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EXPOSURES AND HEARING THRESHOLDS IN MUSIC STUDENTS DUE TO TRAINING SESSIONS

A. JAROSZEWSKI, T. FIDECKI and P. ROGOWSKI

Fr. Chopin Academy of Music
(00-368 Warszawa, Okólnik 2, Poland)

Measurements of SPL's in sound emission from some wind instruments during training sessions of music students show all in excess of L_{Amax} 110 dB and reach L_{Amax} 132 dB in some cases. Long time average spectra in 1/3-octave bands and cumulative distribution functions show that e.g. sound pressure levels L_{A} 50 are often around 100 – 110 dB and in most instruments the spectra cover substantial range of frequencies. Resting hearing thresholds in many students show dips of various depths at 6 kHz, which in some cases reach over 30 dB. TTS_2 measured at 6 kHz following 4-hrs training session reach 40 dB.

1. Introduction

The effects of exposure to music on hearing in musicians can be determined in two ways: by direct audiometric testing and indirectly by measurements of sound levels and duration of exposure in musical performances. In audiometric examination of classical musicians AXELSSON and LINDGREN [1], WESTMORE and EVERSDEN [17], RABINOWITZ *et al.* [14], KARLSSON *et al.* [12], JOHNSON *et al.* [11], JANSSON *et al.* [5]. WOOLFORD *et al.* [18], OSTRI *et al.* [13], and ROYSTER *et al.* [15], JAROSZEWSKI [8], JAROSZEWSKI *et al.* [10], JAROSZEWSKI *et al.* [9] and others all have found audiometric patterns corresponding to the noise induced hearing loss. The audiograms showed notches, mostly at frequency 6 kHz in 30% to over 50% of the tested samples. The depth of these notches varied between HTL 10 dB (OSTRI *et al.* [13], ROYSTER *et al.* [15]), and 20 to 25 dB (RABINOWITZ *et al.* [14], WOOLFORD *et al.* [18] up to 10 – 30 dB (JAROSZEWSKI [8]). The greatest hearing loss was found in musicians playing bassoon, horn, trumpet and trombone (e.g. AXELSSON and LINDGREN [1]). However, some investigators, e.g. WESTMORE *et al.* [17], AXELSSON and LINDGREN [1], have declared that only "*slight degree of hearing loss was found in the averaged hearing thresholds*" even that they also found notch shaped audiograms with the dip at 6 kHz in the tested samples.

In the investigation of sound exposures in Swedish symphonic orchestras JANSSON and KARLSSON [7] reported mean (for all tested music) L_{Aeq} values from 88.9 dB up to 93.1 dB with maximum values reaching 98.6 dB (for specific music and position). They have not observed A-weighted "short-time levels" exceeding 125 dB. Similar data L_{Aeq}

from 85 dB up to 90 dB with weekly equivalent of 85 dB were reported by AXELSSON and LINDGREN [1]. SCHACKE [16], recorded continuos sound pressure levels in orchestra of the Deutsche Oper Berlin, and found average A-weighted levels for brass ranging from 87 dB to 96 dB, with peaks reaching 122 dB and average A-weighted levels for woodwinds varying between 88 dB and 97 dB, with peaks reaching 117 dB. Lower values, in the range from 83 dB to 93 dB were found for violins and violas, however, with peaks reaching 110 dB. The presence of impulsive sounds in the exposure have been, as it is well known, recognised as having substantial contribution in the development of hearing loss (e.g. HENDERSON and HAMMERNIK [4]). It has been observed that interaction of peaks with continuous background produces larger hearing loss than should result from the sum of these components.

In the report by SCHACKE [16] $L_{\mathrm{Aeq\ 8h}}$ for wind instruments was determined at 87.7 dB which is almost twice as much as maximum permissible exposure according to German regulations, HAY [3]. CAMP and HORSTMAN [2] obtained values ranging from $L_{\mathrm{Aeq}} = 84.4$ dB to 98 dB for bass players and horn players correspondingly. While JAROSZEWSKI *et al.* found L_{Aeq} reaching 100 – 110 dB for e.q. trumpet player with substantial amount of impulsiveness. Alarming data on L_{Aeq} values were reported by ROYSTER *et al.* [15]. They found $L_{\mathrm{Aeq\ 8h}}$ values ranging from 74.7 to 94.7 dB and "*maximum peak levels*" in the range from 112.0 to 143.5 dB (A-weighted).

In the present report sound pressure levels L_{Amax}, L_{Aeq} and $L_{\mathrm{A}}\,1$ were measured and spectral analysis in 1/3-octave bands was performed on short selections from performances of music students during their training sessions. The same music selections were used in computation of Cumulative Distribution Functions. Effects of exposure to music noise were determined by comparison of resting audiograms and TTS_2, i.e. threshold 2 min after cessation of the exposure. Estimation of the hearing loss risk in sound exposure of music students playing wind instruments was the aim of this investigation.

2. Procedure and apparatus

Sound pressure level measurements were performed using Bruel&Kjaer precision sound level meter type 2230 which was positioned 1 m from the output aperture of the musical instrument. Readings were taken during actual training sessions and then for chromatic scales fast played over the whole range of the instrument and during short music selections chosen by the performer. Readings were taken 10 times at 2-min intervals during routine training sessions at the Academy of Music. An average of 10 readings for each pressure value measured was taken as characteristic for the given instrument and given performer.

Chromatic scales fast played at the same level over the whole range of the instrument and short (duration 60 s) music selections were recorded on tape using NAGRA IV-SJ recorder and precision omnidirectional condenser microphone B&K type 4133 placed 1 m from the instrument. Long time average spectra analysis in 1/3 octave bands in the frequency range from 20 Hz to 20 kHz were determined for such samples using B&K analyser type 2144. A-weighted levels L_{Aeq} and $L_{\mathrm{A}}\,1$ for the whole range of frequencies are also given. LTAS correspond to the sound pressure levels averaged over the duration of performance. Statistical measures $L_A 1$ correspond to the sound levels, which were present in 1% of the duration of the analysis. Exponential averaging with time constant 1/124 s was used.

Resting hearing thresholds 48 hrs without exposure and shifted thresholds 2 min after cessation of the exposure of 4 hrs duration were measured with the use of clinical audiometer Interacoustics type AC-40 equipped with headphones Telephonics TDH 39P with cushions MX-41/AR, in connection with HP Vectra 486 33U personal computer. Audiometric testing was executed on a sample of 14 representatives of most exposed brass and woodwind sections. HTL(246) indicator was used to determine TTS_2. Only wind instrument data are given in the present report.

3. Results and discussion

The sound pressure level and its spectral and temporal structure depend, as it is known, on the instrument, the performer and also on the type of music. Years of observation of music students training and sound pressure level measurements during training sessions indicated, that particularly in brass and woodwind instruments the sound pressure levels generated are far beyond the SPL's measured in LTAS records for symphonic orchestras. This observation is confirmed by the present investigation. Maximum and equivalent sound pressure levels measured and calculated are represented in cumulative distribution functions and in the LTAS functions. Six examples of these functions obtained for trumpet, trombone, horn, french horn, clarinet and piccolo, are given in Fig. 1 to Fig. 6.

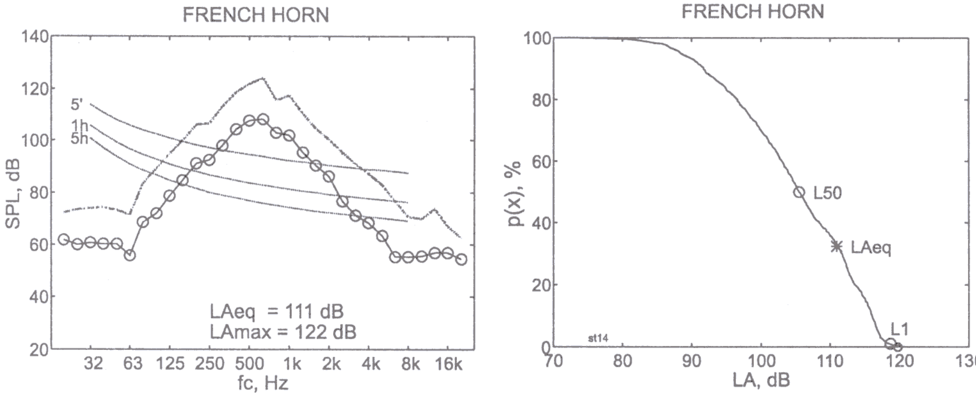

Fig. 1. Long time average spectra and cumulative distribution functions for french horn in typical routine training sessions by music students.

Statistical measures $L_A 1$ and equivalent sound levels L_{Aeq} for these instruments are given in Tab. 1 for easy comparison. It can be easily observed that the data obtained are well beyond the values measured by various researchers in symphonic orchestras.

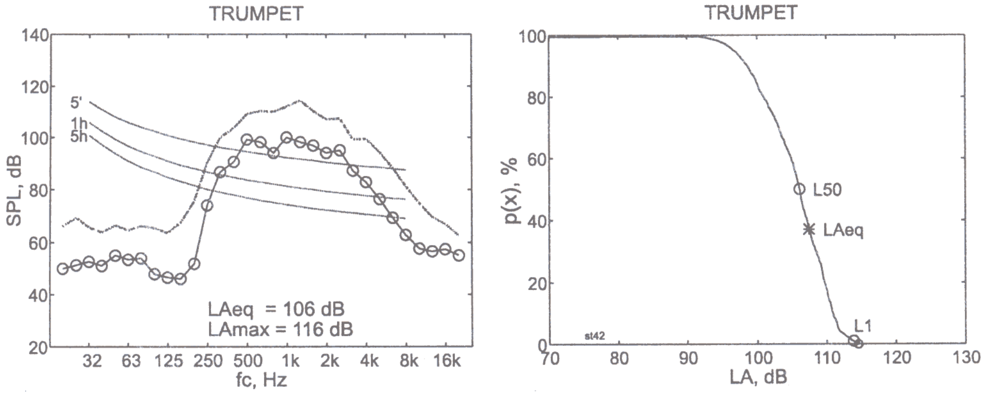

Fig. 2. Long time average spectra and cumulative distribution functions for trumpet in typical routine training sessions by music students.

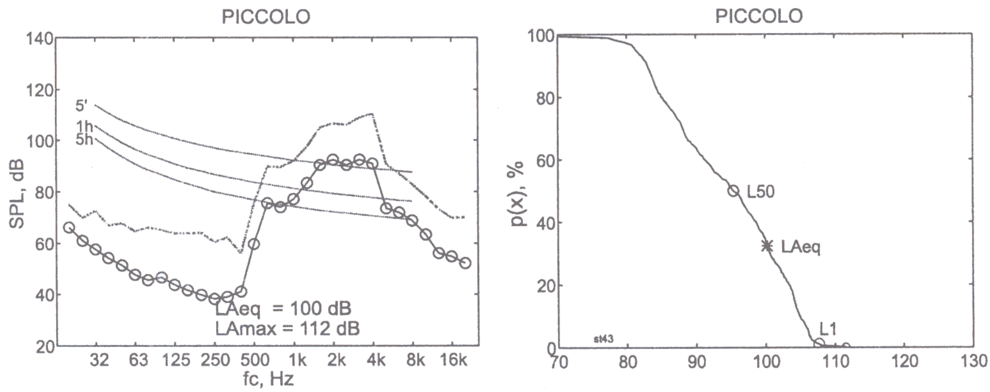

Fig. 3. Long time average spectra and cumulative distribution functions for piccolo flute in typical routine training sessions by music students.

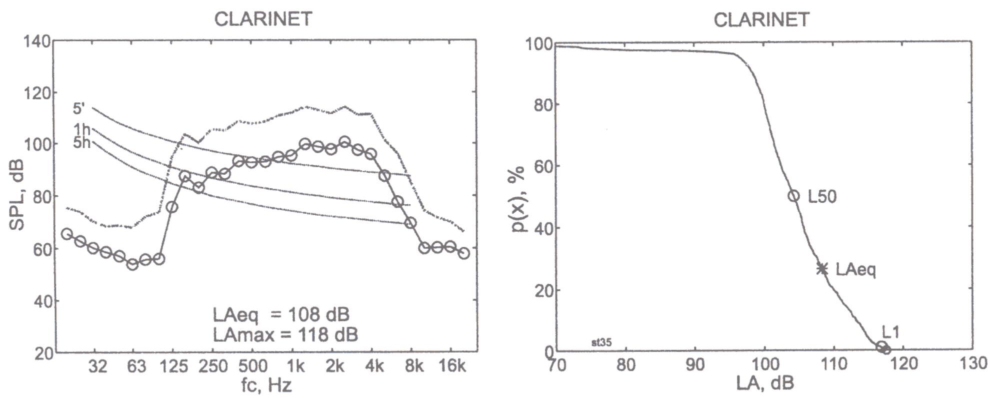

Fig. 4. Long time average spectra and cumulative distribution functions for clarinet in typical routine training sessions by music students.

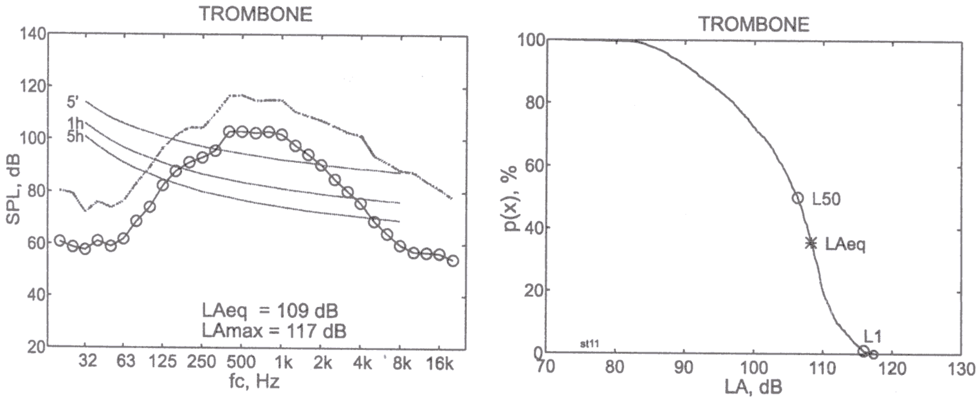

Fig. 5. Long time average spectra and cumulative distribution functions for trombone in typical routine training sessions by music students.

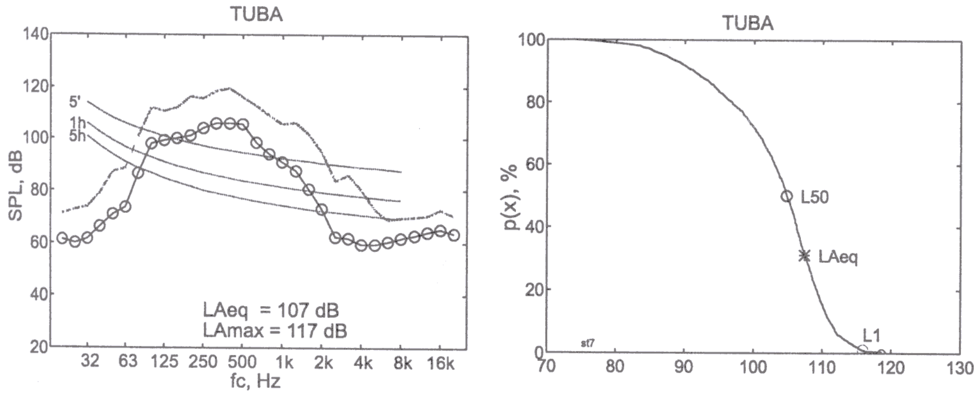

Fig. 6. Long time average spectra and cumulative distribution functions for tuba in typical routine training sessions by music students.

Table 1. Statistical measures $L_A 1$ and equivalent sound pressure levels L_{Aeq} for wind instruments in typical routine training sessions by music students.

Instrument	french horn	tuba	trumpet	trombone	piccolo	clarinet
$L_A 1$, dB	119	116	114	116	107	117
$L_{A eq} 1$, dB	111	107	106	109	100	108

Consequently, temporary threshold shifts following exposures experienced in training sessions are substantial. In 50% of performers notch shaped audiograms were found with permanent selective loss of 10 dB to 30 dB at 6 kHz and comparatively less at adjacent frequencies. The amount of TTS_2 reached 30 dB in some cases resulting in HTL 40 dB, see for example audiogram of the subject PM playing trumpet Fig. 7.

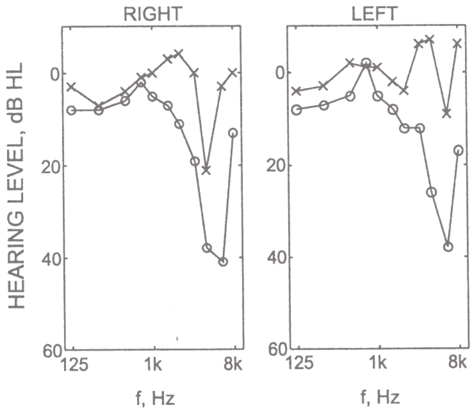

Fig. 7. Resting hearing threshold and TTS_2 for music student playing trombone after 4 1/2 hrs of training.

Resting hearing levels and TTS_2 in the tested sample of 14 music students, after 4–4 1/2 hrs of training in the group of 8–12 persons are presented in Fig. 8. While the averaged threshold shift value is around 15 dB over the range of frequencies between 1 and 6 kHz, the data show large intersubject variability. Thus in some cases the individual TTS_2 reaches 20 dB at least in one ear. The threshold in quiet in the tested sample of 14 students also shows significant decrease of sensitivity. While the averaged data lie within permissible limits spare for the 26 dB V-dip at 6 kHz, some students show substantial amount of permanent threshold shift.

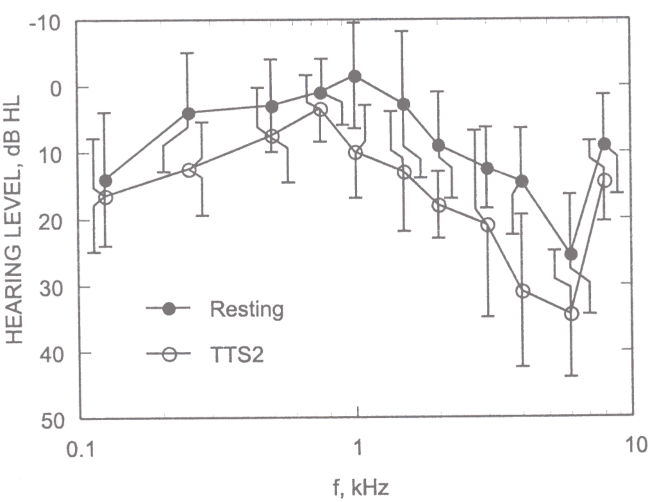

Fig. 8. Averaged resting hearing thresholds and averaged TTS_2 for a group of 14 music students playing wind instruments (both ears). Vertical bars represent standard deviations.

4. Conclusion

Present findings indicate that the exposures experienced by music students during their training sessions are far in excess relative to the permissible doses. Maximum measured values of sound levels are substantially higher than maximum levels observed by other researchers except for ROYSTER *et al.* [15], who recorded in orchestra A-weighted sound levels reaching 140 dB while "*the great majority of peak SPL's were in the range 115 - 129 dB (A)*".

Predictably, such exposures lead to aggregation of NIPTS if acquired over a long period of time and as such should not be ignored. In 50% of brass and woodwind players PTS of 10 dB to 20 dB was found which could be explained only by acoustic trauma.

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References

[1] A. AXELSSON, F. LINDGREN, *Hearing in classical musicians*, Acta Otolaryngologica, Supplement, **377**, 3–74 (1981).

[2] J. CAMP, S.W. HOTSTMAN, *Report on sound levels for Seattle Symphony Orchestra by School of Public Health and Environmental Medicine*, University of Washington, Seattle, WA (1987).

[3] B. HAY, *EEC directives on noise in the environment*, [in:] The Noise Handbook, W. TEMPEST [Ed.], Academic Press, 377–398, London 1985.

[4] D. HENDERSON, R.P. HAMMERNIK, *Impulse noise: a critical revue*, Journal of the Acoustical Society of America, **80**, 569–584 (1986).

[5] E. JANSSON, A. AXELSSON, F. LINDGREN, K. KARLSSON, T. OLAUSSEN, *Do musicians of the symphony orchestra become deaf?*, [in:] Acoustics for Choir and Orchestra, S. TERNSTROEM [Ed.], Royal Academy of Music, Stockholm 1986.

[6] E. JANSSON, K. KARLSSON, *Music acoustics-sound levels and long time spectra recorded within the symphony orchestra and risk criteria for hearing loss*, STL-OPSR, 1/1982, 31–48 (1982).

[7] E. JANSSON, K. KARLSSON, *Sound levels recorded within the symphony orchestra and risk criteria for hearing loss*, Scandinavian Audiology, **12**, 215–221 (1983).

[8] A. JAROSZEWSKI, *Wstępna ocena słuchu młodzieży akademickiej szkół muzycznych*, Prace Inst. Podst. Probl. Techniki PAN, XLII Otwarte Seminarium z Akustyki, Warszawa — Białowieża 12-15.09.1995 r., 491–496 (1995).

[9] A. JAROSZEWSKI, T. FIDECKI, P. ROGOWSKI, *Hearing damage from exposure to music*, Archives of Acoustics, **23**, 1, 3–31 (1998).

[10] A. JAROSZEWSKI, T. FIDECKI, P. ROGOWSKI, R. MONIAK, *Ekspozycja słuchaczy szkół muzycznych na wysokie poziomy dźwięku*, Prace Inst. Podst. Probl. Techniki PAN, XLII Otwarte Seminarium z Akustyki, Warszawa - Białowieża 12-15.09.1995 r., 497–502 (1995).

[11] D.W. JOHNSON, R.E. SHERMAN, J. ALDRIDGE, A. LORRAINE, *Extended high frequency hearing sensitivity: a normative threshold in musicians*, Annals of Otology Rhinology and Laryngology, **95**, 196–202 (1986).

[12] K. Karlsson, P.G. Lyndquist, T. Olaussen, *The hearing of the symphony orchestra musicians*, Scandinavian Audiology, **12**, 257–264 (1983).

[13] B. Ostri, N. Eller, G. Skylv, *Hearing impairment in orchestral musicians*, Scandinavian Audiology, **18**, 243–249 (1989).

[14] J. Rabinowitz, R. Hausler, G. Bristow, P. Rey, *A study of the effect of loud music on musicians of the Orchestre de la Suisse Romande*, Medicine et Hygiene, [in:] Journal Suisse d'Informations Medicine, **19**, 1909–1921 (1982).

[15] J.D. Royster, L.H. Royster, M.C.V. Killian, *Sound exposures and hearing thresholds of symphony orchestra musicians*, Journal of the Acoustical Society of America, **89**, 2793–2803 (1991).

[16] G. Schacke, *Sound pressure levels within an opera orchestra and its meaning for hearing*, 22nd International Congress on Occupational Health, Sydney, Australia 1987.

[17] G.A. Westmore, I.D. Eversden, *Noise induced hearing loss in orchestral musicians*, Archives of Otolaryngology, **107**, 761–764 (1981).

[18] D. Woolford, E.C. Carterette, D.E. Morgan, *Hearing impairment among orchestral musicians*, Music Perception, **5**, 261–284 (1988).