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Noise exposure and hearing thresholds among orchestral musicians

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An assessment of noise exposure and hearing thresholds among orchestral musicians was carried out at the Royal College of Music (RCM). Sound exposure data was taken over a one week period using personal noise dosimeters attached to ten RCM orchestra students during rehearsals and during a performance (Rachmaninoff's *Piano Concerto No. 2* and Sibelius's *Symphony No. 2*). Noise levels (and compliance with the UK's noise at work regulations) depended upon the type of instrument being played and where musicians were seated. For example, the average 8-hour A-weighted dosage for the trumpet was $L_{EP,d}$=88.4 dB(A), while it was only 77.1 dB(A) for the double bass. This suggests that different hearing protection strategies may be appropriate for different musicians. Audiogram data taken from 37 students and 19 staff showed that the students (mean age=24.2, SD=4.0) had statistically significant bilateral notches at 6 kHz, indicative of noise-induced hearing loss. Staff members (mean age=45.7, SD=11.0) also had evidence of notches and additionally presented increased thresholds at high frequencies, indicative of expected age-related hearing loss.

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 in the workplace for many professions (e.g. Taylor *et al.* 1965), relatively little is known about the noise dosages musicians receive or the

effect this "noise" has on musicians' hearing (for reviews, see Royster *et al.* 1991; Fearn 1976, 1993; Lee *et al.* 2005).

In this article, we report our measurements of noise dosages and hearing thresholds in young orchestral musicians and compare those data with our measurements of hearing thresholds from older musicians.

METHOD

Participants

Ten student musicians (two violins, viola, cello, double bass, flute, clarinet, trumpet, trombone, tympani) from the RCM Symphony Orchestra were chosen to participate in the sound level recording study (6 female, 4 male; mean age=25, SD=4.0).

Thirty-seven student musicians (25 female, 12 males; mean age=24.2 years, SD=4.0) participated in the audiogram study, along with 19 staff members (11 female, 8 male; mean age=45.7 years, SD=11.0); not all staff members were currently performing musicians.

Procedure

Noise-exposure was measured during one week of full rehearsals and sectional rehearsals leading up to a performance of Rachmaninoff's *Piano Concerto No. 2* and Sibelius's *Symphony No. 2*, and the performance itself. Measurements were made using Cirrus CR 110A personal noise dose meters, mounted within 10 cm of one ear of each musician. Average A-weighted sound pressure level (L_{Aeq}) and Peak C-weighted sound pressure level (L_{Cpk}) were recorded each minute during measurement sessions (Figure 1).

Average day, maximum day (8-hour equivalent L_{Aeq}), and weekly noise dosages were calculated from L_{Aeq} dB(A) values obtained each minute. These calculations were made according to the UK Control of Noise at Work Regulations 2005, No. 1643. In addition, each C-weighted peak level (L_{Cpk}) above 120 dB(C) was recorded and plotted.

Audiogram measurements were made with participants comfortably seated in a soundproof room. A recently calibrated (June 2006 and June 2007) Kamplex KC 50 audiometer employing an automated Hughson-Westlake procedure was used. Both normal audiometric frequencies and high frequency thresholds were measured: 125, 250, 500, 1k, 2k, 4k, 6k, 8k, 10k, 12.5k, 16k Hz.

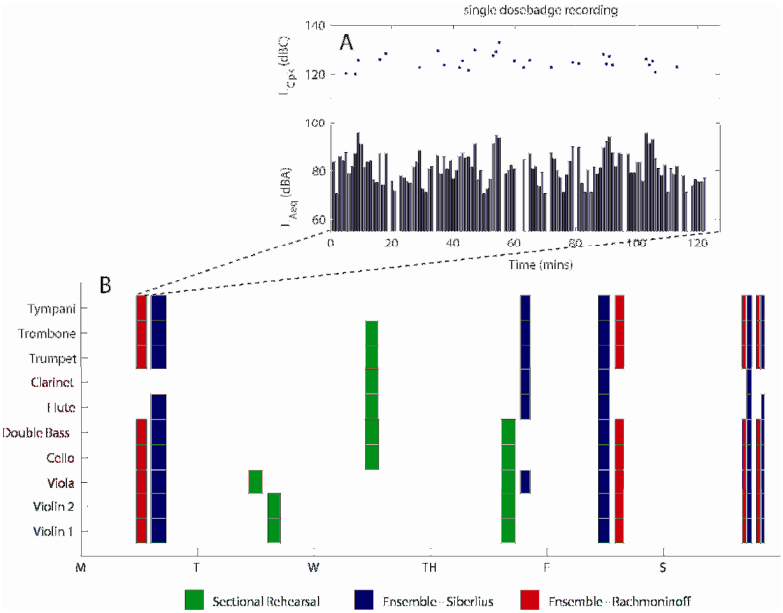

Figure 1. Student orchestral musician workweek chart (panel B) showing the times of rehearsals and performances (Monday to Saturday) during which personal noise level dosimetry was recorded for 10 musicians. Panel A shows one example of dosimetry data collected from the tympani player's dosimeter during a Monday rehearsal. (See full color version at www.performancescience.org.)

RESULTS

Measured maximum personal daily noise exposure levels for seven of the ten musicians registered above 85 dB(A), the specified upper action level in the UK's Control of Noise at Work Regulations 2005 (Figure 2). The exposure levels depended strongly on the instrument being played and where the musician was seated in the orchestra. For example, the cellist registered a maximum daily exposure of 87.9 dB(A), 2.6 dB higher than the maximum day for the trombone player 85.3 dB(A) which was during the same rehearsal; however, during this rehearsal, the cellist was seated in front of the brass section. The trumpet consistently had the highest exposure levels, and always exceeded the upper action level specified by regulations. On the trumpet's maximum day (Monday), he was exposed to the equivalent of eight hours of sound at 90.2 dB(A), well above allowable limits.

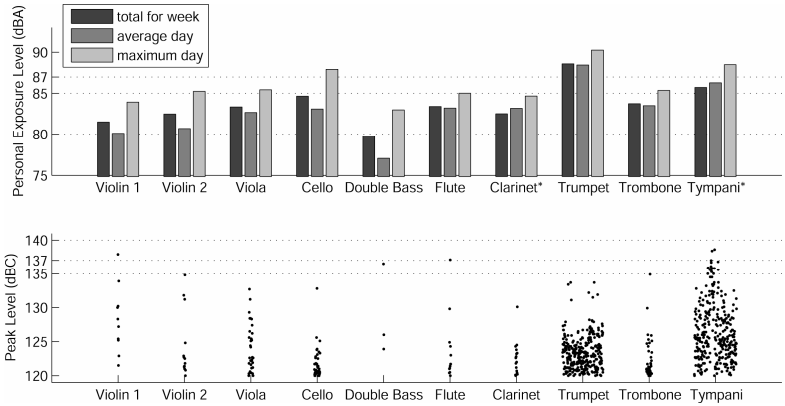

Figure 2. Top panel: Personal daily and weekly dosage levels ($L_{EP,d}$, and $L_{EP,w}$) of 10 student orchestral musicians during one week of rehearsals and performance. Clarinet and tympani data were incomplete (dosimeter failure), so we only have four measurements for their work week (five or six would have resulted in higher weekly levels). The trumpeter received the highest dose, exceeding lower, middle, and upper action levels (dotted lines) of the UK's Control of Noise at Work Regulations 2005 for average day, weekly, and maximum day exposures. Bottom panel: Peak levels greater than 120 dB(C) experienced by players over the course of one week. Percussionists and trumpets appear to be exposed to loud impulsive noise at much greater frequency than other players, and these levels often exceeded lower regulatory action levels and sometimes exceeded middle regulatory action levels.

Measured peak dB(C) levels were generally below 135 dB(C), the lower action level specified in the UK regulations. We suspect that some of the stray impulses recorded were the result of a dosebadge being knocked (e.g. double bass) rather than an actual sound impulse. The timpanist and trumpeter sustained the highest frequency of impulse noises above 120 dB(C) (319 and 305 events, respectively), and the timpanist was exposed to five bursts in excess of 137 dB(C) and three in excess of 140 dB(C) (not plotted).

Audiogram data from the student group showed a statistically significant bilateral threshold notch at 6 kHz, indicative of noise-induced hearing loss. A Wilcoxon signed rank test showed the median threshold at 6 kHz was statistically higher than either the median 4 kHz or 10 kHz threshold. This was true for both left and right ears [$Z(34)=-4.23$, $p<0.001$, and $Z(34)=-3.35$, $p<0.001$, respectively, for left ears; $Z(34)=-4.57$, $p<0.001$, and $Z(34)=-3.93$, $p<0.001$, respectively, for right ears]. Furthermore, paired t-tests indicated

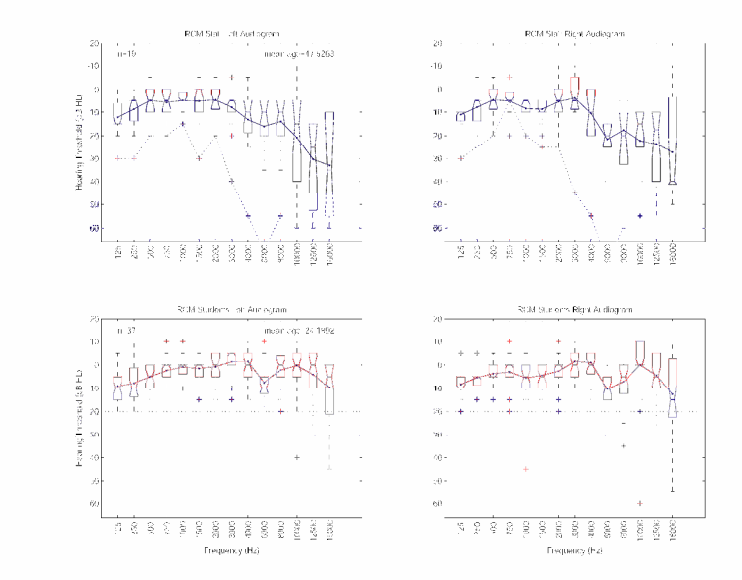

Figure 3. Summary of hearing threshold levels (dB HL) from Audiograms taken from RCM student musicians (bottom panels; mean age=24.2 years, SD=4.0) and staff members (top panels; mean age=45.7 years, SD=11.0). Boxes extend from lower quartile to upper quartile with median hearing level demarked with a red bar, whiskers show extent of the data, and outliers are labeled as red crosses. The mean of the data is plotted as a blue line. The staff members with the highest hearing levels were also the oldest (57, 61, 64 years old); the dotted line shows a 61 year old with the highest thresholds. Bilateral notches at 6 kHz were evident for both students and staff indicative of noise-induced hearing loss. The notch was statistically significant for the student group. (See full color version at www.performancescience.org.)

that the mean threshold at 6 kHz was significantly higher than thresholds at 4 kHz or 10 kHz [all $t(34)>3.96$, $p<0.001$]. Staff data also displayed a bilateral notch, but this was less prominent because staff members also exhibited elevated thresholds at high frequencies, indicative of age-related hearing loss—a loss that tended to blend with and obviate their presumed noise-induced notch at 6 kHz.

DISCUSSION

Noise dosage levels for some musicians (e.g. trumpet, tympani) but not others (e.g. cello) exceeded those specified in UK noise at work regulations that will come into force in April 2008. Our audiogram data suggest that these levels initiate a noise induced hearing loss in young musicians that subsequently contribute (at least in the 6 kHz region) to what would usually be considered "age-related" hearing loss in older musicians. Future research will seek to expand these findings by collecting noise level measurements from a broader range of ensemble types, repertoire, and performance environments. Additional audiograms will be performed with musicians representing the full spectrum of years of involvement; noise data will then be mapped upon these to explore potential links.

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