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HIGH FREQUENCY HEARING LOSS IN PERCUSSION PLAYERS

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In a number of reports it has been observed that a prolonged exposure to music at sound pressure levels exceeding 100 dB leads to substantial temporary threshold shifts TTS_2, reaching 60 – 80 dB in the range of high frequencies. Cumulative effects of such exposures result in acoustic trauma, affecting the perception of pitch, loudness and time, accompanying the decrease of hearing sensitivity. The hearing threshold in percussion players is affected largely at high frequencies, where substantial decrease of sensitivity between 10 and 16 kHz reaching 40 to 75 dB has been observed. In the present report a number of hearing thresholds in percussion players and in control group consisting of musicians who have never played percussion instruments or were long exposed to their sounds have been analysed with reference to their exposure characteristics.

1. Introduction

There has been much concern over the past 30 years about the possibility of developing hearing loss by listening to loud music. Music was early recognised as a source of acoustic trauma (Lebo and Oliphant [16]). Its effects on hearing were studied with reference to the exposures experienced by listening to the rock and roll music, attending to the discotheques, listening to the portable CC and CD players and portable radios and with reference to the exposures experienced by orchestral (Woolford *et al.* [24], Axelsson and Lindgren [1], Royster *et al.* [19], Jansson and Karlsson [10], Gryczyńska and Czyżewski [6], Jaroszewski *et al.* [12]) and rock and roll musicians (Axelsson and Lindgren [3], Axelsson *et al.* [1], Axelsson and Lindgren [2], Jaroszewski *et al.* [11], Jaroszewski and Rakowski [13]).

Early studies of the effects of exposure to music on hearing in musicians by Gryczyńska and Czyżewski [6] show substantial impairment of hearing. In 68% of the tested sample of 51 orchestral musicians music noise induced hearing loss was observed, while largest hearing loss was found in percussion players. In a study by Axelsson and Lindgren [4], noise induced hearing loss from the exposure to music was found in 43% of the tested sample of 139. However, they found largest NIHL in bassoon and french horn players (mean NIHL: 30 – 35 dB) while only moderate (18 dB) in percussion players. These data are in some agreement with the early findings by Jahto and Hellman [9] who found NIHL in 37% of the tested sample, Zelený *et al.* [25] NIHL in 72% of the tested sample, by Woolford *et al.* [24] 25 dB NIHL (61% of tested ears) by Westmore and

EVERSDEN [23] 34% of 68 ears with NIHL, by OSTRI *et al.* [18] who measured HTL in 96 and found NIHL in 50% of males and 13% of females and with more recent findings by ROYSTER *et al.* [19] NIHL in 52.5% of the sample or by JAROSZEWSKI *et al.* [11] in 68% of the tested sample.

Contrasting data were also reported for example by KARLSSON *et al.* [15] who tested hearing threshold levels in 392 musicians, and found median values equivalent to the expected age-effect thresholds according to SPOOR [21]. Nevertheless, a dip at 6 kHz is present in median audiometric data, also in this report. It is thus apparent that no consensus exists on the effect of music exposure on hearing in musicians.

Summarising, almost all researchers arrived at the data that correspond to the noise induced hearing damage in some proportion of musicians tested. This proportion ranges from approximately 35% up to approximately 70% in most of the studies available in the literature. Spare for the study by GRYCZYŃSKA and CZYŻEWSKI [6] who found large HF sloping hearing loss up to 80 dB at 8 kHz in percussion players, hearing loss reported by other investigators were not so large e.g. 30 dB in AXELSSON and LINDGREN [4] or 26.5 and 25.0 dB at 4 and 6 kHz (SD ≅ 20 dB) correspondingly, for the instrument group including percussion in the study by ROYSTER *et al.* [19]. No data is available on hearing in percussion players for frequency range above 8 kHz. The present work reports the experimental data on hearing impairment found in young percussion players in the whole range of audiometric frequencies, with special attention to high frequencies above 8 kHz. The aim of this research was to test the hypothesis that percussion players and particularly xylophone players experience severe hearing impairment in the range of high and very high frequencies due to exposure to impulse music noise.

2. Procedure and equipment

Two groups, each consisting of 40 young musicians (up to 26 years), an experimental group playing percussion and often xylophone, and control group playing other instruments i.e. strings, woodwinds, brasswinds and piano were used as subjects. Average age in both groups was 21 years.

Hearing threshold in quiet was measured in both ears in both groups with the use of electronically controlled audiometer Interacoustics AC 40 connected to a PC HP Vectra which performed data acquisition and data analysis. Air conduction pure tone audiometry with intermittent 250/250 ms signal and 1 dB step level control was used throughout. Tests were performed at 11 frequencies in the low frequency range and at two frequencies in the high frequency range. Headphones TDH 39P with MX41/AR cushions were used in low frequency range and Koss HV/PRO with circumaural cushions in high frequency range.

In an attempt to relate the specific audiometric data with spectral and temporal characteristics of xylophone sounds, both spectral and temporal analyses were performed on samples of xylophone sounds. For spectral analysis short selections performed on a xylophone were recorded on Sony DAT recorder PCM 2300 using Brüel&Kjar 1/2″ condenser microphone type 4133. Spectral analyses were performed using Matlab software.

Temporal analysis included determination of the cumulative peak level distribution function for short selections performed on a MUSSER KELON 42 xylophone and measurements of signal onset times for the entire xylophone scale. This was done with the use of B&K 1/4″ condenser microphone type 4135 with measuring amplifier B&K 2607 connected to digital oscilloscope HP 54501A which memorised single signals for precision graphic measurements. Spectral analysis was performed also on these signals to eliminate the effects of limited frequency response of recording channel of DAT.

3. Results

Hearing threshold data of young percussion players are presented in Fig. 1 as mean of 80 audiograms for left and right ears and standard deviations in the experimental group. Hearing threshold data for musicians not exposed to percussion sounds, i.e. for control group are given in Fig. 2 also as mean of 80 audiograms and standard deviations in the group. The largest differences between the means of two data sets amount to 9.1 dB at 12.5 kHz and to 24.3 dB at 16 kHz. The analysis of audiometric data for the experimental and control groups is shown in Fig. 3 and Fig. 4. The results of measurements of onset times for the entire xylophone scale show that the onset time is quite small amounting to approximately 10 μs. Examples of xylophone sound C#6 (1108.8 Hz) oscillograms obtained with various time bases are given for illustration in Fig. 5.

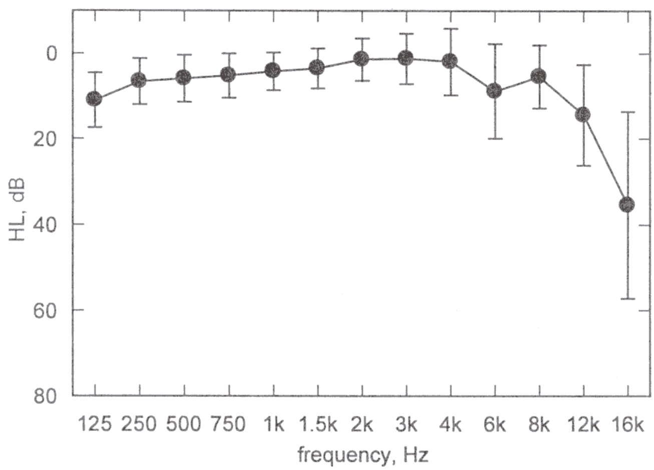

Fig. 1. Hearing threshold level in quiet in percussion players. Means and standard deviations of 80 audiograms; right and left ears.

The results of spectral analysis of the first 5 ms of one representative isolated xylophone sound C5 (523.3 Hz) obtained from the recorded material are given in Fig. 6. It shows maximum sound pressure level spectral density within the range of relatively low frequencies between 500 and 8000 Hz, decreasing towards high frequencies. However, it should be observed that while at low frequencies the peak density reaches 106 dB it

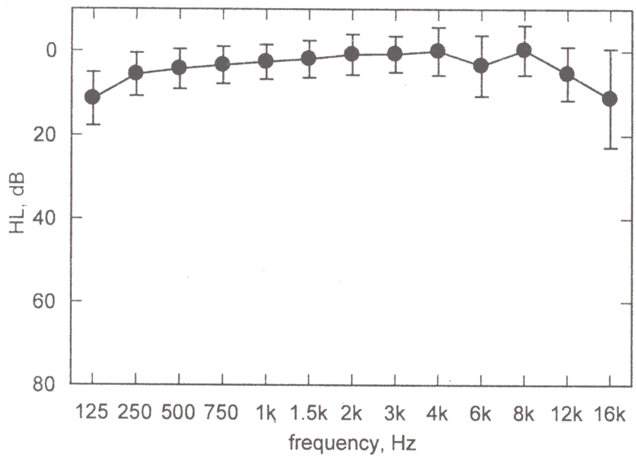

Fig. 2. Hearing threshold level in quiet in non-percussion players. Means and standard deviations of 80 audiograms; right and left ears.

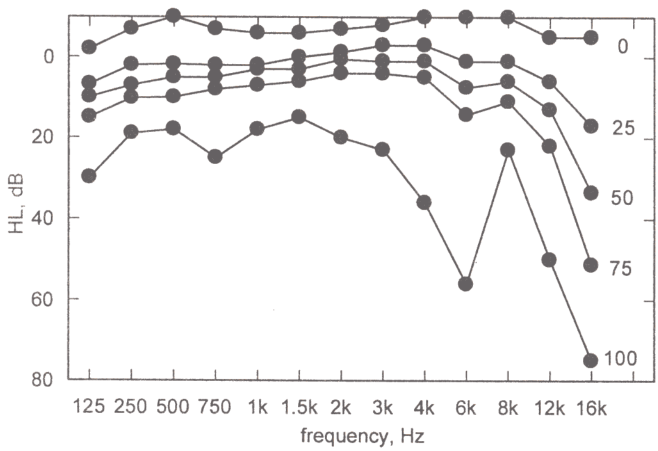

Fig. 3. Statistics of threshold in quiet in percussion players. Quartiles of 80 audiograms; right and left ears.

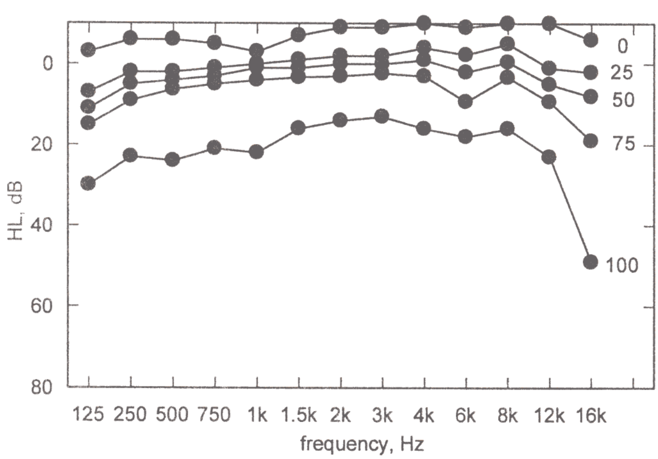

Fig. 4. Statistics of threshold in quiet in non-percussion players. Quartiles of 80 audiograms; right and left ears.

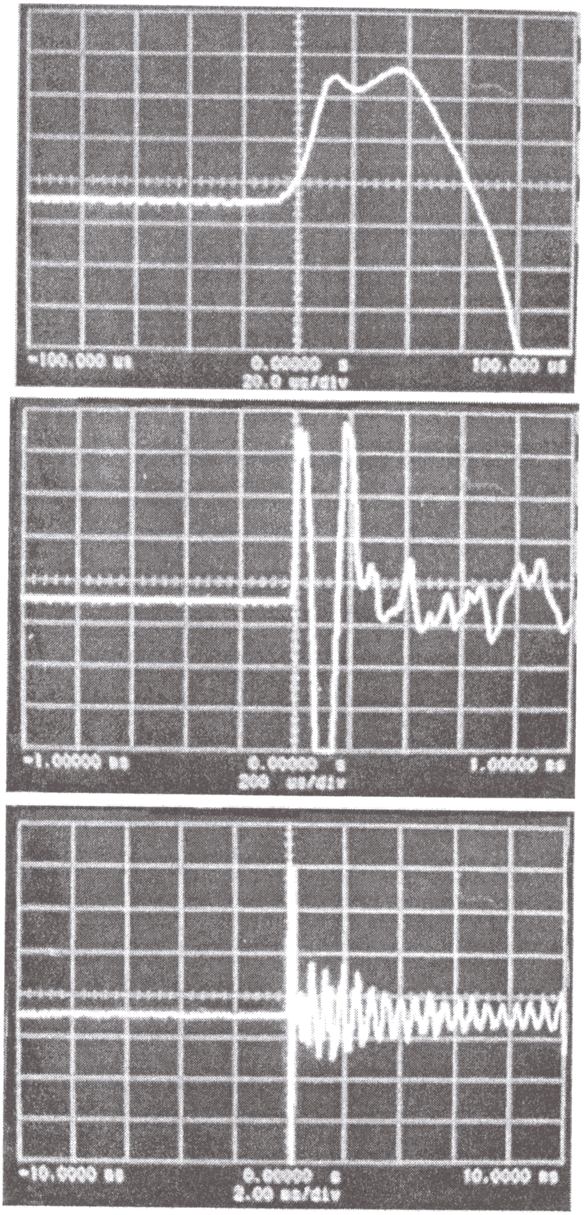

Fig. 5. Examples of oscillograms of isolated xylophone sound C#6 (1108.8 Hz) with time bases 20 μs/div, 200 μs/div and 2 ms/div.

decreases at high frequencies only by 25 dB. It means that at 20 kHz the peak spectral density is still in the range of 80 dB. The results of temporal analysis of the short selections performed on a xylophone, in the form of the cumulative distribution function are given in Fig. 7. These data show some amount of peaks reaching 140 dB.

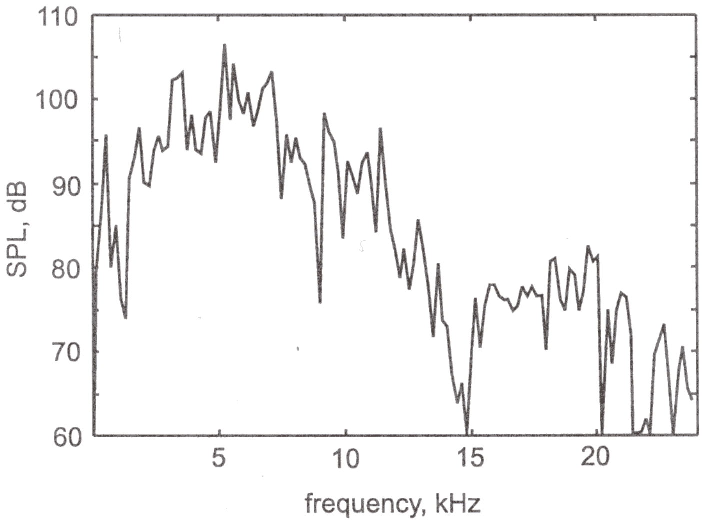

Fig. 6. Amplitude spectrum of representative isolated xylophone sound C5 (523.3 Hz).

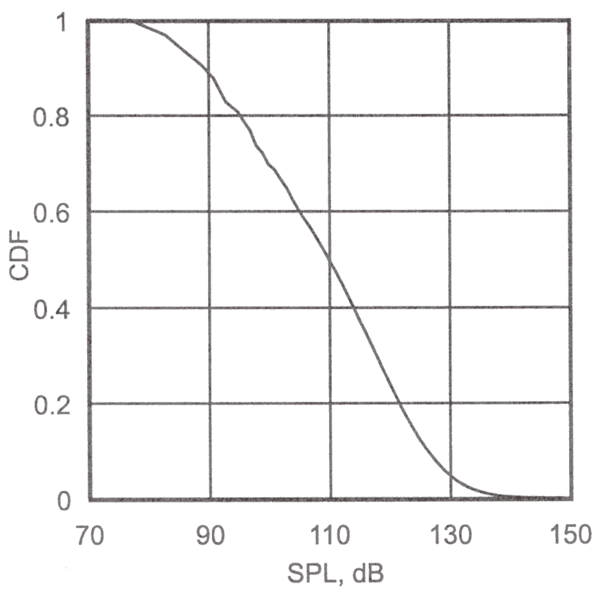

Fig. 7. Peak level cumulative distribution function (CDF) of short selection played on the xylophone.

Temporal analysis of xylophone sound models was performed to test the effect of limited frequency response of DAT recording channel. A number of C#6 (1108.8 Hz) sound samples recorded in digital oscilloscope memory with different time bases were resampled and merged into one structure. Sampling frequency was 192 kHz. This xylophone sound model was then low-pass filtered and resampled with standard DAT sampling frequency — 48 kHz. The shapes of initial transients in both cases are shown in Fig. 8.

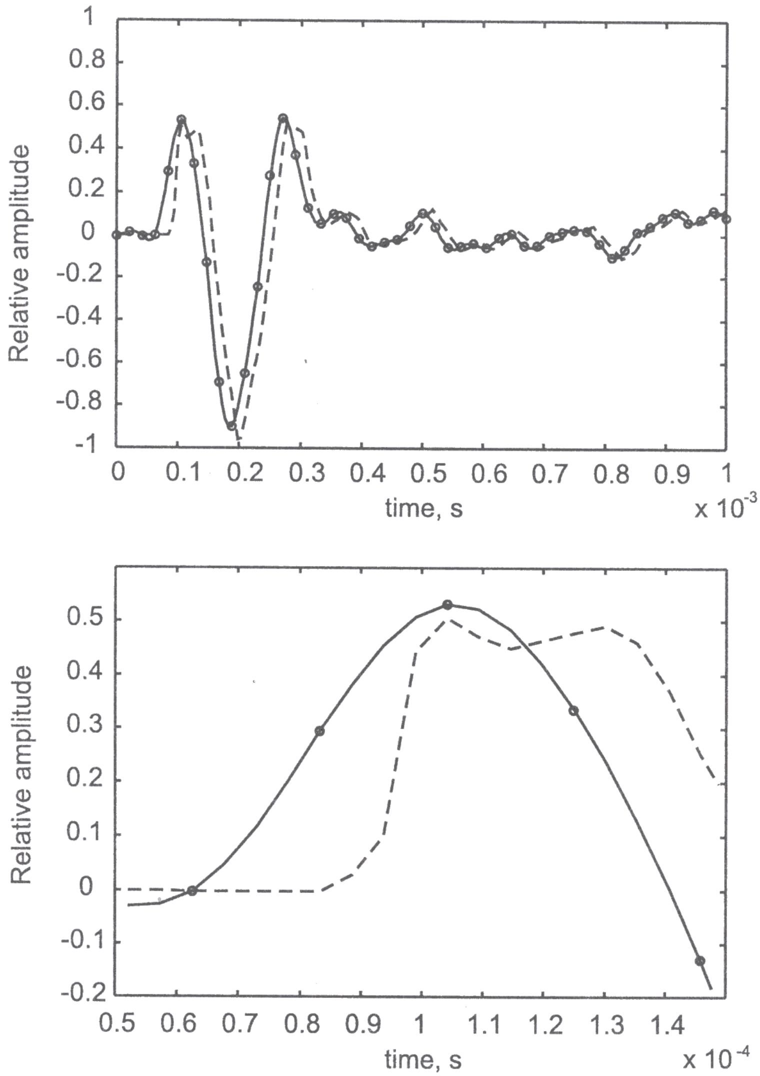

Fig. 8. Initial transients of xylophone sound C#6 (1108.8 Hz) models digitally recorded with sampling frequency 48 kHz (solid line) and 192 kHz (dashed line).

4. Discussion

The experimental data on hearing impairment in percussion players is in partial agreement with the early data from Gryczyńska and Czyżewski [6], from Karlsson *et al.* [15] and from Ostri *et al.* [18] who found substantial hearing loss in percussion players, but who used conventional LF audiometry up to 8 kHz only. Contrasting results were reported by Osterhammel and Osterhammel [17] who compared hearing thresholds in 286 normal hearing subjects and 28 noise exposed subjects with typical 4 – 6 kHz

V-dip. Their data show that in all age groups (30 – 39, 40 – 49, 50 – 59) thresholds reach normal values at very high frequencies, even for subjects with severe impairment at low frequency. However it should be stressed that no details are available as to what noise their subjects were exposed to, spare for information that it was industrial noise.

Histological examination of cochlea in man and in animals shows that impulsive sounds cause damage particularly in the basal end of cochlea i.e. place of location of high frequency receptors, HAWKINS and JOHNSON [8], JORDAN *et al.* [14], SONDIJN [20]. It is beyond any doubt that small rise times of percussion sounds give more energy in the high frequency range of their spectral density than any other musical instrument does. This results in increased excitation and consequently damages of auditory receptors in that range in case of exposure to very high sound pressure levels of percussion sounds reaching 140 dB SPL.

It should be observed that the exposure to "live" percussion sounds is evidently more dangerous to hearing because of very short rise times of sound pulses which are smoothed in the recorded material. This notion is in agreement with the early experimental evidence from WALKER and BEHAR [22] who found that impulse events recorded on tape lead to fairly less TTS than "live" pulse events. HAMERNIK *et al.* [7] suggest: "increasing of susceptibility to NIPTS from the lowest to the highest audiometric frequencies which further grows by 5 to 10 dB for pulses with spectral peak at high frequencies". This suggestion is in agreement with experimental data from FAUSTI *et al.* [5] who measured high frequency thresholds in subjects exposed to impulsive noise (gunfire) and found large thresholds shifts above 8 kHz.

5. Conclusions

From the experimental evidence it is apparent that percussion sounds have quite destructive effect on hearing. The particularly dangerous effect results from very rapid onset of some percussion sounds, like these of xylophone. Such an effect is not present in any other musical instrument. The net effects of the exposure to percussion sounds manifest themselves in the significantly worse hearing threshold in percussion players relative to the control group of other musicians.

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