J Am Acad Audiol 29:83–89 (2018)

# Sound Exposure of Healthcare Professionals Working with a University Marching Band

DOI: 10.3766/jaaa.17018

Jeffrey A. Russell*
Moegi Yamaguchi*

**Abstract**

**Background:** Music-induced hearing disorders are known to result from exposure to excessive levels of music of different genres. Marching band music, with its heavy emphasis on brass and percussion, is one type that is a likely contributor to music-induced hearing disorders, although specific data on sound pressure levels of marching bands have not been widely studied. Furthermore, if marching band music does lead to music-induced hearing disorders, the musicians may not be the only individuals at risk. Support personnel such as directors, equipment managers, and performing arts healthcare providers may also be exposed to potentially damaging sound pressures. Thus, we sought to explore to what degree healthcare providers receive sound dosages above recommended limits during their work with a marching band.

**Purpose:** The purpose of this study was to determine the sound exposure of healthcare professionals (specifically, athletic trainers [ATs]) who provide on-site care to a large, well-known university marching band. We hypothesized that sound pressure levels to which these individuals were exposed would exceed the National Institute for Occupational Safety and Health (NIOSH) daily percentage allowance.

**Research Design:** Descriptive observational study

**Study Sample:** Eight ATs working with a well-known American university marching band volunteered to wear noise dosimeters.

**Data Collection and Analysis:** During the marching band season, ATs wore an Etymotic ER-200D dosimeter whenever working with the band at outdoor rehearsals, indoor field house rehearsals, and outdoor performances. The dosimeters recorded dose percent exposure, equivalent continuous sound levels in A-weighted decibels, and duration of exposure. For comparison, a dosimeter also was worn by an AT working in the university's performing arts medicine clinic. Participants did not alter their typical duties during any data collection sessions. Sound data were collected with the dosimeters set at the NIOSH standards of 85 dBA threshold and 3 dBA exchange rate; the NIOSH 100% daily dose is an exposure to 85 dBA over 8 h. Dose data for each session were converted to a standardized dose intensity by dividing the dose percentage by the duration of the exposure and setting the NIOSH standard as a factor of 1.0. This allowed convenient relative comparisons of dose percentages of vastly different exposure durations. Analysis of variance examined relationships of noise exposures among the venues; post hoc testing was used to assess pairwise differences.

**Results:** As hypothesized, ATs were exposed to high sound pressure levels and dose percentages greatly exceeding those recommended by NIOSH. Higher sound levels were recorded in performance venues compared with rehearsal venues. In addition to the band music, crowd noise and public address systems contribute to high sound levels at performances.

**Conclusions:** Our results suggest that healthcare providers working with marching bands are exposed to dangerous levels of sound during performances. This is especially true at venues such as football stadiums, where crowd noise and public address systems add to sound pressure. A hearing conservation

---

*Clinic for Science and Health in Artistic Performance, School of Applied Health Sciences and Wellness, College of Health Sciences and Professions, Ohio University, Athens, OH

Corresponding author: Jeffrey A. Russell, Ohio University, School of Applied Health Sciences and Wellness, Athens, OH 45701; Email: jeff.russell@ohio.edu

This research was funded by grants from the Ohio University Research Committee Discretionary Fund and the Ohio University School of Applied Health Sciences and Wellness.

This article was presented at the 34th Annual Symposium of the Performing Arts Medicine Association, New York, NY, July 7, 2016.

program, including protection, should be required for all healthcare staff who work with marching bands. Moreover, our results should inform hearing conservation practices for marching musicians, directors, and support personnel.

**Key Words:** athletic trainer, noise, noise dosimetry, marching band, sound pressure

**Abbreviations:** ANOVA = analysis of variance; AT = athletic trainer; $LA_{eq}$ = equivalent continuous noise level in dBA; NIOSH = National Institute of Occupational Safety and Health; OSHA = Occupational Safety and Health Administration; SDI = standardized dose intensity; $SDI_8$ = standardized dose intensity for an 8-hour exposure

## INTRODUCTION

Hearing impairment is a substantial and worsening health concern. Whereas it is an obvious problem, for example, in noise-laden industrial workers (Masterson et al, 2016) and rock musicians (Størmer et al, 2015), and when using personal listening devices (Kumar and Deepashree, 2016), it is also increasingly recognized in other types of musicians (Emmerich et al, 2008; Gopal et al, 2013; Rodrigues et al, 2014; Schmidt et al, 2014; Dudarewicz et al, 2015). Decibel levels with continuous noise equivalent ($L_{eq}$) values between 84 and 90 have been reported in orchestral music (O'Brien et al, 2008). These authors also reviewed and collated additional literature that reported similar levels: 77 to 95 dBA, with peaks to 122 dBA.

The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) both have addressed the issue of noise exposure in industry and provided guidance for noise exposures that are likely to be detrimental to hearing (NIOSH, 1998; OSHA, 2008). NIOSH has set a recommended exposure limit of 85 dBA for 8 h with variance in A-weighted decibels and duration established according to a 3 dBA exchange rate. OSHA, on the other hand, is less conservative in setting their limit at 90 dBA for 8 h with a 5 dBA exchange rate. Whereas their standards are helpful for moderating overall noise dosage, these organizations do not focus specifically on music as an activity that carries risk to hearing, even though, as previously noted, several authors have reported the potential for musicians to develop hearing loss if they participate in instrumental music without hearing protection. To our knowledge, there are no government or institutional standards in place that quantify safe music exposure levels for musicians and for music teachers, directors, and others associated with music performance.

There are minimal data published on sound levels associated with marching band music. Studies may not be published in research manuscript format (Keefe, 2005a,b), or articles that are available may appear in music education trade literature (Presley, 2007) rather than peer-reviewed scientific journals. It is not difficult to surmise that the heavy orientation of marching music toward drum lines and brass creates the potential for hearing impairment in the absence of prophylactic protection, even in view of the variable sound exposure of musicians in typical band rehearsals. Jin et al. (2013) reported on a hearing conservation program for marching musicians that found a lack of notches consistently appearing in their participants' audiograms, as well as no standard threshold shift. Nonetheless, the authors recommended hearing protection, as well as a refinement in how marching musicians' audiograms are performed.

Therefore, in light of the voids in the literature about sound exposure in marching band and the perceived need to understand this exposure not just for band members and directors but also for medical personnel who work with marching bands on a regular basis, the purpose of this study was to determine the sound exposure of healthcare professionals (specifically, athletic trainers [ATs]) who provide on-site care to a large, well-known university marching band. We hypothesized that sound levels to which these individuals are exposed would routinely exceed the NIOSH daily percentage allowance.

## MATERIALS AND METHODS

### Participants

Four staff ATs and four athletic training students ("AT" will henceforth identify any of these individuals) from the same university volunteered for the study. All were required to work with their university's marching band, which is customarily ranked each year among the top university marching bands in the United States. The ATs spent varied amounts of time working with the band; one AT was assigned to the band full-time, whereas the others were assigned through a staffing rotation. During any given marching band activity, at least two ATs accompanied the band to administer healthcare to the musicians. The study protocol was approved by the university's Institutional Review Board, and the participants provided their informed consent.

### Equipment

During the Fall 2015 marching season, whenever an AT was present with the band in the course of delivering healthcare, the AT wore an Etymotic ER-200D personal noise dosimeter (Etymotic Research, Elk Grove, IL;

Figure 1); there was a maximum of three ATs wearing dosimeters at any given time. That is to say, one AT wearing a dosimeter at one marching band event constituted one observation. Thus, each event yielded one to three measures of its sound exposure, with the majority yielding two or three.

The Etymotic dosimeter records sound data in A-weighted decibels (dBA). The devices were set for the NIOSH standard setting of 85-dBA threshold at a 3-dBA exchange rate (NIOSH, 1998). This model collects noise data over 220-msec increments, sums the increments in 3.75-min blocks across the exposure duration, and stores these data in nonvolatile memory for a session record of 16 blocks per hour. The dosimeter produces equivalent continuous noise levels in dBA ($LA_{eq}$) and cumulative dose percentage values during the exposure period. The ER-200D noise dosimeter model previously has been reported as valid and reliable for measuring music sound levels (Cook-Cunningham, 2014).

A dosimeter was worn in a clinician's left breast uniform pocket (or in a position as close to this as possible if outerwear was required by weather conditions) during each episode of assignment to the band's healthcare team. Care was taken to ensure the dosimeters' microphones were not obstructed. Manufacturer-supplied windscreens were used on the dosimeters at all times.

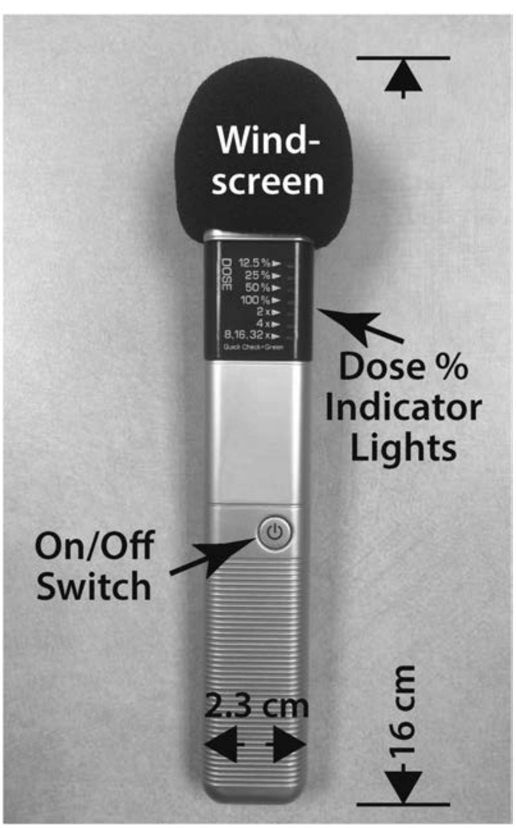


**Figure 1.** Etymotic ER-200D personal noise dosimeter with functional parts identified.

For outdoor applications, the manufacturer recommended the windscreen to reduce extraneous wind-induced noise; it also was used indoors to provide instrumentation consistency across the observations.

### Marching Band

The university marching band maintained ~250 members during the season. The instruments comprising the band were percussion (snares, timbales, tenors, basses, and cymbals), trumpets, mellophones, euphoniums, trombones, sousaphones, alto saxophones, tenor saxophones, and clarinets. (The band does not use flutes or piccolos.) No attempt was made to influence the ATs' participation in their healthcare practices, e.g., by moving closer to or farther away from instruments expected to generate higher sound levels. They were instructed simply to position themselves as usual and necessary to complete their activity supervision, injury assessment, and treatment duties.

During rehearsals, the typical location of the ATs as they attended to their duties was between 10 and 20 m from the band's location on the field. On occasion, they were as close as 3–7 m. During football games, the ATs sat as close as 1–3 m, either directly in front of or directly behind the band in the grandstand, depending on the stadium set-up. During half-time shows, the ATs were on the sidelines 15–25 m away from the band. During parades, the ATs were consistently alongside or behind the band at a distance of 1–5 m.

### Data Collection

The primary venues at which the dosimeters were worn were outdoor rehearsals in a sports stadium, indoor rehearsals in a field house, and performances that included outdoor football games and outdoor parades. In addition, for venue comparison purposes, a dosimeter was (1) worn by an AT in the university's performing arts medicine clinic during the course of her work and (2) placed in an indoor rehearsal room during sessions when the full band engaged in seated music practice. (An AT was not present with the dosimeter in these rehearsals as the band was not marching.)

Each AT switched on his or her dosimeter on arriving at the appointed venue and switched it off on finishing work at the venue. Subsequently, the dosimeters were attached to a computer for data download. The data of interest were session duration, $LA_{eq}$, and dose percentage. These were stored in a spreadsheet for data analysis.

### Data Analysis

To account for the wide range of exposure durations encountered among the data collections and the relative greater intensity of sound exposure when high dose percentages are compacted into short durations, a standardized dose intensity for an 8-h exposure ($SDI_8$) was calculated for the exposures of each AT. The goal of this was to provide an easy comparison of collected sound data against a reference value for the NIOSH daily dose standard of 100% that occurs when exposed to 85 dbA for 8 h. We used the NIOSH standard instead of the OSHA standard to be as conservative as possible in our analysis and recommendations. The subscript 8 following the standardized dose intensity (SDI) denotes that the SDI calculation is based on the 8 h NIOSH limit.

First, the dose percent value for a session was divided by the amount of time in hours over which that dosage was obtained during the session. The NIOSH standard yielded a value of $100 \div 8.0 = 12.5$. Then, we used the following equation that divided that NIOSH value into a session's dose percentage per unit time. This allowed the calculation of a quantity for each of our collected observations that served as a multiplicative factor to compare against NIOSH (with the NIOSH $SDI_8$ equaling 1.0, i.e., $12.5 \div 12.5$):

$$SDI_8 = \frac{\left(\frac{\text{Dose \%}}{\text{Exposure Time in decimal hours}}\right)}{12.5}$$

Means and standard deviations were calculated for dose %, $LA_{eq}$, duration of exposure, and $SDI_8$ for all five venues where the dosimeters were worn. Data from the outdoor performance, outdoor rehearsal, and clinic venues were analyzed via analysis of variance (ANOVA). Levene's test was used to assess violation of homogeneity of group variances. For those data with unequal group variances, differences in means among the venues were evaluated with Welch's modification of ANOVA to control for unequal variances and differing sample sizes. Otherwise, standard ANOVA was applied. Games–Howell post hoc testing assessed pairwise differences between venues to control for unequal group variances, whereas Tukey's honest significant difference was used in the instance where the group variances were not significantly different. All analyses were generated using the Real Statistics Resource Pack software for Excel, Release 4.3 (Zaiontz, 2015). The alpha level was set a priori at 0.05.

## RESULTS

Figure 2 offers a typical graphical presentation of a dosimeter's data. Means and standard deviations of the data are presented in Table 1. Predictably, the clinic data for percent daily exposure were substantially lower than any other values and, with a maximum of 4%, offered little contribution to daily noise exposure. Performance exposures reached a maximum of 557%, more than five and a half times that recommended by NIOSH for an entire day.

Levene's test revealed nonhomogeneity of group variances for dose percentage and $SDI_8$ but not for $LA_{eq}$. Thus, for the first two, Welch's ANOVA indicated that the means among groups (clinic, rehearsals, and performances) were significantly different for dose percentage ($F_{[2,63.34]} = 53.78, p < 0.001$) and $SDI_8$ ($F_{[2,62.63]} = 40.31$, $p < 0.001$). Conventional ANOVA identified significant differences among the means of the three groups for $LA_{eq}$ ($F_{[2,113]} = 136.41, p < 0.001$). In addition, all three venues were significantly different from one another for each of the three variables; post hoc pairwise differences between means are provided in Table 1.

Twenty-five of 65 outdoor rehearsals (38%) exceeded the NIOSH daily dose standard of 100%, whereas 25 of the rehearsals also exceeded the reference $SDI_8$ of 1.0. For performances, 27 of 38 (71%) exceeded 100% daily dose and 34 of 38 (89%) exceeded the reference $SDI_8$ of 1.0.

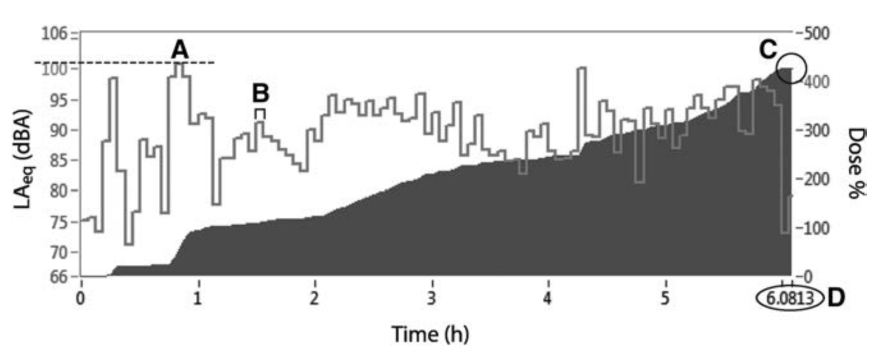


**Figure 2.** Graphical representation of a single dosimeter's data from a single performance. The solid line represents the fluctuation of the $LA_{eq}$ across the duration of the event. The upward trending solid area indicates the increasing dose percentage throughout the duration of the event. (A) The maximum $LA_{eq}$ recorded during the event, in this instance ~101 dBA and marked by an added dotted line. (B) The span of a single 3.75-min block of sound recording. (C) The dose percentage of sound exposure for the event, in this instance ~430% (NIOSH recommendation = 100%). (D) The duration of the event in hours, in this instance just over 6 h.

**Table 1. Minima, Maxima, Means, and Standard Deviations of Sound Exposure Data**

| | | Outdoor Rehearsal | Outdoor Performance | Clinic | Field House Rehearsal | Practice Room Rehearsal |
|---|---|---|---|---|---|---|
| Number of observations | | 65 | 38 | 13 | 4 | 7 |
| Event duration (hh:mm:ss) | Min | 0:11:34 | 0:24:37 | 1:34:56 | 0:56:53 | 0:57:34 |
| | Max | 2:59:01 | 6:50:26 | 5:09:08 | 1:48:26 | 1:27:35 |
| | Mean | 1:16:24 | 3:18:53 | 3:33:24 | 1:19:43 | 1:12:08 |
| $LA_{eq}$ (dBA) | Min | 75.96 | 62.67 | 62.67 | 85.58 | 98.99 |
| | Max | 93.02 | 100.46 | 75.81 | 91.42 | 108.86 |
| | Mean ± SD | 84.0 ± 4.1* | 91. 0 ± 10.6* | 69.4 ± 3.4* | 88.1 ± 2.4 | 102.9 ± 3.5 |
| Dose % | Min | 2 | 2 | 0.75 | 21 | 30.4 |
| | Max | 93 | 557 | 4 | 61 | 3530 |
| | Mean ± SD | 17 ± 19$^{\dagger}$ | 203 ± 158$^{\dagger}$ | 2 ± 1$^{\dagger}$ | 36 ± 19 | 1265 ± 1117 |
| Standardized dose intensity (NIOSH = 1.0) | Min | 0.12 | 0.40 | 0.01 | 1.14 | 25.35 |
| | Max | 6.38 | 35.67 | 0.12 | 4.41 | 248.08 |
| | Mean ± SD | 1.24 ± 1.35$^{\ddagger}$ | 5.24 ± 5.82$^{\ddagger}$ | 0.04 ± 0.03$^{\ddagger}$ | 2.31 ± 1.44 | 84.92 ± 79.41 |

*Notes:* *significantly different at $p < 0.001$; post hoc pairwise differences significant at $p < 0.002$.
$^{\dagger}$significantly different at $p < 0.001$; post hoc pairwise differences significant at $p < 0.001$.
$^{\ddagger}$significantly different at $p < 0.001$; post hoc pairwise differences significant at $p < 0.001$.

## DISCUSSION

The purpose of this study was to determine the sound exposure of healthcare professionals (specifically, ATs) who provide on-site care to a large, well-known university marching band. Our hypothesis that sound levels to which these individuals were exposed would routinely exceed the NIOSH daily percentage allowance was confirmed. Overall, our findings are quite alarming and should inform hearing protection practices in not only healthcare workers who serve marching bands but band directors and musicians, as well. Performances at football games are particularly loud; band practices inside a confined rehearsal room are dangerously so.

The fact that high sound levels are detrimental to hearing health is intuitive. Prior research reports the adverse effects of various styles of music on hearing, for example, orchestral (Emmerich et al, 2008; Rodrigues et al, 2014; Schmidt et al, 2014), rock and roll ( Samelli et al, 2012; Halevi-Katz et al, 2015), and jazz (Käharit et al, 2003; Gopal et al, 2013; Halevi-Katz et al, 2015). However, to our knowledge, this is the first study to quantify sound levels of marching band music across a season-long variety of venues. We performed this study initially out of interest for the hearing health of healthcare professionals, specifically ATs, who work with marching bands. In light of our findings, everyone in proximity to a marching band while it is playing—directors, logistics and equipment managers, and musicians themselves—are at risk, given the high levels of sound pressure we measured.

All of the ATs who participated in this study were required to wear in-ear hearing protectors; this remains a precautionary measure among our staff. However, requiring them for healthcare professionals is different than requiring them for musicians as musicians are reticent to adopt them (O'Brien et al, 2012; 2015). Ear protection is only one aspect of a hearing conservation program, and apart from education, exposure control, sound pressure monitoring, audiological evaluation, and appropriate legislation, wearing hearing protectors may occur sporadically in musicians (O'Brien et al, 2014; 2015). This suggests that additional measures, such as those employed in a hearing conservation program, are essential.

Keefe (2005a) recorded sound pressure levels in a university and a high school marching band. While his data suggest the same conclusion that ours do—that marching band sound exposure exceeds safe levels compared with NIOSH recommendations (Keefe, 2005a)—he recorded some dose percentages (2,245%) that exceeded our maximum recorded percentage for an outdoor university football game performance (557%) by about four times. We also noted that his football game exposure time was shorter than ours (mean = 2.5 h compared with 4.8 h); this suggests that his participants experienced extremely high sound intensities while playing at the games. Whereas he did not specify the brand or type of sound meter he used or the exact location of its placement for data collection, we suspect the noted disparities may highlight a difference in his data collection device or the location of his sound meter during data collection. That is to say, his sound meter may have been embedded within the band whereas our dosimeters were worn by our ATs who were not necessarily near the band at all times during their healthcare work. Indeed, much of these clinicians' time typically is spent observing rehearsals or performances. Considering this, the fact that we still recorded substantial noise exposures lends credence to our postulation that marching band sound volume is dangerous to hearing health. It is logical to assume that were our noise dosimeters worn by musicians playing inside the band's marching block they would have recorded substantially higher $LA_{eq}$ and dose percentage values.

Presley (2007) studied percussionists, specifically those engaged in drum and bugle corps. Using personal noise dosimeters of an unknown type to record sound pressure levels during 12.25 h in a single day of rehearsals, this study differed from ours in that the instrumentalists wore the dosimeters rather than support personnel. His data included all activities of the rehearsal day, including meals and breaks; he reported that 87% of the day was devoted primarily to rehearsal activities. The dose percentages he recorded were well beyond any we encountered, ranging from 898% to 9,455% whereas ours were between 2% and 93% for rehearsals. His measured $LA_{eq}$ values also were at or above those in our study with a range of 92.5–103.1 dBA. Our range for our band's rehearsals was 76.0–93.0 dBA. These differences likely are explained by the percussion only nature of Presley's sample, the long duration of his participants' exposures, and the fact that the dosimeters in his study were embedded with the drum corps' members. Thus, true comparisons of the two studies are limited.

With a mean $LA_{eq}$ of 90.50, performances were virtually 6 dBA louder than the threshold recommended by NIOSH. At the NIOSH-recommended 100% noise dosage of 85 dBA over 8 h, an exchange rate of 3 dBA means that recommended exposure time is halved for every 3 dBA increase in sound level. Thus, our data suggest that our AT staff should have had exposures of only 2 h (halved from 8 to 4 h for the first 3 dBA increase to 88 dBA and halved again to 2 h for the next 3 dBA increase to 91 dBA), when, in actuality, the mean exposure time for performances in our study was more than 3 h, with some events extending well beyond 6 h.

We note that the NIOSH standard of 100% being reached in 8 h was set for an industrial worker's day. Any exposure to noise outside of the noisy industrial setting only compounds an individual's potential for hearing loss (NIOSH, 1998; OSHA, 2008). The same holds true inside any noisy environment. That is to say, if our ATs reached a dose percentage at or above 100% not only when working with the band but also were exposed to noise in traffic, shopping malls, listening to a personal music device, and other sources, their risk for negative effects to their hearing would further increase.

The $SDI_8$ score we devised allowed us to compare the sound intensity of each measurement we collected (even though they were of a wide variety of durations) against the daily noise intensity allotment recommended by NIOSH. We accomplished this by setting the NIOSH standard as 1.0. This allowed every other score to be compared with this as a decimal factor. For example, if an AT received a 250% dose percentage in 1.5 h, the $SDI_8$ for this situation would be 13.3 or more than 13 times as intense as recommended by NIOSH. On the other hand, if that same AT sustained a 250% dose percentage across an 8-h period, the corresponding $SDI_8$ would be 2.5 or two and a half times as intense as NIOSH recommends. Thus, the $SDI_8$ calculation assigns a more severe index to high noise levels received in shorter durations.

$SDI_8$ values for the venues where we collected data ranged from 0.04 (clinic) to 84.92 (indoor rehearsal room). Thus, the typical working environment for an AT, a clinic, had a sound intensity only 4/100 that of the NIOSH value. At the other end of the spectrum, the indoor rehearsal room's $SDI_8$ was, on average, nearly 85 times NIOSH, with one practice session resulting in an $SDI_8$ nearly 250 times as intense as the NIOSH standard.

It is important to understand how dose percentage exposure and $SDI_8$ relate. As previously mentioned, $SDI_8$ assigns a greater intensity to a sound pressure level experienced over a shorter duration than it does to an equivalent sound pressure level experienced over a longer duration. For example, our mean dose percentage for outdoor performances was 203% or approximately twice the daily limit of 100% recommended by NIOSH. On the other hand, when the dose percentages were converted to $SDI_8$ values, the mean $SDI_8$ for the outdoor performances was 5.24 or more than five times the $SDI_8$ of 1.0 for the NIOSH recommendation. The practical implication of this is that using the $SDI_8$ allows more conservative decision-making about sound level exposure than does the simple percentage based NIOSH-recommended exposure, a criterion that has not been updated since 1998.

The few rehearsals inside the field house gave a mean $SDI_8$ of 2.31. Of particular note, however, is that the mean $SDI_8$ values for the typical marching venues, that is, outdoor rehearsals and outdoor performances, were both above the NIOSH $SDI_8$, at 1.24 and 5.24, respectively. That means that the performances were, on average, more than four times as intense in their sound levels compared with the rehearsals. Based on our observations and data analysis, two main factors accounted for this. First, during performances, the ATs were usually stationed closer to the band for a longer duration than they were during rehearsals. Second, at performances, especially football games, there are more noise sources than the band alone: the highly amplified public address system and cheering crowd primary among these.

The sound levels we recorded during rehearsals in an indoor field house large enough to contain a football field were substantially lower than those recorded in an indoor rehearsal room only large enough to contain the 250 band members. Nonetheless, the field house levels did surpass the NIOSH-recommended dosage, a fact put into perspective by the range of $SDI_8$ values of 1.14 to 4.41 (NIOSH = 1.00, mean = 2.31) we calculated for the rehearsals of ~90 min held there. The difference between these two indoor venues is intuitive based on the indoor space volume of the respective venues, but our results underscore the need for vigilance in requiring hearing protection even when it seems that noise levels are tolerable.

Limitations of our study include an inability to specify if actual hearing loss resulted from the sound levels generated by the band's music. We did not conduct audiology testing pre- and postseason as this was not the focus of the research. Such loss is presumed likely based on prior data of hearing loss associated with loud noise and on guidance offered by NIOSH (1998). Furthermore, the variability noted in some of our data suggests that not all marching band rehearsals and performances are associated with potentially injurious levels of sound exposure. Moreover, during performances, we could not partition the noise generation into "band" and "not band," so the sound levels attributable to the band in this environment are unknown. As previously noted, in such scenarios, it is the sum of the band's music, the surrounding stadium crowd, and the public address system that contribute to noise exposure.

In conclusion, ATs who work with a university marching band were exposed to high levels of sound pressure in the course of their work during a season. An SDI value was calculated to allow ready comparison with the recommended standard offered by the NIOSH. Performances created greater risk of sound exposure than did rehearsals, with football game performances being the greatest. This suggests the wisdom of mandatory hearing protection for individuals in these positions, a requirement that will be more effective as part of an overall hearing conservation program. In addition, anyone else—including band members and directors themselves—in proximity to marching bands for extended periods should similarly be offered a hearing conservation program and be advised to adopt hearing protection.

## REFERENCES

Cook-Cunningham SL. (2014) Personal noise dosimeters: accuracy and reliability in varied settings. *Noise Health* 16(70):143–148.

Dudarewicz A, Pawlaczyk-Łuszczyńska M, Zamojska-Daniszewska M, Zaborowski K. (2015) Exposure to excessive sounds during orchestra rehearsals and temporary hearing changes in hearing among musicians. *Med Pr* 66(4):479–486.

Emmerich E, Rudel L, Richter F. (2008) Is the audiologic status of professional musicians a reflection of the noise exposure in classical orchestral music? *Eur Arch Otorhinolaryngol* 265(7):753–758.

Gopal KV, Chesky K, Beschoner EA, Nelson PD, Stewart BJ. (2013) Auditory risk assessment of college music students in jazz band-based instructional activity. *Noise Health* 15(65):246–252.

Halevi-Katz DN, Yaakobi E, Putter-Katz H. (2015) Exposure to music and noise-induced hearing loss (NIHL) among professional pop/rock/jazz musicians. *Noise Health* 17(76):158–164.

Jin S-H, Nelson PB, Schlauch RS, Carney E. (2013) Hearing conservation program for marching band members: a risk for noise-induced hearing loss? *Am J Audiol* 22(1):26–39.

Kähärit K, Zachau G, Eklöf M, Sandsjö L, Möller C. (2003) Assessment of hearing and hearing disorders in rock/jazz musicians. *Int J Audiol* 42(5):279–288.

Keefe J. (2005a) Noise exposure associated with marching and pep bands. http://acoustics.org/pressroom/httpdocs/150th/Keefe.html. Accessed February 6, 2017

Keefe J. (2005b) Noise exposure in marching bands. *J Acoust Soc Am* 118(3):1979.

Kumar UA, Deepashree SR. (2016) Personal music systems and hearing. *J Laryngol Otol* 130(8):717–729.

Masterson EA, Bushnell PT, Themann CL, Morata TC. (2016) Hearing impairment among noise-exposed workers - United States, 2003-2012. *MMWR Morb Mortal Wkly Rep* 65(15):389–394.

National Institute for Occupational Safety and Health (NIOSH). (1998) *Criteria for a Recommended Standard: Occupational Noise Exposure. (DHHS 98-126)*. Cincinnati, OH: US Department of Health and Human Services.

O'Brien I, Ackermann BJ, Driscoll T. (2014) Hearing and hearing conservation practices among Australia's professional orchestral musicians. *Noise Health* 16(70):189–195.

O'Brien I, Driscoll T, Ackermann B. (2012) Hearing conservation and noise management practices in professional orchestras. *J Occup Environ Hyg* 9(10):602–608.

O'Brien I, Driscoll T, Ackermann B. (2015) Description and evaluation of a hearing conservation program in use in a professional symphony orchestra. *Ann Occup Hyg* 59(3):265–276.

O'Brien I, Wilson W, Bradley A. (2008) Nature of orchestral noise. *J Acoust Soc Am* 124(2):926–939.

Occupational Safety and Health Administration (OSHA). (2008) Occupational noise exposure. Standard Number 1910.95. Retrieved from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735. Accessed February 6, 2017.

Presley, D.L. (2007). An analysis of sound-level exposures of drum and bugle corps percussionists. *Percussive Notes* 45(4):70–71, 73–75.

Rodrigues MA, Freitas MA, Neves MP, Silva MV. (2014) Evaluation of the noise exposure of symphonic orchestra musicians. *Noise Health* 16(68):40–46.

Samelli AG, Matas CG, Carvallo RM, Gomes RF, de Beija CS, Magliaro FC, Rabelo CM. (2012) Audiological and electrophysiological assessment of professional pop/rock musicians. *Noise Health* 14(56):6–12.

Schmidt JH, Pedersen ER, Paarup HM, Christensen-Dalsgaard J, Andersen T, Poulsen T, Bælum J. (2014) Hearing loss in relation to sound exposure of professional symphony orchestra musicians. *Ear Hear* 35(4):448–460.

Størmer CC, Laukli E, Høydal EH, Stenklev NC. (2015) Hearing loss and tinnitus in rock musicians: a Norwegian survey. *Noise Health* 17(79):411–421.

Zaiontz C. (2015) Real statistics using excel. Retrieved from http://www.real-statistics.com/. Accessed February 6, 2017.