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MUSIC INDUCED HEARING LOSS IN MUSICIANS PLAYING DIFFERENT MUSICAL INSTRUMENTS

C H Mawhinney (1) G C McCullagh (2)

University of Ulster at Jordanstown, Shore Road, Newtownabbey, Co Antrim, N Ireland.

1 INTRODUCTION

With the introduction, in 1990, of mandatory requirements for exposure to noise at work there has been an increased interest in the hearing loss shown by the music world. Sandy Brown, the well known Architect and Musician, has expressed the view that exposure to musical sound at high levels does not seem to result in deafness in sound balancers in broadcasting, recording studios or in pop musicians. Other authors, following extensive studies, have found that, whilst hearing loss due to exposure to high levels of music is less than that which similarly exposed workers in industry suffer, nevertheless there is a definite risk.

One of the first investigators was Jerger [1] who in 1958, found substantial levels of TTS_2 in two groups of rock-and-roll musicians. Flach [2] tested orchestral musicians only and found a general reluctance to hearing tests. In a project covering 42 rock-and-roll musicians exposed to music from amplifiers rated at 35 watt to 300 watt and with sound levels averaging 105 dB(A), Rintleman [3] found that 40 of the subjects had normal hearing although exposed for 3 years on average. Only one subject had a bilateral 4 kHz notch extending to 40 dB and, after a 4 year interval, re-testing yielded a maximum of 10 dB increase. He concluded that, whilst the hearing loss was less than expected, overall there was a definite risk for a minority of musicians.

Flugrath [4] tested 10 groups and found that exposure levels ranged from 95 dB(A) to 112 dB(A). He postulated that the sound spectrum, peaking at 2 kHz, was a fortunate coincidence since the middle ear muscles respond readily to sound at that frequency, giving protection to the inner ear. In audiometric tests on members of one 19 - 20 year old group Rupp [5] found a maximum TTS_2 of 25 dB at 4 kHz and proposed that there should be regular audiometry, that musicians should wear ear defenders, that government should establish safe sound levels and that, in the interim, a 100 dB maximum output might be established. Contrary to Flugrath's view on the protection afforded by the middle ear muscles, Dey [6] gave the opinion that sounds with predominant frequencies in the 1 kHz - 2 kHz range were most damaging. His tests, on 15 males aged between 18 years and 25 years old, involved 2 hours exposure to taped music at 120 dB followed by audiometric testing. Dey concluded that 16% of young men exposed to 110 dB(A) for 2 hours would experience a severe TTS_2 and, if 98% were to be adequately protected, the exposure level would have to be reduced to 100 dB(A).

Testing groups playing in various establishments, Rupp found that sound exposure levels of the musicians varied from 90 dB(A) to 115 dB(A) with a mean level of 105.2 dB(A). He expressed the opinion that Cohen's proposal for safe levels, eg, at 90 dB for 1 hour, was too stringent and suggested that guidelines on exposure of musicians and listeners should be introduced. King [8] compared the sound levels to which pop groups are exposed, in the range from 100 dB - 120 dB, to noise levels emitted by jet aircraft and the exposures of workers in boiler-making factories. In a wider study, Axelsson [7] tested 83 pop musicians with an average age of 26.5 years. He found dips at 6 kHz in the audiograms, deeper in the right than in the left ear and variations in sensitivity between right and left ears. There was a relatively low loss of hearing amongst the musicians tested, with few ears exceeding 35 dB hearing threshold level. Whilst there was a possibility that some musicians with permanent threshold shifts avoid participation in tests others severely affected possibly retire earlier than less sensitive members. The reasons for low threshold shifts were thought to include regular interruptions in playing, short exposure times and low impulse content. Axelsson, who also investigated TTS in musicians and patrons, suggested that a level of 95 dB(A) is high enough for enjoyment whilst low enough to preserve hearing.

AIMS AND OBJECTIVES

The research reported herein is part of a larger study of musicians using electronic amplification equipment. The study includes investigation into means of reducing noise exposure of musicians and listeners. In this study the aims were confined to:

1. Measurement of the sound levels and $L_{EP,d}$ to which musicians and patrons were exposed.
2. Assessment of the hearing level of musicians playing different musical instruments.
3. Assessment of hearing level of control group of subjects and comparison with musicians.
4. Recommendations for reducing exposure of musicians.

INSTRUMENTATION AND METHODS

Subjects were all musicians, professional and amateur selected at random from groups playing in selected venues in Northern Ireland. As a pre-requisite the establishments chosen were required to have accommodation suitable for sound level measurements and audiometric testing. Data collected and measurements consisted of :

1 Sound levels and frequency analysis measured on stage and at selected positions at the patrons.
2 $L_{EP,d}$ measurement by noise dosimeter on stage.
3 Audiometric testing of selected musicians.
4 Proformas for each musician including history of non-musical noise exposure.
5 Audiometric testing of selected control group.

1 SOUND LEVEL MEASUREMENTS

Sound measurements on stage were carried out using a Brüel & Kjær Sound Level Meter Type 2218 complete with 1/3 Octave Band Filter Type 1616. Two Brüel & Kjær Type 4165 ½" microphones matched to ± 0.5 dB were connected to the Sound Level Meter via extension leads and were individually switchable. The microphones were placed on boom stands as close as was practically possible, without affecting performance, to either ear of the musician. Measurements recorded included values of L_{Aeq}, peak SPL's and Octave Band Analysis in the range 250 Hz to 16 kHz. A variety of music including slow, moderate, fast beat and rock was selected for analysis at various stages of each performance.

2 DOSIMETER MEASUREMENTS

$L_{EP,d}$ readings were obtained using 2 Brüel & Kjær Type 4428 noise dosimeters which were positioned with microphones on boom stands close to the Sound Level Meter microphones so that the two microphones were recording the same sound fields.

3 AUDIOMETRY

All threshold tests were conducted in a room remote from the playing area, patrons and other activities within the building. The ambient noise levels were measured on each occasion and were sufficiently low as not to interfere with the audiometric tests. Pure tone air conduction thresholds were obtained using a Peters Audiometer Type AP7 fitted with TDH 39 earphones and an Amplivox noise excluding headset. The audiometer was routinely calibrated [8] and a physical check carried out before each test.

The musicians carried out sound checks at full sound pressure levels before each performance and so audiograms were completed prior to this to eliminate any TTS_2. Rejections on each occasion included musicians with colds, influenza or prescribed drugs and those who had been exposed to loud noise, including music, in the preceding 20 hours.

4 PROFORMAS

A proforma was completed for each musician tested and included details of the subject's noise exposure together with history of hearing problems, employment record, relevant social habits, musical instruments played or vocals, history of playing, frequency of playing and general comments, for example, on hearing and on noise from other instruments.

5 CONTROL GROUP

To ascertain the extent of hearing loss due to exposure to loud music it was necessary to compare musicians with subjects in the same sex, age, background, home environment, family, education and the same socio-economic group. In all 104 subjects, who were either friends, brothers, sisters, cousins or in-laws of the musicians and matched to within ± 5 years, had proformas completed together with audiograms recorded in conditions similar to musicians.

RESULTS

In all, 192 musicians were involved with collection of data over a 4 year period at different venues throughout N Ireland. In some cases full data was not available, 2 subjects died within the study period, 2 emigrated, 12 musicians were rejected with ear problems and 4 were rejected with head injuries. There were 153 subjects remaining of whom 4 were female. The ages of subjects ranged from 18 years to 58 years with an average of 35.0 years.

Of the 153 musicians 87 (56.9%) were professional (full-time with no other employment) and 66 (43.1%) were amateur (with other full-time employment). All 4 females were professional musicians. The range of employments of the amateurs was 26% in industry, 29% in offices, 8% professionals, 21% in sales with the remainder including several drivers, a student, a piano tuner and a medical practitioner. Table 1 shows the distribution of instruments played by the musicians, with the more popular instruments being bass guitar, lead guitar, drums and keyboards.

1 FREQUENCY ANALYSIS OF DIFFERENT INSTRUMENTS

To compare the spectrum of the sounds to which different musicians were exposed octave band analyses were performed for different musical groups. Sample analyses and peak levels are given in Figure 1 - 6 for the mean of 3 lead guitarists, bass guitarists, drummers and keyboard players.

Instruments	No.	%
Vocals (no instruments)	20	13.1
Lead guitar	27	17.6
Rhythm guitar	6	3.9
Steel guitar	3	2.0
Bass guitar	32	20.9
Drums (acoustic and electric)	31	20.3
Keyboards (including accordion)	28	18.3
Saxophone	5	3.3
Trumpet	1	0.7
Totals	153	100

Table 1. DISTRIBUTION OF INSTRUMENTS PLAYED

2 NOISE EXPOSURE MEASUREMENTS

Normally performances lasted for 2 hours either continuous with short breaks for announcements or intermittent with a 20 - 30 minute rest period in the middle. Groups who played continuously had shorter rests between sets of tunes. The loudest ambient noise at the patrons between sets of tunes was 89.8 dB(A).

Maximum values of sound pressure levels $L_{Aeq,10s}$ were measured for individual musicians and levels ranged from 93.5 dB(A) to 117.2 dB(A). Figs. 7-18 show the mean PTS of musicians compared with the PTS of the control group for all the musical sub-groups.

Sample values of $L_{EP,d}$ were measured for individual musicians over the whole performance, and ranged from 84.6 dB(A) to 104.5 dB(A). The mean difference between L_{Amax} and $L_{EP,d}$ for all musicians was 9.2 dB(A).

2 AUDIOMETRIC TESTS

The means of the measured values of hearing levels of the musicians playing different instruments including vocals, were plotted against the means of the hearing levels of the control group. The mean age of the control group was 36.8 years and that of the musicians which was 35.0 years.

DISCUSSION

1 LEVELS OF NOISE EXPOSURE

"Music is different from noise", is a regular comment from musicians, who progress to say that music of the same SPL as noise does not cause the same hearing loss. If the 1990 Noise at Work Regulations were applied to the patrons listening to the 6 groups compared later, then all of the audience would have been recommended to wear ear defenders, including the patrons at the rear of the dance area where the $L_{EP,d}$ was above the First Action Level of 85 dB(A).

Mawhinney [9] reported earlier on sound levels for the 48 groups exposed to levels from 93 dB(A) to 113 dB(A) with most subjects exposed from 105 dB(A) to 108 dB(A).

For all musicians the mean maximum sound level on stage was 105.5 dB(A), the mean $L_{EP,d}$ was 96.2 dB(A) and the difference 9.2 dB(A). For professional musicians the difference was 8.2 dB(A). This is consistent with Brown [10] who found a 10 dB(A) difference between maximum level and $L_{EP,d}$.

2 HEARING LOSS

Figs. 7-18 show the PTS for the different musicians compared with that of the control group. The means of the hearing loss of all musicians show increases at all frequencies for both ears with the left ear showing the largest increases of 6.9 dB at 1 kHz, 6.4 dB at 2 kHz, 5.4 dB at 3 kHz, 3.7 dB at 4 kHz and 5.8 dB at 6 kHz. The lead guitar players were the only musicians whose mean PTS was better by 0.8 dB at 3 kHz than control group. Lead guitar players' right ears, followed by keyboard players' right ears showed the least increase.

Both ears of drummers showed the largest increases of all musicians. Generally the left ear was worse with increases ranging from 5.2 dB at 250 Hz to 11.4 dB at 6 kHz. The left ear is exposed more to the snare drum to the left of the drummer at approximately 600mm from the left ear and played hard for every beat of every bar of music.

It would appear that the mean hearing losses are relatively small, with a maximum of 22.6 dB at 6 kHz left ear for all musicians. Drummers have the maximum of 28.2 dB at 6 kHz left ear. Overall musicians exposed to loud music do not appear to have as great a hearing loss as expected.

3 REDUCING SOUND LEVELS

The HSE Contract Report [11] Survey of sound levels at pop concerts refers to HSE Guidelines of max. L_{Aeq} of 104 dB(A) for the duration of the concert, assumed to be measured close to the PA speakers. With professional musicians the mean difference between L_{Amax} and $L_{EP,d}$ on stage was 8.2 dB(A), and mean difference between L_{Amax} on stage and 2 metres from PA was 4.6 dB(A), (max. 10.2 dB(A)).

Applying HSE criterion of 104 dB(A) and a playing time of 2 hours, then $L_{EP,d}$ = 98 dB(A) and L_{Amax} = 106.2 dB(A) at the PA.

Using collected data, assuming musicians commenced playing at 18 years for 35 years at 4.1 night per week with NIL (E_A) of 108.9 dB(A), this would give an $L_{EP,d}$ of 93.6 dB(A) or L_{Amax} of 101.8 dB(A) on stage (93.6 + 8.2) and 106.4 dB(A) at the PA (101.8 + 4.6). This 106.4 dB(A) is close to the HSE criterion of 106.2 dB(A) and would result in 1.1% of professional musicians exceeding the H_{123} low fence of 30 dB and all musicians having a mean 7% hearing disability (ΣH, 123 kHz better ear)[12].

The musicians were divided into 4 groups depending on exposure level. The first group range 84-89.9 dB(A) $L_{EP,d}$, showed minor increases in PTS over control group (6% mean hearing disability) with L_{Amax} on stage of 97.4 dB(A) and L_{Amax} at PA of 102 dB(A). The second group range 90-94.9 dB(A), showed a significant increase in PTS (7% mean hearing disability) with L_{Amax} on stage of 102.5 dB(A) and L_{Amax} at PA of 107.1 dB(A).

The maximum difference recorded between L_{Amax} on stage and PA was 10.2 dB(A). Applying this to the HSE criterion of 104 dB(A) or 106.2 dB(A) at PA, then L_{Amax} on stage could be 96.0 dB(A). This is lower than the on stage first group. If the PA system was used more efficiently this would reduce PTS for musicians.

CONCLUSIONS

The majority of musicians commented that they chose to play thus because of the enjoyment of playing at high sound levels. They realized that this could increase their hearing loss in later life, but felt that to reduce levels to an extent that would prevent any increase in hearing loss would reduce playing to a level which would not have any pleasure for them or satisfy the patrons to whom they are providing a service.

From the above it will be seen that it is possible to reduce sound levels on stage to a level which, if acceptable to musicians, would significantly reduce hearing loss and still present a safe acceptable level of sound quality to the patrons. It is also obvious that the left ear for all musical groups appears to be more sensitive than the right and, when considering drummers, this is aggravated further by the snare drum. The playing styles of drummers has long been established and are unlikely to change in the future. Therefore some action must be taken to ensure that sound levels produced by drummers, lead and bass guitar players decrease. Acoustic drummers must take additional action to offer protection to themselves and any other musician close to them in an effort to avoid unnecessary hearing loss.

RECOMMENDATIONS

1 Groups playing at large venues should mic up all instruments to a PA of minimum power 1.2 kilowatt and use a sound engineer to achieve at least 10 dB(A) difference between the L_{Amax} on stage and that measured at 2 metres from the PA.

2 The maximum L_{EQ}(1 min.) measured at PA should not exceed 106 dB(A) which should result in on stage level of 96 dB(A).

3 All musicians should have access to monitor speakers and the sound engineer should have communication to musicians.

4 Non vocal drummers, should consider wearing ear plugs and use a monitor to the right.

5 Manufacturers of sound equipment be encouraged to close the open back of guitar combo amplifiers to prevent unwanted sound being projected rearwards to other musicians.

REFERENCES

1 JERGER J F, 1958: Cumulative auditory fatigue, J.of Speech and Hearing Research Vol.1(4), 299-308.
2 FLACH M and ASCHOFF E, 1967: The risk of occupational deafness in musicians, German Medical Monthly, Vol.12, 49-54.
3 RINTELMANN W F and BORUS J F, 1968: Noise-induced hearing loss and rock and roll music, Arch Otolaryng, Vol.88, 57-63.
4 FLUGRATH J M, 1972: Abstract of:- Temporary threshold shift and permanent threshold shift due to rock and roll music, J.of Acoustical Society of America, Vol.51, 151.
5 RUPP R R, 1969: Effects of too-loud music on human ears but, mother, rock'n roll music has to be loud, Clinical Paediatrics, Vol.8(2), 60-62.
6 DEY A H, 1970: Auditory fatigue and predicted permanent hearing defects from rock-and-roll music, The New England Journal of Medicine, Vol.282(9), 467-470.
7 AXELSSON A and LINDGREN F, 1978: Hearing in pop musicians, Acta, Otolaryngol, Vol.85, 225-231.
8 ISO 389.1975, Standard reference zero for the calibration of pure-tone audiometers. Geneva: International Organization for Standardization.
9 MAWHINNEY C H and McCULLAGH G C, 1989: Noise induced hearing loss in musicians in N Ireland-Effects of amplification, Proceedings Institute of Acoustics Vol.2,Pt 9, 33-43.
10 BROWN S,1974:Hearing health and music report to the association of ballrooms, Sandy Brown Associates
11 HEALTH AND SAFETY EXECUTIVE, 1991: Contract research report on survey of sound levels at pop concerts.
12 KING P F, COLES R R A, LUTMAN M E and ROBINSON D W, 1992, Assessment of Hearing Disability.

Organization for Standardization, 1975.

MUSIC INDUCED HEARING LOSS

Fig.1 Mean SPL / Frequency Dist. For 3 Lead Guitarists

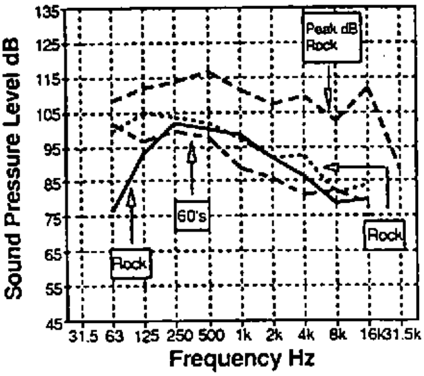


Fig.2 Mean SPL / Frequency Dist. For 3 Bass Guitarists

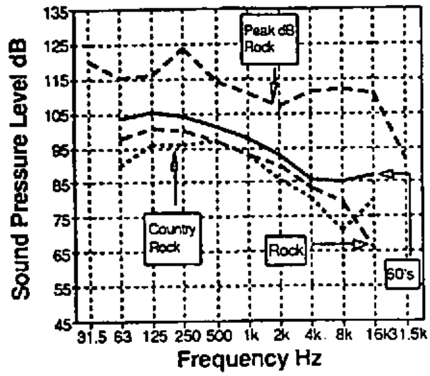


Fig.3 Mean SPL / Frequency Dist. For 3 Drummers

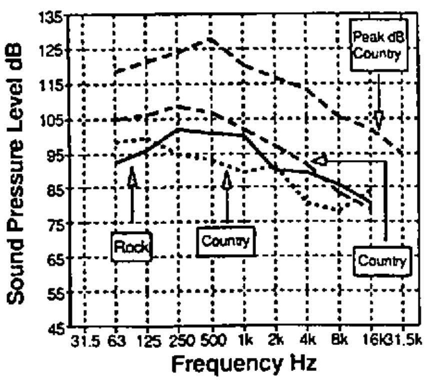


Fig.4 Mean SPL / Frequency Dist. For 3 Keyboard Players

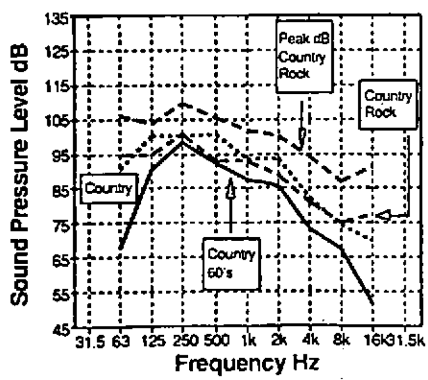


Fig 5. Mean SPL / Frequency Dist. For Lead, Bass, Drums and Keys

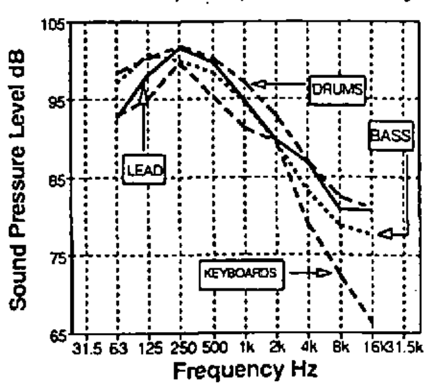
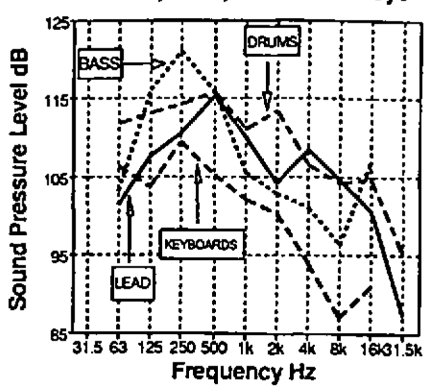


Fig 6. Mean Peak dB / Frequency Dist. For Lead, Bass, Drums and Keys



MUSIC INDUCED HEARING LOSS

Fig.7 Mean PTS Musicians/Control
Left Ear

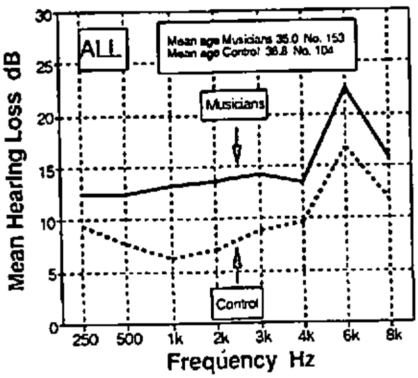


Fig.8 Mean PTS Musicians/Control
Right Ear

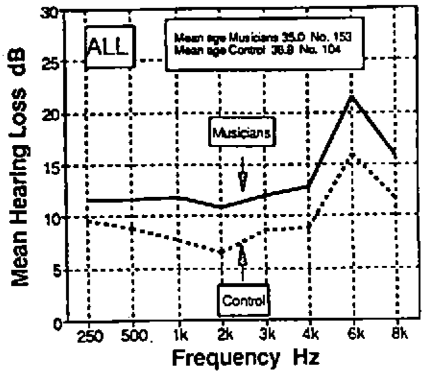


Fig.9 Mean PTS Musicians/Control
Left Ear

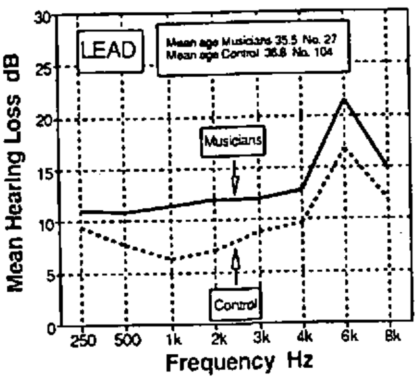


Fig.10 Mean PTS Musicians/Control
Right Ear

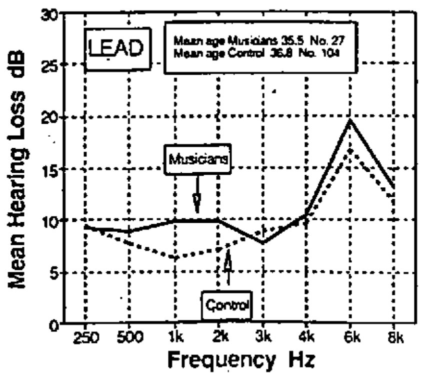


Fig.11 Mean PTS Musicians/Control
Left Ear

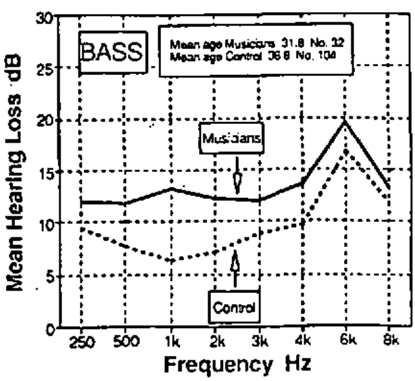
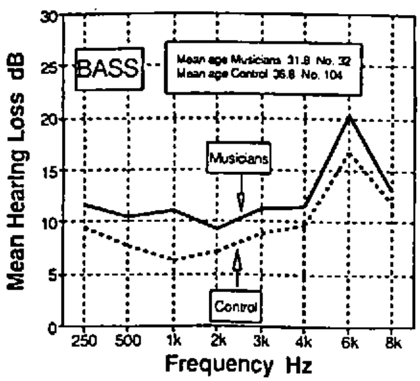


Fig.12 Mean PTS Musicians/Control
Right Ear



MUSIC INDUCED HEARING LOSS

Fig 13. Mean PTS Musicians/Control
Left Ear

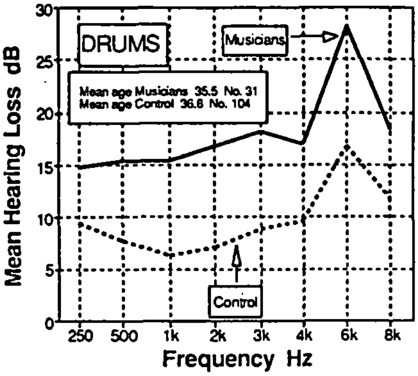


Fig 14. Mean PTS Musicians/Control
Right Ear

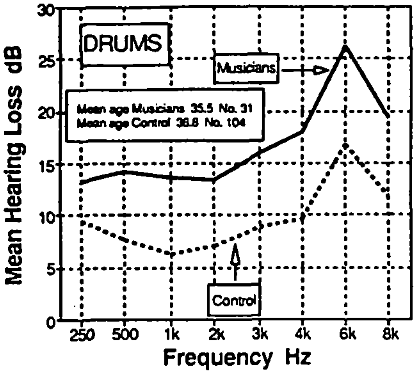


Fig 15, Mean PTS Musicians/Control
Left Ear

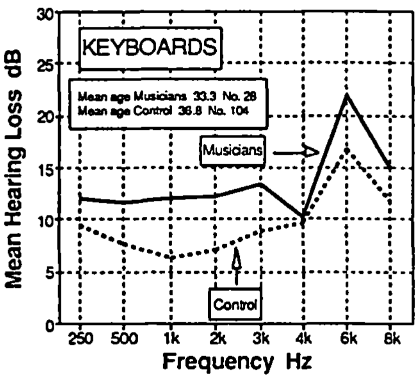


Fig 16. Mean PTS Musicians/Control
Right Ear

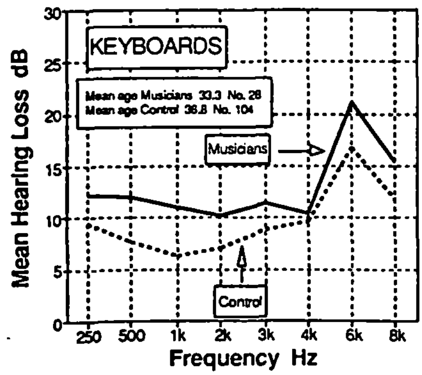


Fig 17. Mean PTS Musicians/Control
Left Ear

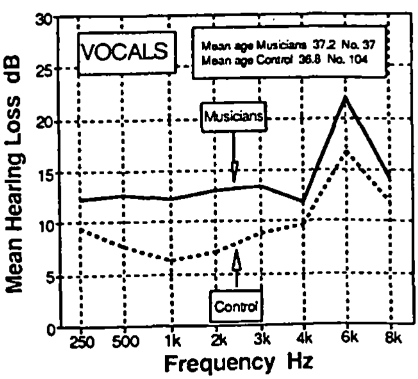


Fig 18. Mean PTS Musicians/Control
Right Ear