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Evidence of noise-induced hearing loss among orchestral musicians

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An assessment of hearing thresholds among student orchestral musicians was carried out at the UCL Ear Institute in conjunction with the Royal College of Music (RCM). Audiogram data taken from 162 students (86 F, 76 M; mean age=23.7 years, SD=4.8) showed a statistically significant notch at 6 kHz in the left ear, indicative of noise-induced hearing loss (NIHL), but no significant notch was found in the right. Noise exposure asymmetry did not appear to account for notch asymmetry as trombone and trumpet players showed evidence of the same left notch trend as lateralized instruments such as violin and viola players. The earliest audiometric indicator of impending NIHL for musicians may be a developing hearing threshold notch at 6 kHz in the left ear.

Keywords: noise exposure; hearing damage; musical performance; orchestral musicians; music students

Both musicians and non-musicians are susceptible to work-related hearing damage from sound, but unlike other professions, the sound musicians create is not a by-product of their work—it is their product. This distinction makes musicians a difficult special case when it comes to determining what noise regulations should apply to them. Although studies have detailed noise-exposure for many professions including musicians (e.g. Taylor *et al.* 1965), relatively little is known about how the "noise" of music affects student musicians' hearing (for reviews, see Royster *et al.* 1991; Fearn 1976, 1993; Lee *et al.* 2005).

In this article, we report our measurements of hearing thresholds in a large cohort of young orchestral musicians.

METHOD

Participants

One hundred and sixty-two RCM students (86 F, 76 M; mean age=23.7 years, SD=4.8) participated in the audiogram study over two years, from 2007 to 2009.

Procedure

Participants completed a consent form and then went through standard clinical audiometric testing. They were subsequently asked to respond to a survey detailing their noise exposure.

Audiogram measurements were made with participants comfortably seated in a soundproof room. A recently calibrated (June 2006, June 2007, and June 2008) Kamplex KC 50 audiometer with TDH-39 earphones were used for the standard audiometric frequencies 125, 250, 500, 1k, 2k, 4k, 6k, and 8 kHz; high frequency headphones were used to measure 10k, 12.5k, and 16 kHz. A manual Hughson-Westlake procedure was used with 5 dB resolution for most subjects, but some were done with finer (3 or 1 dB) resolution around areas of particular interest.

Audiogram corrections

Audiogram data were age-corrected using ISO 7029:2000 in order to remove age effects and leave only noise-related effects (in this case, the removal of age effects did not have an impact on the qualitative results, as the cohort was all young musicians of similar age, range=19-36 years). Accounting for age effects above 8 kHz is not supported by the standard, so for 10, 12, 12.5 and 16 kHz age effects were first estimated by extrapolating the mathematical coefficients used in the ISO standard linearly and then calculating and removing those extrapolated effects of age.

Audiometer calibrations were initially carried out according to ISO 389, but since Lutman and Qasem (1998) reported that this calibration procedure—specifically the pairing of the THD39 or TDH 39P headphone with the specified IEC 303 coupler—creates a resonance that can artificially increase thresholds at 6 kHz, we re-calibrated the audiometer using an IEC 318 coupler. We indeed did discover an artifact that would have increased thresholds at 6 kHz by 3.4 dB in the right and 2.4 dB in the left. This artifact was removed from the data retrospectively. We compared our corrected data with an independent data set taken from students from the Royal Academy of Music (RAM) using headphones that do not have any known artifacts and found

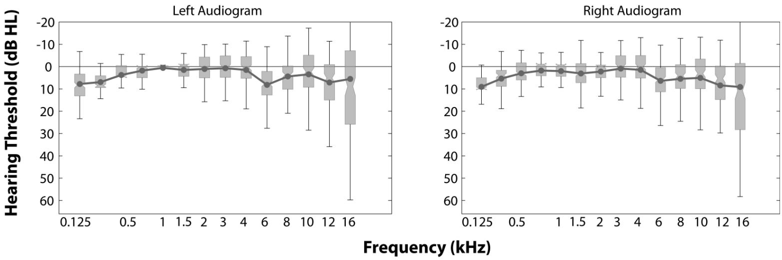

Figure 1. Summary of hearing threshold levels (dB HL) from audiograms taken from RCM students. Boxes extend from lower quartile to upper quartile with median hearing level demarked as the center of a notch; whiskers show extent of the contiguous data (minus outliers). The average of the data is plotted as a thick line. Notches in the inter-quartile boxes display the variability of the median between samples. The width of a notch is computed so that box plots whose notches do not overlap have different medians at the $p<0.05$ significance level. The 6 kHz threshold notch for the left ear was statistically significant. No significant notch was found for the right ear.

the two sets agreed in all statistical aspects, indicating that our correction was successful. (The RAM data will be presented in conjunction with these data in a subsequent paper.)

RESULTS

Audiogram data (Figure 1) from the young musician group showed a statistically significant threshold notch at 6 kHz in the left ear, indicative of noise-induced hearing loss. A Wilcox signed rank test showed the median threshold at 6 kHz was statistically higher than the median from either the 4 or 8 kHz tests ($Z=-6.37$, $p<0.001$, and $Z=-4.52$, $p<0.001$). Further, paired t-tests indicated that the mean threshold at 6 kHz was significantly higher than thresholds taken at 4 kHz or 8 kHz ($p<0.001$ for both). The right also showed that the 6 kHz threshold departed significantly from 4 kHz, but there was no significant difference between 6 and 8 kHz thresholds and therefore no significant notch.

A comparison of two subgroups, trumpet/trombone players versus violin/viola players, was carried out to see whether noise exposure asymmetry—with violin and viola players assumed to get more exposure in their left ears—could account for the asymmetry we saw in the overall audiogram data. We found, however, that both the trumpet/trombone subgroup and the violin/viola subgroup showed the same trends as the entire group data (cf. Fig-

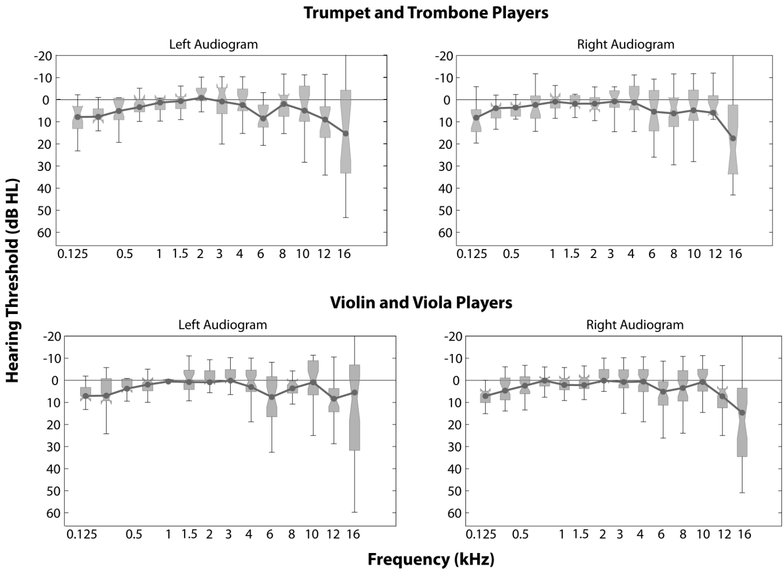

Figure 2. Summary of hearing threshold levels (dB HL) from audiograms taken from 20 trumpet/trombone players (top panel) and 37 violin/viola players (bottom panel), demonstrating that trumpet/trombone players exhibited notches at 6 kHz preferentially in the left ear. Boxes extend from lower quartile to upper quartile with median hearing level demarked as the center of a notch; whiskers show extent of the contiguous data (minus outliers). The average of the data is plotted as a thick line. Notches in the interquartile boxes are centered at the median and display the variability of the median between samples. The width of a notch is computed so that box plots whose notches do not overlap have different medians at the $p<0.05$ significance level.

Table 1. Average hearing threshold levels (dB HL) for 4, 6, and 8 kHz from audiograms from (1) the entire musician group, (2) 20 trumpet/trombone players, and (3) 37 violin/viola payers. All groups show similar trends, with higher thresholds in the left ear at 6 kHz and perhaps higher thresholds in the right ear at 8 kHz. These factors combine to form a more visible notch in left-ear audiogram traces, such as those in Figures 1 and 2.

	Left ear			*Right ear*		
	4 kHz	*6 kHz*	*8 kHz*	*4 kHz*	*6 kHz*	*8 kHz*
All musicians	1.32±0.63	8.02±0.74	4.25±0.75	1.46±0.72	6.41±0.82	5.48±0.92
Violin/viola	3.05±1.39	7.56±1.81	3.63±1.11	0.57±1.20	5.14±1.33	3.44±1.48
Trumpet/trombone	2.57±2.16	8.63±2.43	2.08±1.81	1.98±2.31	6.03±2.31	6.80±2.37

ures 1 and 2), with the left ear being more likely to display a "notch" at 6 kHz. The notch was more likely to be salient in the left because: (1) hearing threshold levels at 6 kHz were generally higher (but not statistically higher, $p=0.15$ in paired t-test) in the left than in the right and (2) hearing threshold levels at 8 kHz were generally higher (but not statistically significantly higher, $p=0.29$ in a paired t-test) in the right ear (see Table 1).

DISCUSSION

Our audiogram data reveal a statistically significant notch in the left ear at 6 kHz across the group of young musicians—a potential hallmark of noise-induced hearing loss—but interestingly, no such notch appeared for the right ear data. We initially suspected that this asymmetry, clearly apparent across the whole group, may have been caused by a subgroup of violin/viola players who receive higher levels of sound in their left ears. However, data for this group alone did not show a preponderance of the asymmetry. An established body of literature suggests that there may be differences in the physiological susceptibility of left and right ears to NIHL (Watson 1967). Exactly what type of differences could account for the asymmetry is still a source of speculation. For example, it is possible that olivocochlear efferents are stronger on the left side or that there is a difference in the middle ear reflex between the two ears (Nageris *et al.* 2007). It is also interesting to note that many reports indicate that TEOAEs appear to be stronger in the right than in the left ear in infants (Keefe *et al.* 2008). It should be noted that in many of these studies the right ear is tested first, which could account for the asymmetry by producing an efferent response prior to the subsequent left ear test.

In conclusion, the earliest audiometric indicator of impending NIHL for musicians may be a developing notch at 6 kHz in the left ear.

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