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Original Article

Examining the noisy life of the college musician: weeklong noise dosimetry of music and non-music activities

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Abstract

Objective: To examine the contribution of all daily activities, including non-music activities, to the overall noise exposure of college student musicians, and to compare their ''noise lives'' with those of non-musician college students. *Design*: Continuous week-long dosimetry measurements were collected on student musicians and non-musicians. During the measurement period, participants recorded their daily activities in journals. *Study sample*: 22 musicians and 40 non-musicians, all students (aged 18–24 years) at the University of Connecticut. *Results*: On every day of the week, musicians experienced significantly higher average exposure levels than did non-musicians. Nearly half (47%) of the musicians' days exceeded a daily dose of 100%, compared with 10% of the non-musicians' days. When the exposure due to music activities was removed, musicians still led noisier lives, largely due to participation in noisier social activities. For some musicians, non-music activities contributed a larger share of their total weekly noise exposure than did their music activities. *Conclusions*: Compared with their non-musician peers, college student musicians are at higher risk for noise-induced hearing loss (NIHL). On a weekly basis, non-music activities may pose a greater risk to some musicians than music activities. Thus, hearing health education for musicians should include information about the contribution of lifestyle factors outside of music to NIHL risk.

Key Words: Hearing conservation/hearing loss prevention, instrumentation, noise, behavioural measures

Introduction

A growing body of research indicates that college music students' exposure to sound routinely exceeds the recommended exposure limits specified by the National Institute for Occupational Safety and Health NIOSH (1998) (e.g. Miller 2007; Phillips and Mace 2008; Chesky 2010; Deiters et al. 2010; Gopal et al. 2013; Washnik, Phillips, and Teglas 2016). Potentially hazardous noise exposure occurs during rehearsals, individual practice, and other music activities (Miller 2007; Chesky 2010; Deiters et al. 2010; Gopal et al. 2013; Washnik, Phillips, and Teglas 2016). Phillips et al. have identified high-frequency hearing loss ''notches'' consistent with excessive sound exposure in college music students and have shown that these notches become more pronounced with increasing years spent in a college music programme (Phillips et al. 2008; Phillips, Henrich, and Mace 2010). Noise exposure has also been generally associated with such negative non-auditory effects as disrupted sleep and increased occurrence of cardiovascular disease (Basner et al. 2014; Gourevitch et al. 2014), although these effects are not well-studied in this population.

In recognition of the risk posed to students' hearing by school music activities, the National Association of Schools of Music (NASM), the accrediting body for schools and departments of music, mandates that basic education be provided to college music students on hazards to hearing health (NASM 2016–2017). This mandate applies to students who are pursuing degrees in music and those who participate in school-sponsored music activities but are pursuing degrees in non-music fields. In conjunction with the Performing Arts Medical Association (PAMA), NASM has issued advisories and recommendations for measuring and monitoring sound levels in rehearsal and practice spaces and altering the environment accordingly to reduce risk (NASM-PAMA 2011).

Although reducing exposure during school-based rehearsal and solo practice would help to mitigate NIHL risk, these activities are not the only contributors to daily noise exposure for college music students (Deiters et al. 2010; Washnik, Phillips, and Teglas 2016).

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Abbreviations

$L_{EX,8h}$	8-h-normalised A-weighted equivalent level
NASM	National Association for Schools of Music
NIHL	noise-induced hearing loss
NIOSH	National Institute for Occupational Safety and Health
PAMA	Performing Arts Medical Association
UConn	University of Connecticut

Other contributors could include performing at athletic events or pep rallies, attending concerts, or participating in noisy social events or other noisy non-music activities. To better understand the risks to hearing health faced by college music students and effectively educate them to protect their hearing, a more complete understanding of the totality of their noise exposure is needed. Unfortunately, the ''noise lives'' of college musicians have not been well-studied. To address this gap, Washnik, Phillips, and Teglas (2016) conducted two days of individual dosimetry on 57 classical music college students, with one day representing the Monday-Wednesday-Friday class schedule and the other representing the Tuesday-Thursday class schedule. On each weekday, noise exposure was measured from morning to evening, for a typical duration of 7-9 h, using an 85-dBA criterion level and a 3-dB exchange rate. Students logged the activities they engaged in during each of the measurement days, including start and end times. Almost one-half of the participants accrued a noise dose in excess of 100% on at least one measurement day, and nearly one-fifth accrued noise doses over 100% on both days. Although the bulk of the participants' cumulative daily noise doses resulted from ensemble and/or practice sessions, Washnik, Phillips, and Teglas (2016) reported that non-music activities ''may also have contributed to overall dose. In fact, one student musician exceeded 100% noise dose during lunch.''

As Washnik, Phillips, and Teglas (2016) argued, day-long dosimetry provides a better representation of college musicians' noise exposure profiles than do measurements conducted in specific settings such as rehearsal and practice spaces. However, a limitation of their study is that noisy activities are not confined to the daytime and early evening hours, or to weekdays for that matter. Significant contributions to daily noise exposure could be missed if dosimeters are turned off too early or if measurements exclude weekends.

To this point, Deiters et al. (2010) performed continuous (24-h) week-long dosimetry on 45 undergraduate music majors. The measurements revealed that hazardous noise exposure occurred at all hours of the day and night, but predominately between 9am and midnight, underscoring the importance of conducting dosimetry for entire 24-h days. Prior to participating in dosimetry, participants submitted a prospective schedule for the week of their music practice and performance hours, and hours to be spent working at a paid job. Almost half of the participants' total noise exposure was associated with scheduled music activities, while the remaining exposure was predominately associated with events that occurred outside their scheduled music or job activities. No information was gathered regarding the nature of the musicians' noisy non-music activities, however.

The finding by both Washnik, Phillips, and Teglas (2016) and Deiters et al. (2010) that potentially hazardous noise exposures occurred outside of scheduled music activities has several important implications. As Deiters et al. (2010) pointed out, engineering and administrative controls of rehearsal, performance, and practice spaces would not substantially benefit those students for whom the bulk of hazardous exposure is accrued during non-music activities. The finding also begs the question as to what the other noisy activities were. If the noise-hazardous behaviours of college musicians were better understood, hearing health education could better serve them, not to mention more effectively fulfil NASM's education mandate. The extent to which noisy non-music activities are typical not just of college music students, but of the general college student population, is an important question as well. Although personal music player use is well documented among college students (Le Prell et al. 2013), a more comprehensive understanding of the noise lives of college students in general could improve hearing conservation efforts directed at this population.

In the current study, we conducted week-long 24-h dosimetry on a sample of college student musicians (both music majors and non-music majors) and non-musicians. In doing so, we sought to answer the following two questions: What are college musicians' noise lives really like? And how do they compare to the noise lives of their non-musician peers?

Methods

Participants

A total of 62 young adults, all students at the Storrs campus of the University of Connecticut (UConn), participated in this study. All participants completed a survey about their current and past involvement in music-related activities. As part of this survey, they were asked whether they currently participated in any music ensembles on campus, and if they responded yes, they were assigned to the musician group ($n = 22$; 4 males, 18 females); otherwise they were assigned to the non-musician group ($n = 40$; 14 males, 26 females) (Table 1). Participants ranged in age from 18 to 24 years, with the musicians being slightly younger on average than the non-musicians (19.5 ± 1.37 years vs. 20.48 ± 1.6 years, $t(60) = 2.47$, $p = 0.02$). With the goal of recruiting a reasonably representative sample of UConn college students, ads were placed in a newsletter emailed to all UConn students on weekdays, containing notices about campus events, including research opportunities. The participants in our sample reported that they were pursuing degrees that spanned the seven UConn schools and colleges that accept undergraduate majors, and the distribution of our participants roughly matched overall UConn demographics (Table 1). Two of the non-musician participants were graduate students.

Among the musicians, most (all but three) were pursuing non-music degrees and were participating in music ensembles for course credit or as a hobby. The total number of music majors on campus is relatively small (~120 out of more than 19,000 undergraduates); however, the music department supports more than 18 different music ensembles, serving both majors and non-majors, with the largest being marching band (~300 members). At the time of testing, the musicians were participating in a variety of ensembles on campus, including the UConn pep band, marching band, wind ensemble, drumline, concert band, colour guard, symphonic band, and/or one of several different choirs. Twelve of the musicians indicated that they were active in more than one ensemble throughout the year, and some musicians played more than one instrument. The distribution of participants by instrument family was: woodwind (9), brass (6), voice (4), percussion (2), piano (2), and strings (1).

Table 1. Group demographics by school/college in which degree is being pursued. For the participant sample, absolute numbers are given in parentheses. Percentages in these two rows add to more than 100% due to rounding.

Group	*Liberal arts and sciences*	*Agriculture, health, and natural sciences*	*Business*	*Engineering*	*Fine arts*	*Education*	*Nursing*	*Unknown/ undeclared*
UConn undergraduate student population[1] ($n = 19{,}030$)	54%	9%	10%	17%	3%	1%	3%	3%
Musicians ($n = 22$)	56% (12)	14% (3)	0% (0)	5% (1)	14% (3)	5% (1)	5% (1)	5% (1)
Non-musicians ($n = 40$)	60% (24)	18% (7)	8% (3)	8% (3)	3% (1)	3% (1)	0% (0)	3% (1)

[1]Based on the most recent institutional student data (Fall 2016).

All but six of the 40 non-musicians reported receiving music training at some point in their lives. However, the musicians had more total years of training than the non-musicians with previous training (11.40 ± 3.51 years vs. 7.00 ± 5.00; $t(54) = -3.64$, $p = 0.001$). The musicians also rated themselves as having a higher music proficiency than the non-musicians (7.77/10 vs. 4.32/10; $t(54) = -5.73$, $p < 0.0005$). Seven of the 40 non-musicians reported that they were currently musically active, although their activities largely involved playing alone (82% of their music activity time), and when they did play with a group, they were ''jamming with friends''. This is in contrast to the musicians who, as a group, reported that they spent ~86% of their music activity time playing in a group and the remainder playing alone. In most cases, the non-musicians had stopped playing altogether once reaching college and, if they did continue to play, did so informally.

Besides the 62 participants already described, 10 additional participants (4 musicians, 6 non-musicians) enrolled in the study and completed all procedures. However, their data were excluded from analysis because they explicitly indicated that the week during which dosimetry was conducted was very atypical for them. For example, one musician, a singer, had laryngitis and did not participate in her usual music and social activities for the week; one non-musician travelled to his parents' home and stayed there for most of the week due to illness.

Dosimetry

Each study participant wore an ER-200DW8 personal noise dosimeter (Etymotic, Inc.) for seven consecutive 24-h days. The dosimeters were configured to an 85-dBA criterion level and 3-dB exchange rate, in conformance with NIOSH (1998), and a 75-dBA threshold. They logged dose data in 3.75-min increments throughout the entire measurement period. The turnoff button was disabled so that participants could not accidentally shut off the dosimeter. The calibration of all dosimeters was periodically checked to ensure that the instruments were operating properly. This was done by generating a continuous 1000-Hz narrowband signal at a nominal level of 90 dB SPL in an Audioscan Verifit test box, and measuring its level with a calibrated Type 1 sound level meter (Larson-Davis 824) and with each dosimeter in ''QuickCheck'' mode. For each measurement, the microphone of the device was positioned at the same location in the test box. Measured dosimeter levels fell within 2.5 dB of the mean of three sound level meter measurements.

Journals

Participants recorded their activities in journals over the entire week. Each entry included the date, time, location, activity, whether or not earmuffs/earplugs or headphones/earbuds were worn, a brief description of setting/sound sources, and subjective comments on loudness.

Procedures

This study was approved by the UConn Institutional Review Board. All participants gave their informed consent and were paid for their involvement in the study. Participants were given a blank journal and a dosimeter with fresh batteries. The participant was instructed to attach the dosimeter to their clothing near the ear (e.g. on a shirt collar), with the microphone inlet uncovered, during all waking hours except when the dosimeter might be damaged (e.g. during sports). Participants were instructed to keep the dosimeter nearby when sleeping or showering. Participants were also instructed as to how to record their activities in their journals (see ''Methods'' Section C above). They were asked to account for all waking hours to the extent possible. A page listing mock journal entries for a period of several hours was included in the front of the journal as a model. After all instructions had been given and questions answered, the investigator turned on the dosimeter and immediately recorded the time of day (in hours and minutes) in a spreadsheet. Participants were scheduled to return in no less than one week to hand in the dosimeter and journal. They were instructed to contact the investigator during the week if any questions or problems developed.

Data analyses

All journal entries were coded by hand into the following broad activity categories: UConn Music (which included any music activity, solo or ensemble, pertaining to the UConn ensemble(s) to which the participant belonged), Non-UConn Music (which included any music activity, solo or ensemble, that was unrelated to any UConn ensemble), Social Events, Transportation, Home/Dorm, Academic, Exercise, Off-Campus Work, and Other (which included activities that did not fall into one of the other categories). The total hours spent in each activity category were calculated for each participant. Hours spent sleeping were calculated either directly from journal entries listing bedtime and awakening or were estimated from the end time given for the last event of one day and the start time of the first event of the next day. Lastly, the sleeping hours and coded activity hours were subtracted from 168, the total number of hours (i.e. $24\,\text{h} \times 7$ days), and the remaining hours were coded as Unaccounted Time.

Dosimetry data were downloaded to .txt files, one per participant, using the ER200D Utility Suite software (version 4.04). The data were then processed individually for each participant using two custom routines programmed in MATLAB (release 2016a, The Mathworks, Inc.). The first routine separated the data by date, using the dosimeter start time recorded by the investigator. Each participant's record thus contained six full 24-h days and two partial days on either end, one when the dosimeter was turned on and the other when it automatically shut off. For each 24-h day, the 8-h-normalised A-weighted equivalent level ($L_{EX,8h}$) was calculated from that day's dose. The data for the two partial days, which always fell on the same day of the week, were later combined into a single $L_{EX,8h}$ and dose, representing the seventh 24-h day. In three cases, a full weeklong dosimetry run was interrupted due to dosimeter malfunction or mishandling. In those cases, the participant was provided with a new dosimeter and a new run was commenced to capture the missing days of the week. Data from the two partial runs were combined into a single full run by taking the mean of the doses for those days of the week that were repeated, and taking the single available dose for those days of the week that were not repeated. Subsequently, all $L_{EX,8h}$ <75 dBA, the threshold of the dosimeter, were rounded up to 75 dBA. Lastly, each participant's average $L_{EX,8h}$ for the entire seven-day week was calculated using the formula:

$$L_{EX,8h} = 10\log\left[\left(\frac{1}{7}\right)\sum_{i=1}^{7}\left(10^{0.1(L_{EX,8h})i}\right)\right], \qquad (1)$$

where $L_{(EX,8h)i}$ is the daily exposure level for day *i*.

Henceforth, the $L_{EX,8h}$ for the entire seven-day week will be denoted ''weekly $L_{EX,8h}$'' in contradistinction to the single-day $L_{EX,8h}$.

The second MATLAB routine identified sections of the dosimetry record that fell at or above 85 dBA and outputted the corresponding time stamps, in 3.75-min increments. The activity category associated with each of these timestamps was then determined based on information provided in the journals. Three separate weekly $L_{EX,8h}$, one for music activities only, one for non-music activities only, and one for all activities combined, were calculated for each musician participant. Subsequently, all weekly $L_{EX,8h}$ <85 dBA were rounded up to 85 dBA, the threshold level below which data points were not extracted by the second MATLAB routine. Statistical analyses were conducted in SPSS v. 12 (SPSS, Inc.).

Results

Musicians and non-musicians allocated their waking hours in roughly similar proportions across all non-music activity categories (Figure 1). For both groups, Home/Dorm was the single largest activity category by far, representing 35% and 39% of the waking hours for musicians and non-musicians, respectively (all numbers rounded to nearest percent). Excluding Unaccounted Time, the next largest categories for both groups were Academic (musicians: 17%; non-musicians: 20%) and Social Events (musicians: 15%; non-musicians: 13%), followed by UConn Music for the musicians only (9%; per the inclusion/exclusion criteria of the study, non-musicians had no UConn Music hours). The remaining activity categories, Non-UConn Music, Transportation, Exercise, Off-Campus Work, and Other, together accounted for 10% and 13% of the musicians' and non-musicians' time, respectively. Unaccounted Time represented 14% and 15% of the musicians' and non-musicians' respective waking hours. Some of this time likely included miscellaneous activities that were not recorded in the journals, such as walking between classes. It also included hours for which there were gaps in the journal records.

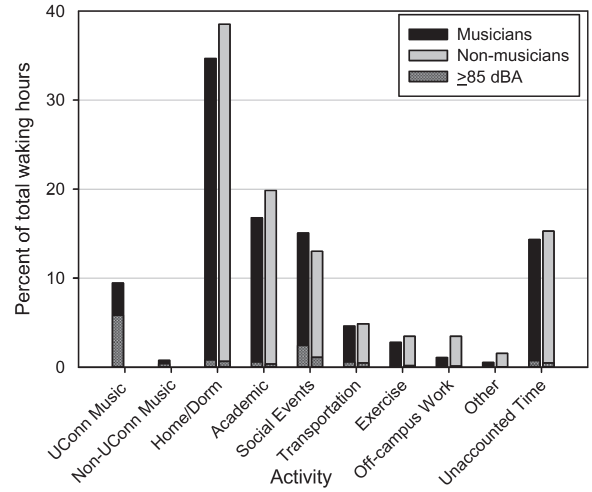

Figure 1. Percent of total waking hours spent in each activity category by musicians ($n = 22$; ~2400 h) and non-musicians ($n = 40$; ~4450 h). The chequered portion of each bar shows the proportion of hours for which noise levels equalled or exceeded 85 dBA.

Across all activity categories, musicians collectively spent a total of 12% of their waking hours in noise levels ≥85 dBA, compared with 3% of waking hours for non-musicians. Musicians' time ≥85 dBA was split nearly equally between UConn Music and all remaining activity categories. Of note, 61% of the time spent in the UConn Music category was at levels ≥85 dBA.

Daily exposure levels varied widely within each group, from 75 dBA to 102 dBA for the musicians and from 75 dBA to 100 dBA for the non-musicians (Figure 2). However, musicians' days were noisier: collectively, nearly half (47%) of their days exceeded a daily dose of 100% (equivalent to 85 dBA $L_{EX,8h}$), compared with just 10% of the non-musicians' days ($t(40) = 6.08$; $p < 0.001$). This finding was not driven by a small number of highly exposed musicians: for 74% of musicians (16 out of 22), three or more days out of the week exceeded a daily dose of 100%, compared with just 13% of non-musicians (5 out of 40); conversely, only 9% of musicians (2 out of 22) never exceeded a daily dose of 100%, compared with 70% (28 out of 40) of the non-musicians.

The dosimetry data were examined by day of the week to see if any exposure patterns emerged within or across groups (Figure 3). On each day, musicians were exposed to significantly higher average daily exposure levels compared with non-musicians (all $p < 0.01$). A mixed-model repeated-measures ANOVA revealed a significant interaction between group and day of the week ($F(6, 360) = 3.96$, $p = 0.004$). The days for which musicians' exposure levels were highest on average and deviated most from the non-musicians' were Tuesday, Thursday, Friday and Saturday. These are rehearsal and performance days for the UConn marching band and drumline, members of which constituted 77% of our musician sample (17 out of 22). For musicians, the day associated with the highest level was Thursday; post-hoc pairwise comparisons revealed that this day's level was significantly different from the levels on Sunday, Monday, and Wednesday (all $p < 0.01$) but not Tuesday, Friday, or Saturday. For the non-musicians, the day associated with the highest level was Saturday; for this group,

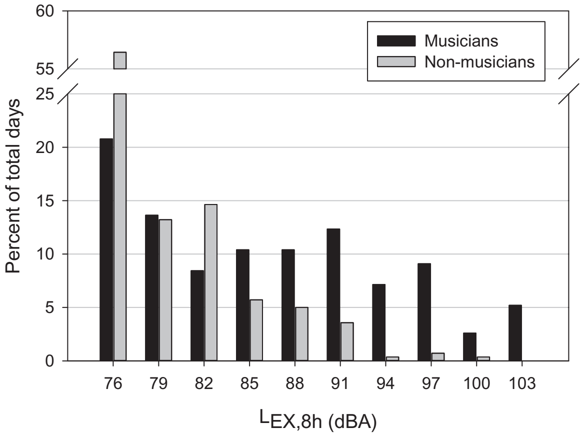

Figure 2. Percent of total 24-h days for which the given 8-h-normalised A-weighted equivalent level ($L_{EX,8h}$) was measured, for musicians ($n = 22$; total days = 154) and non-musicians ($n = 40$; total days = 280). The $L_{EX,8h}$ shown on the abscissa are the upper limits of 3-dB bins.

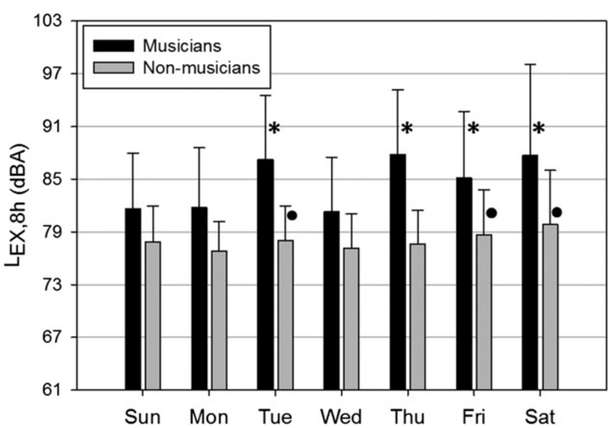

Figure 3. Mean 8-h-normalised A-weighted equivalent levels ($L_{EX,8h}$) on each day of the week for musicians ($n = 22$) and non-musicians ($n = 40$). Error bars show +1 standard deviation. On every day of the week, the musicians' average level was significantly higher than the non-musicians' (all $p < 0.05$). Certain days are marked by asterisks (musicians) or black circles (non-musicians); these include the day on which the highest average level was measured in each group (Thursday for the musicians, Saturday for the non-musicians) and the days whose levels were not significantly different from the highest level (Tuesday, Friday, and Saturday for the musicians; Tuesday and Friday for the non-musicians; all $p < 0.05$).

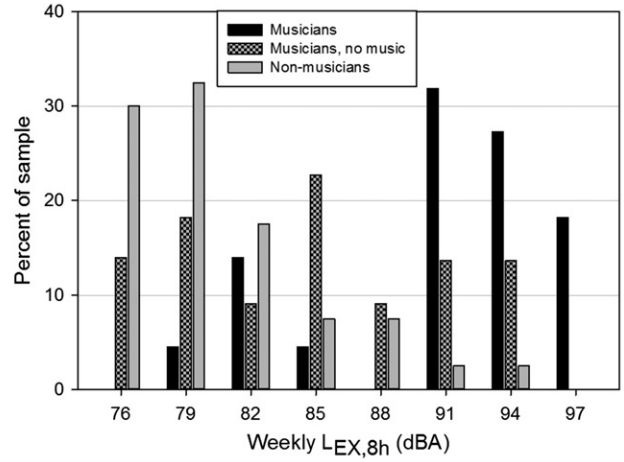

Figure 4. Percent of musicians ($n = 22$) and non-musicians ($n = 40$) as a function of weekly $L_{EX,8h}$. Two distributions are shown for the musicians, one in which all activities were included in the calculation of weekly $L_{EX,8h}$ (black bars) and one in which music activities were excluded (chequered bars). The weekly $L_{EX,8h}$ shown on the abscissa are the upper limits of 3-dB bins.

Saturday's level was significantly different from the levels on all other days of the week (all $p < 0.03$), except for Tuesday and Friday where the difference was trending ($p = 0.08$ and $p = 0.09$, respectively).

Not only did musicians have higher daily exposure levels than non-musicians, they varied more widely in their exposure levels over the course of the week. The range of daily exposure levels over the seven-day measurement period averaged 19.2 dB for musicians and 7.1 dB for non-musicians, a statistically significant difference ($t(33) = 7.30$; $p < 0.001$).

For each participant, daily exposure levels across the week were combined into a weekly $L_{EX,8h}$. The weekly $L_{EX,8h}$ of musicians were significantly higher than those of non-musicians ($t(60) = 7.44$; $p < 0.001$), with means of 89 dBA and 79 dBA, respectively. 77% of musicians (17 out of 22) had weekly $L_{EX,8h} \geq 85$ dBA compared with 15% of non-musicians (6 out of 40) (Figure 4)[1].

Music activities accounted for much of the difference in weekly $L_{EX,8h}$ between the groups, but not all. Even apart from their music activities, musicians led noisier lives than non-musicians with a mean weekly $L_{EX,8h}$ of 83 dBA compared with 79 dBA for non-musicians ($t(31) = 2.74$; $p = 0.010$) (Figure 4). Subtracting out the UConn Music exposure component, 36% of musicians (8 of 22) still had a weekly $L_{EX,8h} \geq 85$ dBA. Differences between the groups in the noisiness of their social activities likely accounted for this finding. The Social Events category contained the largest share of total hours ≥85 dBA for the non-musicians, and the second largest share (after UConn Music) for the musicians. Even though each group reported similar types of social activities (e.g. parties, dining hall) and spent proportionately similar amounts of time socialising, musicians spent proportionately over twice as much time as non-musicians socialising at levels ≥85 dBA (musicians: 2.4% of total waking hours; non-musicians: 1.1% of total waking hours [unrounded]; see also Figure 1).

The portions of the musicians' total exposure attributable to UConn Music alone and to all other activity categories combined are shown in Figure 5. Of the 17 musicians with total weekly $L_{EX,8h} \geq 85$ dBA, 11 received most of their exposure from music activities. These individuals are shown on the left side of the figure. The remaining six, shown on the right side of the figure, received most of their exposure from other activities, primarily in the Social Events category.

Discussion

We investigated the noise lives of college student musicians and non-musicians using a combination of weeklong 24-h dosimetry and journaling. Consistent with previous research, university-related

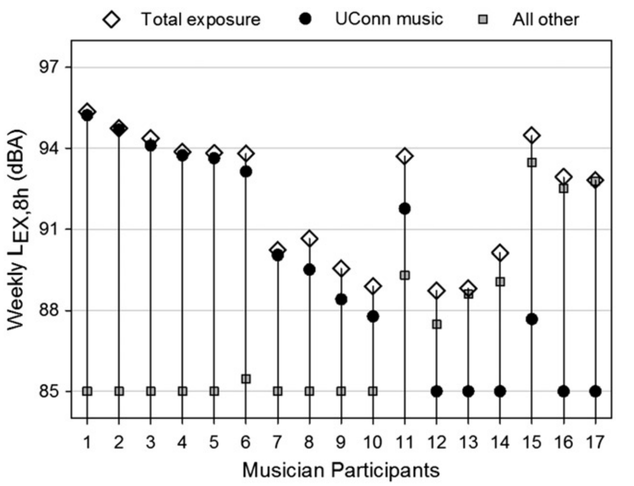

Figure 5. Weekly $L_{EX,8h}$ due to all activities (diamonds), due to music activities only (circles), and due to non-music activities only (squares) for 17 of the musician participants. Note that all weekly $L_{EX,8h}$ <85 dBA have been rounded to 85 dBA. Participants are shown in order of decreasing difference between weekly $L_{EX,8h}$ due to music activities and weekly $L_{EX,8h}$ due to non-music activities. Not shown are five musicians for whom total weekly $L_{EX,8h}$ did not exceed 85 dBA.

music activities, including ensemble and solo rehearsals and performances, were found to be a significant source of potentially hazardous exposure for the student musicians, with more than 60% of music activity time associated with levels ≥85 dBA. Indeed, day-by-day variations in noise exposure for the student musicians were largely reflective of their music practice and performance schedules. However, for a number of the musicians, the risk generated by non-music activities, primarily social events, was even greater than that generated by music activities. In addition, the highest daily exposure levels that were measured, those exceeding 100 dBA, were nearly always associated with either music activities, social activities, or a combination of the two. These findings underscore the critical need for hearing conservation education to address the noise lives of college musicians in their entirety, including the contribution of lifestyle factors and social behaviours to NIHL risk. As the NASM guidelines state, ''[h]ealth and safety depend in large part on the personal decisions of *informed* individuals'' (NASM 2016–2017, page 65, italics added for emphasis).

A majority of the student musicians in our sample were pursuing degrees in fields outside of music, suggesting that they are not on the typical trajectory for becoming professional musicians. They spent on average 10.3 h/week in university-related music activities, including both ensemble and solo practice. This duration of music-making is commensurate with other reports of practice habits among college musicians (Miller 2007; Barlow 2010). For example, Barlow (2010) reported that students enrolled in music courses in the United Kingdom spent an average of 11.5 h/week making music as part of either rehearsals or recording sessions. Likewise, Miller (2007) found that 52% of their sample of music students at a state university played music for 0–10 h a week, with 74% reporting that they played between 0–15 h a week. Thus, our sample of musicians is generally representative of music students at other universities, at least in terms of the time they spend on music activities. However, the degree to which their social activities and attitudes about noise are generalisable to other student musician populations, including those planning to pursue professional careers in music performance, warrants further exploration (Chesky et al. 2009).

A secondary goal of the study was to examine the noise lives of college students who were not participating in music ensembles. Like the musicians, the non-musician participants in our sample were pursuing a variety of majors spanning the various colleges within the university (Table 1). Their mean weekly $L_{EX,8h}$ was 79 dBA, suggesting that most of them are at reasonably low risk for NIHL, unlike the musicians, who had a mean weekly $L_{EX,8h}$ of 89 dBA. The median daily exposure level computed across all individual days, 75 dBA, was similar to the median level of 76 dBA reported by Flamme et al. (2012) for everyday noise exposure in a much larger sample of the general population (ages 20–68 years) of a college town (Kalamazoo, Michigan). The musicians, by comparison, had a much higher median daily exposure level of 83 dBA.

Unlike Washnik (2016) and Deiters et al. (2010), whose studies focussed exclusively on musicians, we were able to compare the noise exposure of musicians and non-musicians. These two groups of young adult college students might be expected to have lifestyles that are fairly similar in many respects. Indeed, we found that both groups participated in similar types of non-music activities for similar amounts of time. Nevertheless, when the portion of total exposure incurred during their music activities was removed, student musicians still had higher daily exposure levels than non-musicians. This was due in large part to the musicians' social activities, which were noisier than those of the non-musicians, despite being broadly similar in nature (e.g. dining hall, hanging out with friends).

The combination of dosimetry plus journaling was key to the discovery that musicians led noisier lives than non-musicians, even apart from music activities. This group difference could not have been determined solely from examining the journal entries. In our review of the journals, we found no clues to suggest that musicians' social activities were noisier than non-musicians', perhaps because of insufficient descriptive detail in the entries. Only when the dosimetry records were matched to the journal entries did this finding emerge. The lack of detail in the journal entries was not surprising in retrospect, considering the instructional set, the challenge inherent in describing attributes of sound such as loudness, and the known inadequacies of self-report. Future investigations could solicit more fine-grained descriptions of the soundscapes encountered by participants, as well as reports of whether the sound exposure was planned or incidental and the degree to which the activity is routinely undertaken. In conjunction with dosimetry and a more narrow focus on social events, such investigations could shed light on the nature of the specific social activities that place musicians at greater risk for NIHL. For now, we are left to speculate that perhaps college musicians' social activities more often involve loud music either as background or foreground, or that musicians as a group tend to seek out, or at least tolerate, louder activities than non-musicians.

Several caveats must be considered in the interpretation of our findings. First, our conclusions are based upon a single week of dosimetry, which may or may not have been representative of a typical week for the participants. We attempted to maximise the likelihood of capturing a typical week by collecting data mid-semester, while courses and extracurricular activities were in full swing, and also by excluding from data analysis a small number of participants who explicitly indicated that their weeks were very atypical. Second, participants may not have adhered at all times to the instructions on wearing the dosimeters. We cannot rule out the possibility that some measurements were deliberately or inadvertently contaminated, such as by the sounds of clothing moving over the microphone inlet. However, our comparison of the journals and dosimetry records did not reveal any substantial discrepancies indicative of flagrant misuse of the dosimeters. Third, a lack of detail in some of the journal entries made it challenging to code activity categories or to discern when one activity ended and another began. As we started to encounter these cases, we developed a small set of common sense decisional rules to ensure consistency in our coding. Fourth, the extent to which participants filled out the journals in real time or constructed entries later in the day from memory is not known. Nevertheless, we believe it is unlikely that these limitations substantially affected the duration of hazardous exposure calculated per activity category, because the journal entries and dosimetry record were well-matched in most cases. A smartphone application that allows activity logging to be completed more easily in real time, similar to one developed for food diaries by Pendergast et al. (2017), would be ideal for future work of this kind. Fifth, our convenience sampling yielded a higher proportion of females than males across both groups, but especially in the musician group. This over-representation of females could have resulted in somewhat lower exposure levels than would be measured in a gender-balanced sample, given that males tend to engage in noisier leisure and occupational activities compared to females (reviewed in Warner-Czyz and Cain 2016). However, in our sample there were no statistically significant differences in weekly $L_{EX,8h}$ between males and females within either the musician group or the non-musician group (all $p > 0.05$), suggesting that a more gender-balanced sample would not have changed our results significantly. Finally, the musician group was on average one year younger than the non-musician group. Previous work in children and adults has shown that age is not a significant contributor to noise exposure levels as measured by dosimetry (Siervogel et al. 1982; Flamme et al. 2012), leading us to conclude that this small age difference is unlikely to have substantially influenced our findings.

Importantly, the effect on total exposure of devices worn in or on the ear was not assessed. Although participants in both groups reported almost no use of hearing protection devices such as earmuffs or earplugs, they reported using headphones/earbuds for music listening and for video-chatting. Median weekly hours of reported use were 1 h for the musicians and 0.8 h for the non-musicians. However, a considerable minority of participants (19% of musicians, 30% of non-musicians) reported over 10 h of use during the week. Conceivably, some participants whose dosimetry record indicated little risk of NIHL throughout the week could be placing themselves at risk with headphone/earbud listening. Given that participant exposure levels under headphones/earbuds are unknown, any conclusions regarding risk of NIHL (or lack thereof), particularly for the non-musicians, must be interpreted with caution.

Conclusions

By combining weeklong 24-h dosimetry with journaling, our study provided unique insight into the noise exposure risks associated with different facets of college life. Not unexpectedly, we found that most student musicians were at risk for NIHL. Our data suggest that most non-musicians are not at risk from sound in their environments, but because exposure from headphone/earbud listening was not measured, their true level of risk remains unknown. Of greater significance for hearing conservation efforts was the finding that, even apart from their music activities, college musicians engaged in riskier noise-exposure behaviours than the non-musician college students, particularly during social activities. For student musicians to make informed decisions about their hearing health, they need to know about the full range of lifestyle factors that contribute to their excess risk of incurring NIHL. Therefore, hearing conservation efforts directed at student musicians should address these lifestyle factors in addition to their music activities.

Note

1. The reader may have noticed that the weekly $L_{EX,8h}$ in Figure 4 are higher than might be inferred from an examination of Figures 2 and 3. This is because the value of the weekly $L_{EX,8h}$ is sensitive to very high daily exposure levels in its calculation.

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