steps toward reducing the rate and severity of performance injuries. A health promotion framework offers a common philosophical and practical basis for such efforts and would allow for effective and sustainable prevention-oriented educational efforts.

- **Without diminishing the concerns for musculoskeletal, vocal, and mental health, schools of music should recognize that noise-induced hearing loss is a widespread and serious public health issue and that music is always implicated as a causal factor.** This problem receives little or no recognition in schools of music. A high priority strategy is needed for informing all music students about the risks for noise-induced hearing loss.
Because many of the physical, psychological, and sociological determinants for performance injuries are well established before young musicians attend college, schools of music must prepare health-conscious music educators and produce injury-free musicians. Music education faculty must acknowledge the possible negative consequences of learning and performing music and prepare future teachers accordingly.

HPSM recommendations for action included a call for NASM accredited schools to offer coursework that covers occupational health concerns and that music students be routinely informed and educated about hearing loss prevention as part of ensemble-based instruction. Soon after the HPSM recommendations were disseminated, two professional music education organizations responded with requests for help to develop official health position statements for their respective memberships. These statements include similar language to HPSM and are posted on the websites of McNC: National Association for Music Education (MCN, 2008), and Music Teachers National Association (MTNA, 2008).

HPSM provided a platform for developing and disseminating an expert and consensus-based set of recommendations directly to NASM and NASM Schools of Music. The experts involved agreed that hearing health should be a prioritized issue and dealt with in all music education contexts. HPSM recommendations have helped guide certain schools of music to become health promoting as defined by the World Health Organization (WHO, 2009) and contributed to defining problems while providing the basis for developing local, regional, and national actions. The outcomes of HPSM are attributable to the generous support of funding agencies, partnering organizations, and the tremendous dedication and hard work of numerous individuals. Profiles are available on the HPSM website (HPSM, 2005).

The UNT College of Music leads by example

In response to the HPSM recommendations, an internal Safety in Instructional Activities policy was applied to all ensemble-based music courses offered by the UNT College of Music (COM). The purpose and scope of the policy are to assure a safe teaching environment at UNT and to establish a review procedure by which safety in instructional activities will be achieved (UNT, 2008). The COM applied this policy by labeling all ensemble-based classes as a Category 2 in a three level rating scale. The faculty member teaching a Category 2 level class is responsible for explaining applicable safety considerations at the beginning of each term and to reiterate such considerations as appropriate throughout each term. Therefore, every student enrolled in any UNT music ensemble based course attends a lecture from the instructing faculty about hearing conservation at the beginning of each semester. To my knowledge, UNT is the first and only NASM accredited school of music to officially label ensemble-based educational classes as risky to hearing due to the potential for excessive sound levels created during educational activities, and to adopt such a policy.

To help implement this policy, the National Hearing Conservation Association (NHCA) Taskforce on Music-Induced Hearing Loss (Brian Fligor (chair), Marshall Chasin, Kris Chesky, Lee Hager, Michael Santucci, and Laurie Wells) assisted in the development of educational goals and objectives as both a resource for UNT faculty and other accredited schools of music and conservatories. An article describing the UNT policy and consensus-based supporting materials was published in Hearing Review (Chesky, 2006). An educational video of Dr. John Murphy (chair of UNT’s Division of Jazz Studies) delivering the education-based intervention was produced by UNT Texas Center for Music & Medicine (TCMM) in order to showcase the potential ease, effectiveness, and direct personal nature of this simple and inexpensive education-based intervention. The video is free and available online (TCMM, 2008; http://media.unt.edu:8080/ramen/cdl/MUAG1500/video/hearing_loss_ensemble.rm).

Also in response to the HPSM recommendations, a new UNT undergraduate course was designed and proposed titled: ‘Occupational Health; Lessons from Music’. The course is open to all UNT students regardless of major and satisfies university core curriculum credit. It was first offered in 2006 and has served approximately two thousand students. One fourth of this three credit hour course focuses on hearing health and hearing conservation. Students learn that music is a sound source capable of permanently harming human hearing, how hearing is permanently damaged from excessive sound exposures, health and safety standards and procedures related to noise exposure, and how music can be learned, taught, performed, and consumed in ways that are not risky to hearing. Students are shown an educational video designed to encourage them to get a free hearing exam (TCMM, 2007a) which is offered to students through a multi-disciplinary partnership with the UNT Speech and Hearing Department.

The course was recently approved to fulfill a new entry-level university core category that will come into effect for the 2011 fall semester, increasing the likelihood that this course will become mandatory for all UNT undergraduate students majoring in music. Information about this course has been distributed widely and used as a precedent and model for other schools of music across the United States and the European Union. A profile of these education-based efforts can be viewed online (Rossetti, 2008). Samples of related activities include a guide for professional music educators (Chesky, 2008a) and a video of a 5th grade music educator teaching children about NIHL (TCMM, 2007b).

Research developments

Prevalence of hearing problems

Research regarding musician populations is small and insufficient. In general, musicians are an underserved population and occupational health of music professionals is an understudied topic. Research efforts conducted at UNT are ongoing and have included epidemiological and attitudinal surveys of musicians. For example, one study funded by the Grammy Foundation examined the prevalence of self-reported hearing problems among a heterogeneous group of musicians as a function of both primary performance area and primary instrument (Chesky & Henoch, 2000). Results showed that 21.7% of the 3292 musicians responding perceived having a problem with hearing with the highest rate of occurrence in rock/alternative musicians; in musicians who were included in the non-classical grouping; and in musicians who played amplified instruments, drum-set, and primary brass instruments. For most instruments, comparisons showed that non-classical musicians reported a higher rate of occurrence for hearing problems. For instance, 28.1% of the classical trombonists reported problems with hearing compared with 44% of the non-classical trombonists. Similar differences can be seen between non-classical and classical musicians whose primary instrument is acoustic bass (28.8% vs 7.4%), acoustic guitar (15.4% vs 5.3%), clarinet (28% vs 15.6%), trumpet (37.8% vs 25.4%), and voice (21.3% vs 13.4%)

Attitudes of music students

Another study assessed the attitudes of music majors toward noise and compared them to students not majoring in music (Chesky et al, 2009). Participants (N = 467) filled out a questionnaire designed to
assess attitudes toward noise in youth culture and attitudes toward personal influence of their sound environment. Results showed that students majoring in music have a healthier attitude toward sound compared to students not majoring in music. Findings also showed that music majors are more aware and attentive to noise in general, likely to perceive sound that may be risky to hearing as something negative, and are more likely to carry out behaviors to decrease personal exposure to loud sounds. Due to these differences, music majors may be more likely than other students to respond to education and benefit from a hearing loss prevention program.

Hearing protection

A call for research on hearing protectors emerged from the 2007 NHCA conference session organized by Dr. Brian Fligor (Santuichi et al., 2007). This session was presented as a debate and focused on the pros and cons of flat frequency attenuating earplugs (also commonly called ‘musician earplugs’) and whether they should be universally recommended for musicians. Recognizing inadequate research on this topic, one outcome of this conference session was a call for prospective field studies of flat frequency attenuating earplugs with musicians. In response, the UNT field study of flat attenuating earplugs was published in 2009 (Chesky et al., 2009). The purpose of this study was to evaluate and compare how college music majors responded to using ER20 earplugs (Etymotic Research, Elk Grove Village, Illinois, USA). The specific aims were to determine the influences of earplugs on changes in perception and abilities to communicate in a high intensity musical environment, attitudes and perceptions towards earplugs, and short-term comfort and changes in comfort over time. Following an adaptation period of up to two weeks, this study also assessed the influence of these earplugs on the music students’ perceived ability to play music. A total of 323 college students participated in this study and the results confirmed the general principle that earplugs can be challenging for the user, especially when used in environments that are both loud and require verbal interaction. In response to using the ER20 earplugs while performing music, the students reported decreases in abilities to hear self, hear others, and to communicate musically. Additional field studies are needed to further understand why musicians report that they rarely use hearing protectors when they play music (Laitinen & Poulsen, 2008; Laitinen, 2005; Emmerich et al., 2008).

Exposure assessment

Little is known about actual sound levels and associate risk indices generated in schools of music. This deficiency seriously restricts opportunities to establish hearing loss prevention programs. Without such evidence, recommendations for action can be and are often baseless, speculative, and in some cases, biased. To address this problem, a research program was designed and implemented with the intent to develop the largest database of noise dosimeter data ever collected from routinely occurring musical events in a college school of music environment. In UNT classrooms where ensemble-based instructional activities routinely meet, noise dosimeters (Model #703+, Larson Davis, Provo, Utah, USA) were installed to run for ten hours per day over a two semester time frame. Data were downloaded every 24 hours and transferred to a designated host computer and then systematically organized into corresponding instructional activities. One data base was developed to manage typical industrial-based noise dosimeter indices for each class period as listed in the university course catalogue. Most events (classes) were 50 minutes long. A second time series database was established and included quantitative indices for each second of each event. At the end of a full academic year, the first data base (aggregate view) grew to include 666 individual instructional events (classes). This data set allowed for an examination of dose levels across rooms, ensemble types, and over time for individual courses.

Preliminary results demonstrated that ensemble-based instructional activities within the UNT College of Music, an NASM accredited school of music, can and do exceed threshold values that warrant concern and intervention. Using the criteria specified by NIOSH in 1998 (3 dB exchange rate, 80 dBA threshold, 85 dBA criterion level) about 40% (N = 242/666 individual events) exceeded 100% dose (Chesky & Araujo, 2008). Because this data set included routine measurements over time, across ensembles, rooms, etc., we were able to observe that dose levels for these instructional activities are highly variable over time for both the same and different ensemble-based class activities. This general finding suggests that the differences are linked to behavioral factors including the pedagogical approach of the instructor.

To explore this further, a basic model was developed for transforming time series data (dBAleq/s) into graphical representations suitable for comparisons across events and as the basis for modification to how students are instructed during this type of class activity. These ideas were presented during the NIOSH D.R.E.A.M. Workshop (Chesky, 2008) and, according to feedback from several individual ensemble instructors, offer practical benefits due to being able to see and understand important details about what happened during their classes, including information regarding the frequencies of time spent at various music dynamic levels. Subsequently, time series data were used to calculate measures of moments (skewness, kurtosis, Gini index), maximum and peak sound pressure levels (LMax, LPeak), dispersion (coefficient of variation), and percent of time playing for each event. Once calculated, these summary indices were then transferred back to the aggregate (per event) database and used for regression modeling with dose as the dependent variable. A detailed application of this approach to wind band ensemble-based learning activities was recently reported in the Medical Problems of Performing Artists journal (Chesky, 2010).

Direct reading assessment methodologies

Our data set makes obvious what musicians and music teachers already understand and value: that music is fundamentally human expression and therefore highly dependent on decisions made by individuals. This data set also shows that single risk indexes derived from a single event are not sufficient representations of what happens over time during ensemble-based instructional activities in schools of music or for understanding factors related to elevated levels. Because dose levels measured during ensemble-based instructional activities are highly variable over time and traceable to behavioral factors and the pedagogic approach of the instructors, there is an essential role in schools of music for routine and continuous noise exposure assessment. However, existing noise dosimeter technologies were not designed for this unique application and if used routinely would require an unsustainable commitment of manpower and computing resources. For this to be feasible and effective, sound assessment technologies must be simpler to employ, automated, and able to provide more relevant and timely information.

To help solve this dilemma, UNT is working on methods for routinely collecting and reporting sound data that separates the software and hardware components of the traditional dosimeter. This project is
in its infancy but shows promise for automated tracking of exposure levels, while at the same time offering students and teachers meaningful insight about the sound levels they produce during instruction activities. The goal is to develop a system that supports our efforts to increase awareness and knowledge, supports our efforts toward developing student and faculty competency to manage risk, and to ensure institutional accountability.

Discussion

Theorists in social epidemiology have utilized the image of a running river to metaphorically describe a chain and range of causal influences from individual factors to distal social factors. One approach uses the surface water to represent the flowing and dynamic nature of human behaviors that can be conceptualized at the individual or population level (Glass & McAtee, 2006). Time is depicted along a horizontal axis and used to examine life course factors from birth to death. A nested hierarchy of systems are depicted vertically, from genes, to cells and organs (under the water features), to ever increasing larger social factors that are external to the individual (above the water). This metaphor emphasizes a contextual rather than mechanistic orientation to health and considers causal inferences as they relate to social phenomenon.

Towards the top of the vertical hierarchy (macro-level), governments (and related national/state and large area dynamics) frequently function as risk regulators by establishing laws designed to constrain adverse conditions on behalf of the general public. In order to lessen the social, economic, and public health burden related to hearing loss, governments in many regions of the world regulate working conditions by setting and enforcing standards designed to protect workers from various hazards including excessive exposure to noise. These processes involve risk assessment, engineering controls, worker training, outreach, education and assistance.

In the United States, the Occupational Safety and Health Administration (OSHA), the Mine Safety and Health Administration (MSHA), and the Federal Railroad Administration (FRA) require employers to determine if workers are exposed to excessive noise in the workplace. If so, employers must implement feasible engineering or administrative controls to eliminate or reduce the likelihood of harm. Where controls are not sufficient, employers must implement an effective hearing conservation program. However, this regulatory oversight is rarely applied to music or musical activities. A letter written in 1983 and archived on the OSHA website asserts that exposure to loud music in places of entertainment is a matter of choice, and that exposure of musicians to noise in such establishments is also a matter of choice, as in the loudness of the music they play (Hillenbrand, 1983).

In contrast, the European Parliament and the Council of the European Union adopted measures in 2003 (DIRECTIVE 2003/10/EC) designed to protect citizens from the risks arising from noise exposure and damage to hearing (European Parliament and The Council of The European Union, 2003). This directive called on Member States to develop a code of conduct providing for practical guidelines to help workers in the music and entertainment sectors. In response, the Control of Noise at Work Regulations in the UK came into force on April 2008 for the music and entertainment sector, and applies to all workplaces where live or recorded music is produced. Since 2008, cases of symphony orchestras exceeding the EU regulation have been profiled in various media outlets including the New York Times (Lyall, 2008), the Telegraph (Wilson, 2008), and the Times (Craine, 2008). These stories showcase the dilemmas inherent in government regulation of artistic expression. And even though these laws do cover schools, there is no indication of a specific reaction, position statement, or policy from the AEC in response to the new EU Directive. Regardless, some schools of music are endeavouring to be proactive. For example, the Royal Academy of Music in London is adding mandatory hearing tests for students to a Noise Management Program (White, 2009).

Considering a life course perspective for many musicians, the acquisition of knowledge and skills often begins at a very young age. Starting as early as pre-school levels, private and public school music teachers influence the values, beliefs, and behaviors of young musicians. Students interested in majoring in music at the college level must audition for acceptance. Once admitted, students start to embody the collective values, beliefs, and actions that characterize these institutions.

Placed under the macro level, Glass & McAtee (2006) use the term ‘mezzo-level’ to label schools and communities on the vertical hierarchy of social forces that can or may influence behaviors related to various public health concerns. As emphasized throughout this paper, it is my belief that musicians should be educated early and often about music and its relationship to hearing health. Looking forward, I believe that a fundamental change is necessary at the school levels (mezzo level), regardless of whether governments regulate noise levels produced during musical events or not. It is essential that all music professionals be trained to appreciate these concerns as early as possible and to eventually possess a level of competency appropriate for managing the risks associated with their artistic and educational activities. Furthermore, fundamental changes at the school of music level will influence the existing lack of interest, interdisciplinary dialogue, and knowledge sharing within and between schools of music about this topic. Attitudes among school of music administrators and faculty do influence potential growth, research, and the testing of ideas and possible solutions.

Associations like NASM and AEC are guardians of important values, work, and aspirations in the field of music, including many important relationships in and for music. Establishing a culture of responsibility and accountability related to hearing health through changes to accreditation standards is absolutely compatible with these deeply-held values. In addition to advising instructors of ensemble-based instructional activities to consider and respond to risks associated with ensemble-based instructional activities, accrediting associations must recognize the broad and profound public health benefits of preparing music students to meet these challenges as responsible professionals. Parallels and precedence for such actions exist in other arts areas with comparable concerns. For instance, the Accreditation Handbook of the National Association of Schools of Art and Design (NASAD, 2009–2010) lists ‘A working knowledge of legal codes and regulations related to construction, environmental systems, and human health and safety, and the ability to apply such knowledge appropriately in specific project programs’ (p. 99) as essential competencies for art students majoring in interior design. Stated in the Accreditation Handbook of the National Association of Schools of Dance (NASD, 2009–2010), students preparing for careers as dance teacher ‘develop a physical and conceptual understanding of movement and its expressive possibilities, including issues associated with student health and safety’ (p. 90).

Change is on the way, and through partnerships, consensus building, raising awareness, developing model courses of actions, and by exploring research-based solutions, there will be a day when all schools of music and the students they serve recognize and value the importance of addressing these challenges.
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References


Measurement and Prediction of Sound Exposure Levels by University Wind Bands

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The purpose of this study was to determine sound exposure levels generated in two college wind bands. Dosimeter data from a large sample of ensemble-based instructional activities (n = 43) was collected over time and processed to assess associations with predictor variables that may be relevant to this context, including indicators of time spend at various intensity levels, maximum and peak sound levels, degree of variability of sound levels over time, and the percentage of time playing music. The mean dose per event for the entire sample was 109.5% and ranged from 53.8% to 166.9%. Results of linear regression analysis revealed that regressors accounted for a significant proportion of the variance in dose (F = 128.42, p < 0.000) and a statistically significant and very large (96% variance accounted for) contribution to the prediction of dose. Findings implicate the critical role of the instructor and teaching pedagogy. Med Probl Perform Art 2010; 25:29–34.

Participation in music ensembles is a key component of music education. In the United States, music education is generally mandatory in public elementary schools and then typically offered through ensemble-based classes such as choir, orchestra, and band. For students pursuing music degrees at the college level, a variety of ensemble classes are often required. In fact, basic criteria for accreditation by the National Association of Schools of Music (NASM) require that schools of music offer instruction in and opportunities for ensemble participation.

Because sounds generated by school-based music ensembles are assumed capable of reaching exposure levels sufficient to harm hearing, prevention of noise-induced hearing loss (NIHL) has become a concern on behalf of students in public school music education programs in the United States and for those enrolled in college programs accredited by the National Association of Schools of Music. Similar concerns exist for orchestras and schools of music and conservatories in the European Union.

The potential for over-exposure in this context was recently reported in a study of wind band classes. The study reported that college students participating in these instructional activities were exposed to sound levels in excess of the 100% allowable dose as defined by National Institutes of Occupational Safety and Health (NIOSH). While this study supports the assumption that wind band ensemble-based instructional activities in schools of music can exceed exposure limits, it provides little about the ecological and behavioral factors that may influence these exposure levels.

When contemplating research studies that explore these factors, it is important to recognize that routine ensemble-based instructional activities within schools of music are not musical performances but rather performance-based instructional activities designed to facilitate growth in artistry, technical skills, collaborative competence, and knowledge of repertoire. In this setting, the pedagogical (teaching) skills of the instructors are employed to impart specialized knowledge considered essential to becoming a music professional. Because the instructor specifies instructional content and directs learning activities, the argument can be made that the sounds generated during ensemble-based instructional activities are largely dependent on the instructor. If so, the instructor ought to be considered a “risk regulator” according to current concepts in behavioral science and public health, because the instructor dictates and controls the sounds produced during instructional activities. The author of the recent wind band study implied this concept when suggesting that the music literature could be modified or that the conductor (instructor) could request that students “hold back on the amount of volume they put forth” in order to reduce risk to hearing.

Unfortunately, the research completed to date is largely insufficient to make this connection convincingly. For example, there is a lack of longitudinal studies that report sound levels over a time frame consistent with an academic semester. Furthermore, there are no known studies with sufficient data designed to characterize details that are dependent on the pedagogic approach employed or generated by a specific instructor or across individual instructors. Running such studies is challenging because the measurement protocols for assessing occupational noise exposure typically produce A-weighted Leq (equivalent continuous noise level) and the time-averaged (integrated) indices, as well as the percent of allowable dose, as expressions of noise exposure and risk. These outcomes provide little insight into epidemiologically relevant characteristics of the sounds generated during ensemble-based instructional activities.

This article reports on a study designed to ascertain the extent that exposure levels generated in college wind bands exceed limits considered risky to hearing. The specific aims were to collect data from a large sample of ensemble-based instructional activities and to assess associations with variables that may be relevant to this context, including indicators of time spend at various intensity levels, maximum and peak sound levels, degree of variability of sound levels over time, and percentage of time playing music.
METHODS

The College of Music at the University of North Texas is a comprehensive music school with one of the largest enrollments of any music institution accredited by the NASM. The College of Music offers numerous ensemble experiences for students and is active in addressing the relationship between music and noise-induced hearing loss. At this university, wind band music is studied in a 3000-ft² room designed specifically for ensemble-based instructional activities and is labeled Instrumental Rehearsal Room (IRR). The IRR was selected for this study based on the desire to evaluate and compare intensity levels generated over time from two different wind bands that are similar in size, instrumentation, and genre and taught by different instructors. The ensembles included two typical college-level wind bands labeled symphonic and concert band, respectively.

Procedures

A noise dosimeter (Model #703+, Larson Davis, Provo, UT) was permanently mounted in the IRR directly above the position of the instructor. A single data collection point was employed because of the focus on temporal characteristics (as opposed to spatial) and because previous studies do indicate that location within the wind band ensemble setting has minimal effect on sound exposure levels. Fixed mounting was selected in order to avoid problems associated with attaching dosimeters to individuals prior to every event over the course of a 15-week study period and to eliminate measurement artifact due to accidental bumping of dosimeter microphones mounted to students playing musical instruments. The dosimeter was set for A weighting with a time history sample interval of 1 per second. Criterion level was set for 85 dB with 3-dB exchange rate according to the NIOSH standard.

One 10-hour data record was downloaded per day via the dosimeter software (Blaze™, Larson Davis) and then constrained to the time history interval associated with each class meeting time (170 min) as posted in the university course catalogue. Result summaries (dose, L eq, L Peak, and L Max) for each 2.5-hour event were generated by the Blaze™ dosimeter software.

- **Dose** is the percentage of time that a person is exposed to noise that is potentially damaging to hearing. It is calculated by dividing the actual time of exposure by the allowed time of exposure, where 0 represents no exposure and 100 or more represents complete exposure.
- **L eq** is the level of a constant sound, expressed in dB, that in a given time period has the same energy as does a time varying sound.
- **L Peak** is the maximum value of the instantaneous, frequency-weighted, sound pressure in a given time interval.
- **L Max** is the maximum value, expressed in dB, of the frequency and exponential-time-weighted sound level in a given time interval.

After screening data to ensure that classes met as scheduled, summary indices were transferred to an aggregate database developed in SPSS (SPSS, Inc., Chicago, IL). A time-series data record for each event, that included summary indices for each second were exported to a second database developed in R (ver. 2.9.2; www.r-project.org). This time-series database was used to calculate skewness, kurtosis, Gini index, coefficient of variation, and percent of time playing music (above 72 dBA) for each event. Once calculated, these summary indices were then transferred to the aggregate (per event) database.

Analytic Procedures

Descriptive parametric statistics were used to characterize and compare dosimeter indices over time and across the two wind bands. Linear regression was used to determine the relationships between dose and seven regressors. Regressors included measures of moments (skewness, kurtosis, Gini index), max and peak intensity levels (L Max, L Peak), dispersion (coefficient of variation), and percent of time playing. The coefficient of variation, the ratio of the standard deviation (SD) to the mean, was selected for comparing the degree of variation from one data series to another. To determine the relative importance of each regressor to the model, relative importance metrics with bootstrap (500 bootstrap replicates) confidence intervals were calculated.

RESULTS

Dosimeter data were collected during the fall semester (2007). The achieved sample included 43 separate events. Each event lasted 170 minutes. A total of 25 events were collected for the symphonic band and 18 for the concert band. As shown in Table 1, the mean dose per event for the entire sample was 109.5% and ranged from 53.8% to 166.9%. The mean dose for the symphonic band was 121.0 and significantly higher (t = –3.97; p < 0.000) when compared to a mean dose of 93.6% for the concert band. The mean L eq level for the symphonic band was significantly higher than the mean L eq level for the concert band. Similarly, the mean L Max level was significantly higher (t = –2.83; p < 0.05) and the L Peak level was significantly higher (t = –2.45; p < 0.05) for the symphonic band compared to the concert band.

Based on these indices, it can be concluded that the risk for NIHL was generally higher in the symphonic band than the concert band. However, for both groups, individual events did not generate similar dose levels over time. As shown in Figure 1, the doses levels per event varied considerably over time for both wind bands. The scatter plots with linear fit lines show that the dose levels increased slightly over time (linear R² = 0.05) for the symphonic band and decreased slightly over time (linear R² = 0.138) for the concert band.

The results of the linear regression analysis, used to determine the relationships between dose and the seven regressors, revealed that this set of variables accounted for a statistically significant proportion of the variance in dose (F =
128.42, p < 0.000). The model summary shown in Table 2 illustrates a statistically significant and very large (96% variance accounted for) contribution to the prediction of dose. As shown in Table 3, skewness, kurtosis, and LMax had non-significant coefficients indicating that they did not contribute much to the model. However, the high tolerance collinearity statistics imply that the variance in these predictors cannot be explained by the other predictors. For the other coefficients, the tolerances were close to 0 and the variance inflation factors were high, particularly for Gini index and coefficient of variation, suggesting high multicollinearity between these predictors.

In order to determine the ranking and relative importance of each regressor, relative importance metrics with bootstrap confidence intervals were calculated using the package Relaimo in R. Figure 2 shows the relative importance metrics in a bar graph with 95% bootstrap confidence intervals for each for the seven regressors. Gini index had the highest relative importance metric (26.5%; 95% confidence interval [CI] 0.21 to 0.33) followed by coefficient of variation (20.8%; 95% CI 0.14 to 0.27).

### DISCUSSION

In this study, sound exposure levels were measured during routine wind-band instructional activities within a large school of music. Consistent with previous studies of college wind band exposure levels, exposure levels did exceed 100% allowable dose on certain days as defined by NIOSH. This finding warrants the implementation of a hearing conserva-

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**TABLE 1. Descriptive Characteristics of Dosimeter Indices for Concert Band, Symphonic Band, and Total**

<table>
<thead>
<tr>
<th></th>
<th>Concert band</th>
<th>Mean (SD)</th>
<th>95% CI</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose</td>
<td>18</td>
<td>93.589</td>
<td>82.883</td>
<td>-104.294</td>
<td>127.6</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>121.020</td>
<td>111.559</td>
<td>-130.481</td>
<td>166.9</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>109.537</td>
<td>101.540</td>
<td>-117.535</td>
<td>166.9</td>
</tr>
<tr>
<td>L_eq</td>
<td>18</td>
<td>89.100</td>
<td>88.579</td>
<td>86.8</td>
<td>90.6</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>90.256</td>
<td>89.902</td>
<td>87.9</td>
<td>91.7</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>89.772</td>
<td>89.435</td>
<td>86.8</td>
<td>91.7</td>
</tr>
<tr>
<td>LMax</td>
<td>18</td>
<td>102.872</td>
<td>102.254</td>
<td>99.9</td>
<td>104.7</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>103.780</td>
<td>103.423</td>
<td>101.2</td>
<td>106.1</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>103.400</td>
<td>103.745</td>
<td>99.9</td>
<td>106.1</td>
</tr>
<tr>
<td>LPeak</td>
<td>18</td>
<td>120.322</td>
<td>119.363</td>
<td>117.2</td>
<td>125.7</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>121.780</td>
<td>120.988</td>
<td>116.2</td>
<td>125.4</td>
</tr>
<tr>
<td></td>
<td>43</td>
<td>121.170</td>
<td>120.544</td>
<td>116.2</td>
<td>125.7</td>
</tr>
</tbody>
</table>

SD, standard deviation; CI, confidence interval.

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**FIGURE 1.** Scatter plots of dose by date over academic semester by ensemble.
tion program within this school of music. Our approach is to formally label all ensemble classes as “at-risk instructional activities” and to implement the university policy for such activities, offer and encourage the use of free hearing examinations, and provide an academic course that covers related topics as recommended by the Health Promotion in Schools of Music Project.

This study’s sample size and approach to understanding exposure levels over time and across wind bands confirmed that exposure levels vary considerably over time. This insight substantiates fundamental limitations with short-term or snapshot dosimeter assessments in a music education setting. This study also suggests that a time series approach to the evaluation of exposure levels increases the understanding of why a music-learning event is risky to hearing. However, the current study relied on a time history sample interval of 1 per second. Additional studies are needed to determine possible advantages of shorter integration periods.

Representing a major benefit over typical dosimeter indices, the analyses of regressors selected for this study offer focused intervention opportunities when used as the basis for reducing risk. The relative importance indices associated with these regressors show that the Gini index and the coefficient of variation alone accounted for over 45% of the variability of dose and that dose levels were not primarily influenced by the maximum levels produced by the ensemble or even by how much time the instructors talked. Dose was strongly related to distribution patterns of intensity levels over time. Because the Gini index was positively correlated with dose, and higher Gini coefficients indicate more unequal distributions, dose is contingent on the degree of equality of time spent at various intensity levels. Together with increases in variability or dispersion, as denoted by positive correlations with the coefficient of variation, dose levels for the events in this study are largely related to time spent across a wide range of intensity levels produced during instructional activities.

To illustrate these relationships, Figure 3 shows a histogram of sound levels (L<sub>eq</sub>/sec) generated during all the instructional events (n = 43) measured in this study. Data points (dB L<sub>eq</sub>/sec, n = 438,600) derived from the time series database were collapsed into 3-dB categories of intensity levels and used to compare the patterns of percentage of time spent at various dB levels across the two wind bands. Keeping in mind that a 3-dB increase represents a doubling of intensity levels, this view helps illustrate why the average dose level for symphonic band (121.0%) was significantly higher when compared to the concert band (93.6%). Represented by the differences in bar height for each 3-dB category, this graph shows that the concert band spent more time during instructional activities generating music at soft to medium dynamic levels compared to the symphonic band. The symphonic band spent more time generating music at high dynamic levels. Similar patterns can be seen when comparing individual events.

At this point, the reasons for the differences in time spent at various intensity levels over time and between these two longitudinal sets of instructional activities are unclear and beyond the scope of this study. However, possible scenarios are important to consider. One possible factor may be the health, and therefore perceptual acuity, of the instructor. There is evidence that music instructors experience NIHL due to negative consequences of teaching wind band music over a period of years or decades. Because noise damages

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### TABLE 2. Linear Regression Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>SEE</th>
<th>R² Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.981&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.963</td>
<td>0.955</td>
<td>5.5099</td>
<td>0.963</td>
<td>128.461</td>
<td>7</td>
<td>35</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Predictors: (constant), percent playing, Gini index, L<sub>peak</sub>, L<sub>Max</sub>, kurtosis, skewness, coefficient of variation. Dependent variable: dose.

SEE, standard error of the estimate.

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### TABLE 3. Standardized Coefficients and Significance Levels for Regressors Used to Predict Dose

<table>
<thead>
<tr>
<th>Model</th>
<th>Standardized Coefficients</th>
<th>95.0% CI for B</th>
<th>Correlations</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>t</td>
<td>Sig.</td>
<td>Lower Bound</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>-7.520</td>
<td>0.000</td>
<td>-1353.500</td>
<td>-778.078</td>
</tr>
<tr>
<td>Gini index</td>
<td>-1.752</td>
<td>-3.241</td>
<td>0.000</td>
<td>-24653.882</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.097</td>
<td>0.723</td>
<td>0.475</td>
<td>-32.021</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.093</td>
<td>0.500</td>
<td>0.000</td>
<td>75.397</td>
</tr>
<tr>
<td>Coef var</td>
<td>2.649</td>
<td>5.029</td>
<td>0.000</td>
<td>1.499</td>
</tr>
<tr>
<td>L&lt;sub&gt;Max&lt;/sub&gt;</td>
<td>0.028</td>
<td>0.011</td>
<td>0.612</td>
<td>1.949</td>
</tr>
<tr>
<td>L&lt;sub&gt;peak&lt;/sub&gt;</td>
<td>0.097</td>
<td>2.146</td>
<td>0.039</td>
<td>0.067</td>
</tr>
<tr>
<td>% Playing</td>
<td>1.327</td>
<td>5.847</td>
<td>0.000</td>
<td>4.585</td>
</tr>
</tbody>
</table>

VIF, variance inflation factor.
the ear’s ability to perceive high-frequency sounds much earlier and more severely than the low-frequency sounds, wind band instructors with NIHL may be at a disadvantage in perceiving levels and relative differences in dynamics. NIHL may impact what the instructor perceives as normal and accurate, for example, when directing students to produce music at pianissimo levels or with particular tonal balances during orchestrations involving varied high-frequency pitches.

Additional factors could be interrelated to the pedagogic (teaching) approach used by the instructor. The varied patterns of time spent at various intensity levels shown in this study may reflect differences in the selected literature, educational goals and objectives, musical expectations, or other details related to how the instructor decides to teach music students in this context. The differences may be traceable to what the instructor regards as essential for facilitating growth in student artistry, technical skills, collaborative competence, and knowledge of repertory.

Nevertheless, the main point from this study is that the levels of risk for hearing damage (dose) measured in this study can be accounted for and traced to the patterns of time spent at various intensity levels. The basis for these patterns are behavioral and under the direction and control of the instructor.

CONCLUSION

While this study suggests that risk from over-exposure may be addressed through reasonable changes to how students are instructed, the extent that this is possible is considerably less clear. Research provides some evidence that music students have a healthier attitude toward loud sounds compared to nonmusic college students, but little is known about the knowledge base, attitudes, and teaching flexibility of wind band instructors in light of the relationships between how music is taught and the potential for NIHL. Similarly, no known research studies have reported on the knowledge base and attitudes regarding these relationships among school of music administrators.

FIGURE 2. Relative importances for dose with 95% bootstrap confidence intervals. Perc, percent of playing time.

FIGURE 3. Differences in percentage of time spent over entire semester at various intensity levels by ensemble. Data points (dB L$_{eq}$/sec; n = 438,600) derived from the time series database were collapsed into 3-dB categories of intensity levels and used to compare the patterns of percentage of time spent at various dB levels across the two wind bands. A 3-dB increase represents a doubling of intensity levels.
Considering a systems approach to behavioral science and public health, we also can look upstream and consider broader social contexts that may be influential and therefore highly relevant to what might occur in schools of music. For example, in the European Union, the Control of Noise at Work Regulations came into force as of April 2008 for the music and entertainment sector and applies to all workplaces where live or recorded music is played. Similar to how the Occupational Safety and Health Administration (OSHA) regulates occupation exposure in the U.S., this regulation is law and not optional. If applied to the context of the current wind band study, the instructors and all students involved would likely be required to use hearing protectors. In the U.S., there is no regulatory statute that covers music students exposed to sound levels in excess of exposure limit values. However, the Centers for Disease Control and Prevention is now calling for the development of policies designed to protect students from sounds produced during school-based activities. This directive specifically cites music classes. If similar to the NIOSH standard or the European Union Regulation, new policy would likely require students to use hearing protectors during music-learning activities. Despite the fact that certain hearing protectors have been marketed to musician communities for over 20 years, this intervention is grossly understudied. Recent reports suggest they are problematic and may add additional problems.

Although not regulatory by design, accrediting organizations also have an effect on what takes place in schools of music. For example, founded in 1924, National Association of Schools of Music (NASM) is an organization of schools, conservatories, colleges, and universities with approximately 615 accredited institutional members. NASM uses national standards that characterize basic requirements and conditions for the study of music at precollegiate, collegiate, and graduate levels. Because institutional membership is gained only through the peer-review process of accreditation, the standards have a definitive impact on curriculum and subsequent knowledge base of students educated by these institutions. Though the NASM accreditation Handbook currently mentions the need for quiet instructional environments and for schools to assist students in acquiring information regarding performance injuries, the NASM Handbook does not yet mention hearing loss, hearing conservation, tinnitus, music as a sound source capable of harming human hearing, or any other related topic. Similarly, it does not declare that an educated music professional should know about music as a potentially harming agent to hearing, the role of the educated musician, teacher, or ensemble director in the prevention of NIHL from music, or the role of NASM member institutions in the prevention of risk due to exposures generated during ensemble-based instructional activities. Addressing these omissions at this level would have a substantial, cost-effective, and sustainable impact on awareness, knowledge, and the potential hearing loss prevention competency of current and future music professionals, including those who direct ensemble-based instructional activities. Formal petitions for this inclusion have been presented to NASM.

REFERENCES