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Assessment of occupational personal sound exposures for music instructors

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Abstract

Daily activities performed by music instructors generate high sound levels that could potentially lead to overexposure. Adverse outcomes associated with high-exposure to sound, such as hearing loss and tinnitus, can be especially devastating to music instructors as hearing is essential to both job performance and career reward. The primary objective of this study was to compare sound exposures of music instructors to recommended exposure limits. Secondary objectives were to identify high-exposure activities and to evaluate potential similar exposure groups by examining between- and within-worker exposure variability. Personal sound exposure measurements from music instructors were collected using dosimeters during full workdays for up to 4 weeks over multiple semesters at a university's school of music. Study participants completed an activity log to record work-related activities throughout each day of sampling. Dosimeters logged 1-sec sound equivalent levels in A-weighted decibels. These data were used to calculate 8-hr time-weighted averages, daily dose, and activity-specific contributions to that dose to determine if daily exposures exceeded the recommended limit of 85 dBA and to identify high-exposure activities that could be targeted for future intervention. Seventeen participants were sampled for a total of 200 days. Approximately one-third of daily exposures exceeded recommended limits. The groups with the highest exposures were brass and conducting instructors. Conductors experienced the highest between-day variability in daily exposures. Activities that contributed the most to daily dose included group rehearsals, personal practice sessions, and performances, while classes and administrative work did not substantially contribute to daily dose. Daily exposures were highly variable, ranging from 60–95 dBA (mean = 81 dBA, sd = 8 dBA), and were influenced by instructional area and musical activity. Future exposure assessments for music instructors should include sampling for multiple days, and those above-recommended limits should be placed into hearing conservation programs.

Keywords

noise; dosimetry; hearing conservation; teachers; musician

Introduction

Music instructors' jobs require them to be exposed to sound, and, unlike noise, this sound is purposefully generated and necessary. Their jobs also require precise hearing, so auditory damage resulting from excessive sound exposure could be especially detrimental to their careers. While musicians are at risk of noise-induced hearing loss (NIHL) (Di Stadio et al. 2018), little has been published specifically on music instructors' sound exposures. The data available, however, suggest a risk of excessive sound exposure during instructional activities. Behar et al. (2004) reported that 61% of the music teachers they sampled reached or exceeded an exposure level of 85 dBA for an 8-hr day, while Mace (2005) reported that 35% of time-weighted averages (TWAs) measured among university music teachers sampled over two days exceeded the 85-dBA limit for at least one of the days. Louder exposures have been reported for band directors where daily doses for five high school band directors ranged from 338–1980% (Hayes 2013). Additional studies have focused on professional orchestral musicians that have reported high sound exposures during solitary personal practice (O’Brien et al. 2013) and during performances and group rehearsals (Schmidt et al. 2011). Since many music instructors are also performers, these results suggest instructors may be frequently exposed to high sound levels throughout their careers.

It is difficult to estimate the number of working music instructors, as educators are typically grouped by school level and not by area of expertise. However, in 2019, the Bureau of Labor Statistics (BLS) estimated approximately 94,000 art, drama, and music teachers employed in postsecondary schools (Bureau of Labor Statistics. United States Department of Labor (BLS) 2020a) and over 10,500 music directors and composers (BLS 2020b). These estimates likely do not account for self-employed music teachers, who may make up a substantial portion of private lesson instructors, or music instructors teaching in elementary, middle, and secondary schools. Despite difficulty in estimating the size of this group, it is apparent they represent a large group of workers who are potentially at risk of occupational exposure to sound levels that could lead to auditory damage that would compromise their ability to do their jobs.

Characterizing sound exposure is challenging for music instructors because their daily exposures are highly variable due to differences in musical selections and work actvities (e.g., lessons, rehearsals). Behar et al. (2004) suggested that the difficulty in identifying a “typical” workday for music instructors could be a reason why there is so little research focusing on this group. Studies employing minimal sampling strategies (e.g., by only measuring during specific activities, sampling for only 1 day) are limited in their ability to characterize exposure. Restricting sampling to specific rehearsals and classes may underestimate actual occupational exposure if instructors are required to perform other duties during the day. Additionally, focusing only on “worst case” events may overestimate actual risk. The American Conference of Governmental Industrial Hygienists (ACGIH®) recommends evaluation of atypical noise exposures (e.g., when between-day noise exposure variation is high) by allowing the daily dose to exceed 100% for any one day as long as no day is more than 300% dose *and* that the sum of daily doses over a 7-day period does not exceed 500% (ACGIH 2018). Given the potential variation in exposures to music, it is difficult to determine exposure and adherence to guidelines based on only 1 day of sampling. Thus, there is a clear need for personal monitoring to be performed for multiple, full workdays to determine exposure, estimate risk of NIHL, and to determine the need for hearing conservation program (HCP) inclusion.

Collecting information on task-specific (activity-specific) exposures provides additional benefits, including the identification of high-exposure sources, which helps to target interventions more effectively (Seixas et al. 2003). For jobs with high variability, either in type, duration, or scheduling of tasks, task-based assessments help to explain observed differences between full-shift measurements. This variability is likely one reason that current literature regarding music instructors report a wide range of daily exposures (79 dBA [Behar et al. 2004] to over 105 dBA [Maffei et al. 2011]). The inherent variability present in music instructors' daily exposures, resulting from both musical repertoire and range of activities performed, justifies the collection of activity-specific data to understand what activities drive daily and weekly exposures and contribute to overall risk of auditory damage. Thus, the identification of activity-specific contributions to dose is needed to inform recommendations regarding control strategies for music instructors.

Another benefit of sampling instructors for multiple, full workdays, while also gathering activity-specific exposure data, is to determine if and how these workers can be grouped into similar exposure groups (SEGs). Since it is often impractical to sample every worker, it is common to establish SEGs in which workers can be grouped with others with comparable exposures based on their job roles (e.g., activities performed, areas worked). The SEGs may be evaluated to determine if groupings are appropriate by gathering a large number of personal samples from workers and using statistical models to calculate between- and within-worker variability (Peretz et al. 2002, Hewett 2015). Evaluating potential SEGs may help provide guidance for future exposure assessments of music instructors.

The objective of this study was to characterize sound exposures for music instructors by comparing daily and weekly exposures to recommended limits. One secondary objective of this study was to gather activity-specific sound measurements to identify high-exposure activities which may be targeted in future interventions. A final objective of this study was to examine exposure variability between and within music instructors in different instructional areas to understand if and how they should be grouped into SEGs.

Methods

Sampling strategy

Faculty and graduate teaching assistants (TAs) employed at a university's School of Music were invited to participate in this study via a mass email. Participants had to be over 21 years of age and be willing to wear dosimeters for full workdays while keeping an activity log of daily work activities. The study design was approved by the University of Iowa's Institutional Review Board (IRB). For each week of completed participation, participants were eligible for a modest incentive ($10). This School of Music defined 13 instructional areas (e.g., brass, strings), which were used to aggregate data in an effort to establish SEGs without directly identifying participants. Sampling weeks were randomly selected using a random number generator in Microsoft Excel (Redmond, WA). Once recruited, participants were scheduled to start sampling during the next available sampling week. Participants were invited to wear dosimeters for up to 2 full weeks of measurements for both the fall and spring semesters, for a maximum of 4 weeks of measurements over the academic year 2017 and 2018.

Participants were trained on the operation of personal dosimeters. The primary dosimeters used for the study were dBadge2 Pro Personal Noise Dosimeters (Casella, Bedford, UK).

Additionally, a Quest NoisePro DLX dosimeter (3M, Maplewood, MN) was selected for use by two participants during four days of sampling that included performances because the Quest belt clip and small wired microphone made it more desirable to wear during performances. Participants were instructed not to wear dosimeters in the rain or high wind and to avoid bumping the windscreen. Before participants began monitoring, the study team verified that participants could properly mount a dosimeter, turn it on and off, start and stop a measurement run, and charge the dosimeter. Dosimeters were pre-calibrated to 114 dBA before sampling by the study team using a Casella CEL 120/2 calibrator. A Quest C-10 calibrator (3M) was used for the NoisePro.

Dosimeters were placed on participants at the start of a workday, clipped to the left shoulder within the hearing zone. Participants playing instruments that would interfere with left-mounted dosimeters (e.g., violins, trombones) were instructed to wear the dosimeter on their right shoulder. Sound exposure measurements were collected over the course of a full day, including evenings, if work events occurred. At the end of the workday, the participants turned off the dosimeter and placed it in a docking station overnight for charging. At the start of the next day, the process repeated and was continued for a full work week, lasting 2 to 7 days depending on participants' schedules. Dosimeters were collected from participants at the end of the sampling week and post-calibrated. All dosimeters were set to log 1-sec A-weighted sound equivalent levels (L_{eq}) and to calculate TWAs and daily dose for two criteria settings simultaneously: (1) a modified NIOSH setting with a criterion level of 85 dB, an exchange rate of 3-dB and a reduced threshold of 70 dBA and (2) an OSHA hearing conservation setting with a criterion level of 90 dBA, an exchange rate of 5-dB and a threshold of 80 dBA. The reduced threshold of 70 dBA was used to better characterize sound exposures during quiet periods (Green and Anthony 2015; Schaal et al. 2019). Incorporating measurements between 70 dBA and 80 dBA into dose measurements has a negligible effect on exposures at and above exposure limits (> 85 dBA)) but allows for the differentiation between periods that could be considered "effective quiet" (<70 dBA) and intermediate levels that are below the normal 80 dBA threshold.

Participants were instructed to fill out activity logs during monitoring to indicate what activities they performed during 30-min blocks of time. Preliminary discussions with music instructors indicated six broad activity categories: individual lessons, group rehearsals, personal practice, performances, office/administrative work, and meetings. During both the consent meeting and the start of sampling, these categories were discussed with participants to ensure understanding and to identify any additional activities. A seventh category, "other performance duties," was created to code supervision periods before performances (e.g., checking in students for performances) and general follow-up after performances (e.g., visiting with attendees). Participants were instructed to use "NA" to code any time periods during the day with non-work-related activities, including breaks and lunch times. At the end of the sampling week, logs were reviewed with participants to confirm activities and address any issues that may have arisen with coding.

Periodic, unannounced in-person checks were made by the study team to ensure participants were wearing dosimeters correctly and that observed activities matched the participant logs.

Additionally, the dBadges' Motion Index report, indicating the percentage of time movement was detected during the measurement run, was examined to verify wearer compliance.

Data analysis

Date and time-stamped 1-sec sound levels (L_{eq}) were downloaded from the dosimeters using the dBadge2 Download utility (Casella, Bedford, UK) or the Detection Management Software (3M, Maplewood, MN) and then imported into Microsoft Excel. Additional variables coded into the dataset included Participant ID, Semester, Week, Day, and Instructional Area. Based on entries in activity logs, the time-stamped sound data were manually coded to one of the eight "Activity" codes as well as "Occurrence", which allowed for calculating separate dose contributions for different periods of the same activity. The coded dataset was imported into SAS version 9.4 (SAS, Cary, NC) for analysis.

Daily dose and TWAs were calculated, using both the modified NIOSH setting and OSHA Hearing Conservation criteria, from 1-sec data in order to remove any logged sound levels that were not work-related (i.e., periods coded as "NA"). When possible (i.e., days with no "NA" periods), these calculations were compared to the dosimeter's summary reported values to ensure agreement (+/− 1 dBA). The equations used for these calculations are included in online supplemental materials. Any days with less than 8 hours of sound data were assumed to have no work-related exposure above 70 dBA for the remainder of the day. Exposures for days with more than 8 hours of sound data were calculated as TWAs that represented an equivalent 8-hr exposure level. The TWAs calculated with modified NIOSH criteria were compared to the NIOSH REL and ACGIH TLV® of 85 dBA (100% dose). The TWAs calculated with OSHA criteria were compared to the 85-dBA action limit (AL) (50% dose) to determine requirements for participant inclusion into an HCP (OSHA 2018). Daily exposures were tested for normality using the Shapiro–Wilk test in SAS.

Weekly exposure averages were calculated according to methods described in ISO1999:2013 (International Standards Organization (ISO) 2013). One-sec L_{eq} levels were used to calculate a daily sound exposure normalized to an 8-hr day (LEX,8hr). The $L_{EX,8hr}$ levels for each week and participant ID were then normalized to a 5-day week for comparison ($L_{EX,w}$). The resulting $L_{EX,w}$ measure is the equivalent sound level corresponding to the variable sound exposures throughout the week. Weekly exposures were tested for normality using the Shapiro–Wilk test. These weekly exposure averages were compared between instructional areas using ANOVA. The Tukey–Kramer procedure was used for post-hoc comparisons between pairs of instructional areas. Additionally, for each week, daily dose percentages were added to calculate participants' weekly dose to quantify the proportion of weeks that exceeded 500%.

Using SAS, one-way random effects models were used to characterize exposures differences between and within instructors for each instructional area using the following equation (Tornero-Velez et al. 1997):

$$X_{ij} = \mu_y + \beta_i + \varepsilon_{ij} \quad (1)$$

where β_i represents the random deviation of the i-th instructor from the group mean (μ_y), and ε_{ij} represents the random deviation of the i-th instructor from his or her own mean exposure on the j-th day. Parameter estimates from these models include the between- (σ^2_B) and within-instructor variance (σ^2_W) for each instructional area which, when added together, sum to the total variance for each area (σ^2_y). To further characterize exposure by instructional areas, variance components estimated by these models were used to calculate the exceedance (Eq. 2), defined as the probability that a randomly selected instructor's exposure would exceed the exposure limit (85 dBA), as well as the probability of overexposure (Eq. 3), defined as the probability that a randomly selected instructor's mean exposure would exceed the exposure limit:

$$\rho\gamma = P\{X_{ij} > OEL\} = 1 - \Phi\left\{\frac{OEL - \mu_y}{\sigma_y}\right\} \tag{2}$$

$$\theta = P\{\mu_{x,h(i)} > OEL\} = 1 - \Phi\left\{\frac{OEL - \mu_y - \frac{\sigma_W^2}{2}}{\sigma_B}\right\} \tag{3}$$

To identify high-exposure activities, activity-specific dose contributions were calculated similarly to daily dose exposures, but the sum of the ratios of time exposed to time allowed was limited to the duration of each individual activity occurrence. The L_{eq}, or the sound level equivalent to the average sound energy over the given time period, was calculated for each activity occurrence using the following equation:

$$L_{eq,\,occurrence} = 10\log 10\left[\frac{\sum_{i=1}^{n} 10\left(\frac{L_{eq,\,1sec}}{10}\right)}{n}\right], \tag{4}$$

where n is the relative time, or duration of each activity (e.g., 30 min for an individual lesson, 60 min for a group rehearsal).

Results

Daily and weekly exposures

Of the approximately 125 faculty and teaching assistants employed at the school of music, 18 participants responded to the recruitment email and were enrolled in the study. Seventeen participants completed sampling, and each wore the dosimeters between 2 and 25 days (median = 10 days). Ten participants were faculty and seven were graduate teaching assistants (TAs). There were three participants from each of five instructional areas (Brass, Conducting, Music Education, Voice, and Woodwinds) and two participants from Strings. Between 16 and 50 days of exposure measurements were collected for each instructional area. Of the 207 days sampled, 3 days were missing due to participants forgetting to turn on or wear dosimeters, and 1 day was missing due to instrument error. Two days were excluded due to short duration (less than 1 hr of sound data). An additional day was excluded due to the monitor not being worn, as indicated by the dBadge2 Motion Index and confirmed by the participant. Table 1 summarizes the daily sound data for the final 200 useable sampled days collected according to instructional area, job title, and gender. All differences between pre- and post-calibrations were within 1 dB.

Of the 200 daily exposures, 67 (33.5%) exceeded the recommended limit of 85 dBA when calculated with the modified NIOSH setting (Table 2). When compared by instructional area, percentages of TWAs over the REL ranged from approximately 5–69%. Brass was the only instructional area where the mean TWA was above 85 dBA. The distribution of TWAs, calculated with the modified NIOSH criteria, by instructional area, is shown in Figure 1. When calculated with the OSHA HC criteria, only 8% of TWAs exceeded the AL of 85 dBA. Brass and conducting were the only two areas with TWAs above the AL, with 28% and 12% of daily exposures exceeding 85 dBA, respectively. For all areas, participants' daily exposures were varied within each workweek. Differences between the maximum and minimum daily exposures ($L_{EX,8hr}$) within each week ranged from 1–33 dBA. Participants in the conducting group experienced the highest variability (34 dBA) in daily exposures overall. Daily TWAs, across all participants, were not normally distributed (Shapiro–Wilk = 0.97, $p < 0.001$).

Across all participants, 41 total weeks were sampled, with $L_{EX,W}$ranging from 71–92 dBA. Figure 2 shows weekly exposure levels compared by instructional area. Weekly exposure levels were normally distributed (Shapiro–Wilk W = 0.97, $p = 0.37$) with a mean of 83 dBA and a standard deviation of 5 dBA. Average weekly exposures levels between areas ranged from 76 dBA (sd = 4 dBA) (Music Education) to 88 dBA (sd = 3 dBA) (Brass). Weekly exposures for instructors in music education were significantly lower ($p < 0.05$) than weekly exposures for those in brass, conducting, woodwinds, and voice. Weekly exposures for brass and conducting instructors were also significantly higher than woodwinds. Weekly exposure levels for fourteen weeks (34%) exceeded 85 dBA. Brass and conducting groups each had 6 weeks exceeding 500% dose, and strings and woodwinds each had 1 week exceeding 500%. For participants with at least 2 weeks of sampling, differences between the maximum and minimum weekly exposures ranged from 1–10 dBA.

Activity exposures

Across all 200 useable sampling days, participants reported 1,282 distinct activities. Time periods marked as "NA" (not work-related) or periods not specifically identified (i.e., "I was teaching all day with a break in the afternoon", "I was practicing but had to keep stopping") were excluded from the analysis. Thus, sound data were analyzed for 1,057 activities. The activities with the highest contributions to daily dose were group rehearsals, personal practice, performances, and other performance duties. Of the 131 group rehearsals sampled, 23% exceeded 100% daily dose and lasted, on average, for approximately 90 min. Practice sessions, on average, lasted for approximately 40 min. Approximately half of the 90 practice sessions sampled contributed to 40% of daily sound dose and 11% exceeded 100% dose. Many participants had multiple personal practice sessions and group rehearsals each day. Only 23 performances were sampled, as they occurred less frequently than other activities. Additionally, due to restrictions on concert dress attire and performance recording, many participants did not wear a dosimeter during performances. Of the 23 sampled performances, over 40% exceeded 100% daily dose with contributions as high as 784%.

Random effects model output

The highest estimates of between-instructor variability were observed for brass, strings, and music education, indicating that instructors in these areas did not have similar exposures to each other (Table 3). The estimates for between- and within-instructor variability for conducting and voice instructors indicated differences between instructors were minimal compared to differences in day-to-day exposures for these groups. For brass and strings, the between- and within-instructor variabilities were similar, indicating differences in exposures day-to-day and between instructors are both occurring.

Table 3 also lists the exceedance fraction estimates for each instructional area. The exceedance fraction, sometimes referred to as the probability of noncompliance, for the underlying population distribution of music instructors was 30%, and for specific areas ranged from approximately 3% (Music Education) to 67% (Brass). Thus, the likelihood that any one exposure for a brass instructor exceeded the 85-dBA REL was much higher than for those in other instructional areas. The estimated overexposure probabilities indicate the chances that an instructors' mean exposure will exceed the 85-dBA REL. Brass had the only substantial estimate for overexposure (31.4%).

Discussion

Daily and weekly exposures

Results of the current study demonstrate a risk of NIHL for music instructors. Nearly one-third (33.5%) of daily exposures exceeded recommended limits, and 15 of the 17 participants (88%) had at least one daily exposure above the 85-dBA REL. The instructional areas with the highest exposures were brass and conducting. The exceedance estimate for brass (66.6%) indicates that approximately two of three workday exposures are expected to be above the 8-hr TWA of 85 dBA. When calculated with OSHA HC settings, three participants (18%) in these two areas had at least one daily exposure above the 85-dBA AL. Therefore, instructors within these areas need to be placed in hearing conservation programs.

While brass and conducting exposures were more consistently above recommended limits, instructors in other areas, such as strings, voice, and woodwinds did have loud days (>85 dBA). For these areas, approximately 15–25% of samples were above the REL and every participant in these areas had at least one exposure above the 85-dBA REL. It should be noted that these calculations assumed no substantial exposure (>70 dBA) occurred during unsampled periods during the remainder of the day. Any additional sound exposure above 70 dBA would increase daily dose. Participants reported not wearing dosimeters for all performances that occurred during sampling weeks, so it is likely that some of these exposures are underestimated. Even though instructors in these three areas did not have exposures above the 85-dBA AL, all of them had exposures above the 85-dBA REL. Since hearing is such a critical aspect of the job, these instructors would also benefit from inclusion into HCPs.

The 30-dBA range of daily exposures in our study (60–95 dBA) and the proportion above 85 dBA (~30%) are similar to findings from the Mace (2005) study that reported 35% of university instructors had daily exposures exceeding NIOSH limits, with brass instructors being the highest exposed group. The similarities in study design (instructors in a postsecondary institution from a variety of instructional areas for multiple days) may have contributed to similar findings. However, Maffei et al. (2011) reported higher exposures for music instructors in a music academy with $L_{EX,8hr}$ from 85.9–105.4 dBA (Maffei et al. 2011), which may have both different work assignments and acoustic environments to this study.

Thirty-four percent of the 41 weeks sampled exceeded NIOSH and ACGIH recommended weekly limits. Weekly exposures were normally distributed, whereas daily exposures were not. In this institution, activities are scheduled in such a way that each instructor may have different activities on a given day, but across each week, the activities performed were similar. Thus, the variability between weekly exposures was less than the variability between daily exposures. Calculating weekly exposure levels allowed for better comparisons of workers with differences in both the duration of the workweek and daily exposures. For instance, one participant in strings had a week with one daily exposure above 85 dBA (at 87 dBA), but the resulting weekly equivalent exposure was only 82 dBA; this suggests that the one day at 87 dBA (147% dose) was not a substantial enough to impact the entire week when other daily exposures ranged between 77 dBA and 82 dBA. This follows with the ACGIH recommendation that 1 day in the work week may exceed 100% dose as long as no days are over 300% and the workweek does not exceed 500% (ACGIH 2018). In this specific case, the weekly dose totaled 252%, below recommended guidance. In contrast, within the conducting group, there were multiple weeks containing days with TWAs of approximately 60–65 dBA as well as days with TWAs over 90 dBA. Even with multiple quiet days during the week, equivalent weekly exposure levels for this group ranged from 83–92 dBA. The loudest daily exposures were impacting the weekly equivalent levels to a much greater extent than the quiet days. Maffei et al. (2011) also calculated $L_{EX,W}$ in their study and reported similar results. At the music academy where they sampled, teachers were typically employed 2 days per week. Even with limited teaching days, and assuming no substantial exposure for the remaining days, the authors reported equivalent weekly exposure levels as high as 101.4 dBA.

Activity analysis

The activity-specific dose measurements clearly show that there are some activities that substantially contributed to daily dose. High sound levels occurred during performances and group rehearsals with many musicians playing a wide range of instruments together, but high exposures also occurred during solitary practice. Similar to results published by O’Brien et al. (2013), some participants in this study exceeded the 100% daily recommended dose in one 60-min practice session. In general, even though fewer noise sources (e.g., people, instruments) involved in solitary practice compared to a group rehearsal, musicians often continually play at elevated sound levels during their own practice, eliminating the time that they might not be generating music during group rehearsals. In group rehearsals, there were more rest periods when sound levels were predominantly coming from the conductor's spoken instructions.

It is important to characterize these activities by sound level and duration to understand their contribution to daily and weekly dose of music instructors. In the literature, L_{eq} comparisons are reported between activities (Behar et al. 2004; Mace 2005) with emphasis often placed on loud activities. For example, L_{eq} for band rehearsals are reported to range from 85–96 dBA (Behar et al. 2004; Owens 2004), which is consistent with our results, where group rehearsals across areas averaged 88 dBA (sd= 6 dBA). It is also important to assess exposure levels for quiet periods, such as office work, as it is beneficial to understand whether instructors have opportunities for recovery periods during a workday. Effective quiet (<70 dBA) allows for recovery of temporary threshold shifts in hearing (ACGIH 2018) and does not contribute to daily dose. While it is unclear if adequate time at work would be available for this recovery, identifying quiet periods may help to aid in the recommendation of administrative control strategies to reduce overall daily exposure. Music instructors will inevitably have high exposures for special events, like concerts, so from an administrative perspective, it would be helpful to be able to schedule more quiet activities on the hours and days preceding and following these events.

Similar exposure groups

Similar exposure groups were examined by aggregating study participants by the instructional areas in which they teach. Other studies in the literature tend to group exposures by instrument type (Mace 2005; Maffei et al. 2011) as they are expected to produce similar exposures. Due to the relatively small sample size (17), this study was limited to grouping by instructional areas. Therefore, it is likely that some of the between-worker variance observed in each instructional area may be due in part to differences in primary instruments. However, these variances may also be due to differences in job requirements. The enrolled teaching assistants had, on average, higher daily exposures than the faculty members within their same instructional area. These differences indicate that assigning instructors to SEGs based solely on instructional area may not be appropriate and job requirements and schedules may also need to be incorporated into SEG assignments. These exposure differences within instructional areas were especially apparent when examining brass and strings data, where the random effects model indicated higher between-instructor variability than within-instructor variability (Table 3) and mean TWAs for TAs were 89 dBA (sd = 3 dBA) and 84 dBA (sd= 3 dBA) compared to the faculty means of 83 dBA (sd= 1 dBA) and 79 dBA (sd = 3 dBA) for brass and strings, respectively. Activity logs indicated the TAs in these areas wore the dosimeters for more group rehearsals and practice sessions than their faculty counterparts. This is not to suggest that the faculty are not participating in group rehearsals or personal practice, but the TAs were more likely to perform these activities at the school of music and were therefore more likely to be included in sampling. Faculty were more likely than TAs to participate in community ensembles and perform their own music at off-campus locations. In this study, few faculty members wore dosimeters off-campus, and it is likely that the faculty exposures may be underestimated.

A possible explanation for high within-worker variability is the inherent differences in the music that is played throughout the year. A 2010 study investigating sound levels produced during university wind band practices, reported band director doses ranging from 53.8–166.9% for individual practices (Chesky 2010). Chesky explained that since separate rehearsals for the same ensembles did not produce consistent doses over time, a portion of the variability in sound exposure may come from the music being studied/performed. O'Brien et al. (2008) discussed the impact of repertoire on exposure variability as well and reported L_{eq} for three different pieces performed during one program that ranged from 81.9–95.7 dBA. Thus, it is understandable that the pieces being rehearsed on a given day will affect musicians' exposures.

Limitations of this study include its small sample size, its one location for sampling, and missing off-site and performance activities. When performing, participants were reluctant to wear dosimeters because they did not want the devices to be a distraction to themselves or others. Additionally, some participants found it difficult to travel with dosimeters if they had off-site activities. It may be beneficial in future studies to find alternative ways to sample exposures during these types of activities. While a substantial amount of qualitative data was collected on the activity logs, participants were not asked to record additional factors that may have contributed to variation in sound levels observed within activities, such as the number of students or instruments present, the acoustic characteristics of the rooms, or the music being played. These details were the tradeoff for gathering long-term exposure data from multiple participants, which is a strength of this study. As all participants were employed by the same institution, their exposures are affected by their environment and the specific construction of the school where the majority of measurements were made.

Conclusions

Based on single-day and weekly dose data, music instructors, especially in brass and conducting, are at risk for NIHL due to their exposures to high sound levels that exceed recommended limits. Exposures are highly variable and are influenced by instructional area and musical activity. Activities that contributed the most to daily dose included group rehearsals, personal practice sessions, and performances. In future studies, the frequency of these activities should be evaluated and used in combination with instructional area and musical instrument to help establish SEGs, which would be beneficial in minimizing sampling and help to target controls for specific groups of music instructors.

Recommendations

Future sampling for music instructors should include multiple days of sampling to capture the range of required activities and better characterize exposure than sampling for a single day. Before sampling, job requirements should be reviewed, and weekly activities should be discussed with instructors. If the job requires or assumes any off-site performance or service components, then the exposure contributions from those activities, along with personal practice, should be included in the assessment. Due to the variety of activities required and inherent variability in music, sampling sound exposures on 1 day is insufficient to characterize the exposure and the risk of hearing loss over a career of music instruction. The difference in daily exposures across one participant's week in our study was as high as 33 dBA. Obtaining a single day's exposure metric for a person with such high daily variability may grossly misclassify their sound exposure.

Sampling should be performed using NIOSH or ACGIH criteria (85-dBA criterion, 3-dB exchange rate) to better characterize variable exposures. If information regarding exposure <80 dBA is necessary, a reduced threshold of 70 dBA should be used; however, the threshold reduction would not be necessary if only using these data to assess compliance with exposure limits. If, during sampling, any daily exposure exceeds 300%, the worker should be considered overexposed and placed in an HCP. Baseline audiograms should be given upon hire and annually to identify if any hearing threshold shifts occur. If one daily exposure exceeds 100%, sampling should continue for the remaining days of the workweek to determine if the weekly total exceeds 500%. If there is only 1 day with exposures above 100% dose, the activities for that day should be examined to identify potential control options. Additionally, the frequency of such high-exposure activities should be determined.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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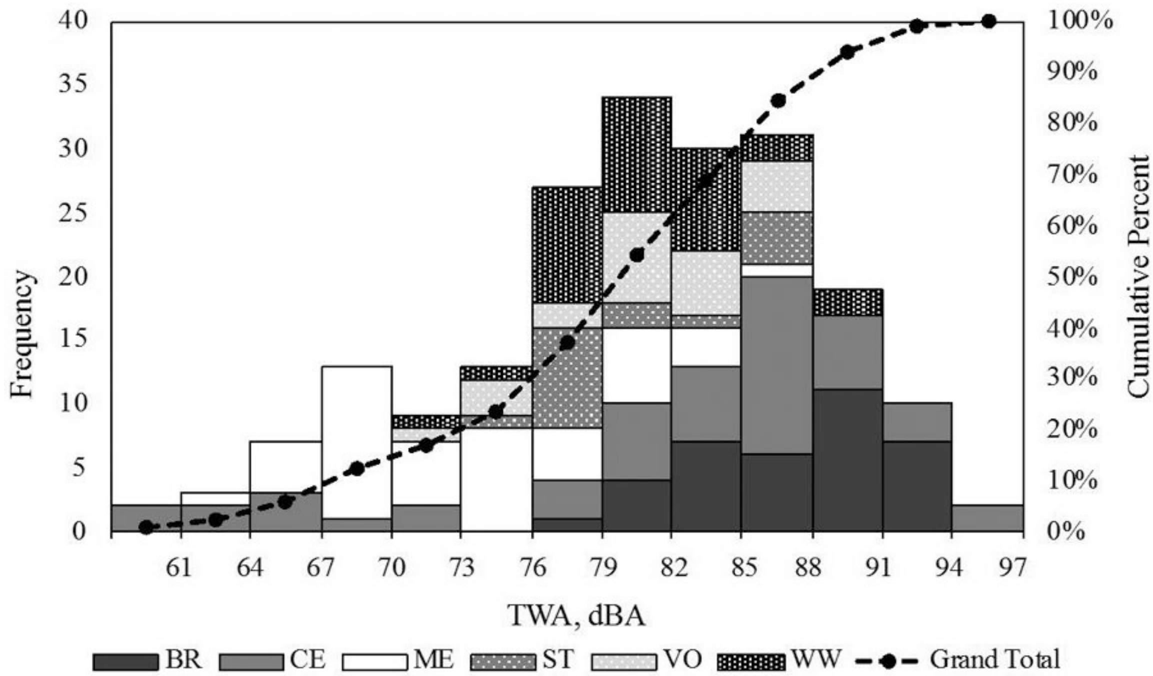

Figure 1.

Stacked histogram of daily TWAs calculated with modified NIOSH criteria (n=200) separated by instructional area (BR=brass, CE=conducting, ME=music education, ST=strings, VO=voice, WW=woodwinds)

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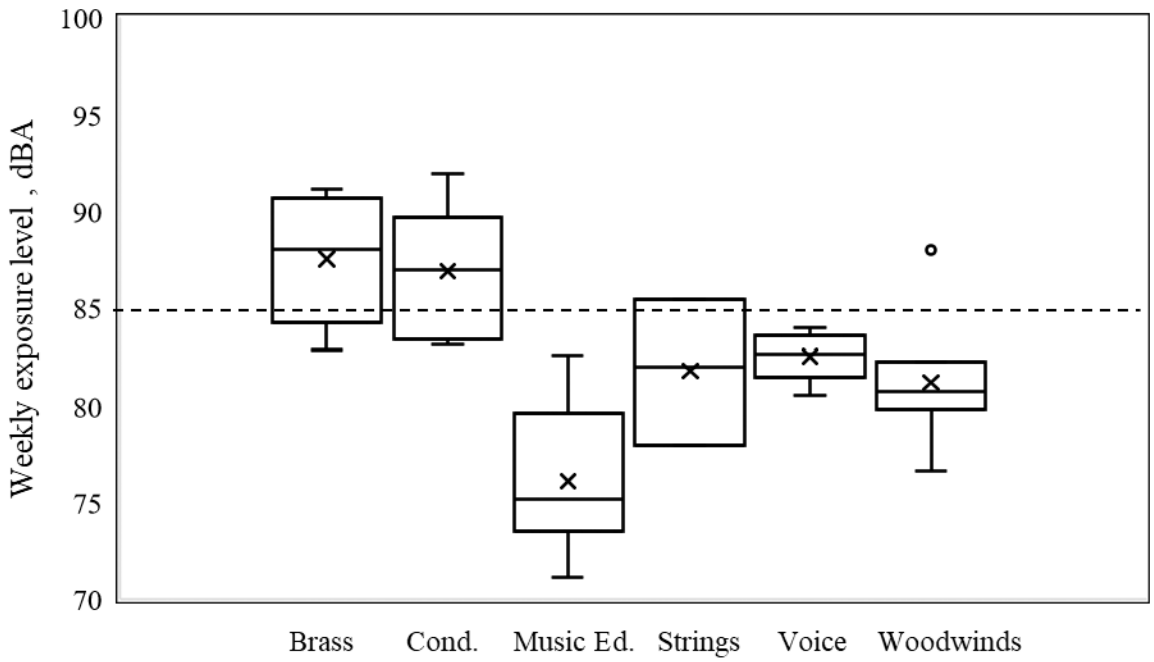

Figure 2.
Box and whisker plot of weekly exposure levels compared by instructional area. The dashed reference line indicates the recommended limit of 85 dBA.

Table 1.

Descriptive statistics of daily exposure data (n=200)

Factors	Description	Count	Percent
Instructional area	Brass	36	18.0
	Conducting	50	25.0
	Music Education	44	22.0
	Strings	16	8.0
	Voice	22	11.0
	Woodwinds	32	16.0
Job Title	Faculty	108	54.0
	Teaching Assistant	92	46.0
Gender	Female	75	37.5
	Male	125	62.5

Table 2.

Summary of sampled daily TWAs calculated with NIOSH[1] and OSHA[2] criteria

Instructional Area	No. of workers	No. of TWAs	Mean (SD) (dBA)		95^{th} percentile		% above 85 dBA	
			TWA_{NIOSH}	TWA_{OSHA}	TWA_{NIOSH}	TWA_{OSHA}	TWA_{NIOSH}	TWA_{OSHA}
Brass	3	36	87.5 (3.9)	80.5 (5.2)	92.8	86.7	69.4	28.0
Conducting	3	50	82.1 (9.6)	72.9 (14.1)	94.2	89.2	50.0	12.0
Music Education	3	44	73.9 (5.9)	61.3 (9.2)	84.0	75.4	4.6	0.0
Strings	2	16	80.8 (4.0)	73.8 (5.2)	87.1	82.4	25.0	0.0
Voice	3	22	81.5 (4.3)	71.5 (5.4)	87.0	77.6	22.7	0.0
Woodwinds	3	32	81.2 (3.9)	73.8 (5.0)	89.4	83.4	18.8	0.0
Total	17	200	81.0 (7.6)	71.8 (11.0)	91.6	85.8	33.5	8.0

[1]Modified NIOSH criterion using 3 dB exchange rate and reduced 70 dB threshold

[2]OSHA Hearing Conservation criterion using 5 dB exchange rate and 80 dB threshold

Table 3.

Parameter estimates from random model output and calculated exceedance and overexposure based on daily TWAs calculated with modified NIOSH setting

Instructional Area	No. of instructors	No. of TWAs	Mean exposure[2]	Between-instructor variability[2]	Within-instructor variability[2]	Exceedance	Overexposure
			$\hat{u}$	σ_B	σ_W	γ	θ
Brass[A]	3	36	86.8	3.3	2.6	66.6	31.4
Conducting[A]	3	50	82.1	0.0	9.5	38.0	*
Music Education	3	44	73.0	3.5	5.2	2.8	0.0
Strings	2	16	81.4	3.3	3.1	21.2	0.5
Voice	3	22	81.9	1.2	4.2	24.1	0.0
Woodwinds	3	32	81.9	2.6	3.3	23.5	0.0

[A] Brass and conducting exposures were not normally distributed

[B] Mean exposure and variability expressed as standard deviation, both have units of dBA

* Between-instructor variability was estimated to be 0 resulting in an undefined overexposure estimate