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NOISE INDUCED HEARING LOSS IN MUSICIANS IN NORTHERN IRELAND - EFFECTS OF AMPLIFICATION

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INTRODUCTION

The EEC Directive [1] on the protection of workers from exposure to noise at work, which is shortly to be introduced in the United Kingdom in the form of mandatory Regulations and an associated Code of Practice, has considerable implications for industry as a whole and for employees in a variety of wide ranging occupations which would not normally be considered as Industrial in nature. The Directive is intended to cover all employees exposed to excessive noise and as such includes persons habitually exposed to loud noise in Swimming Pools, at Motor Racing Tracks and certainly extends into the world of music.

A report in the New Scientist [2] indicates that the British Entertainment and Dancing Association are concerned about the effects of this impending legislation on Discos and Theatres and believe that Disc Jockeys and Musicians, who are regularly exposed to Sound Levels in excess of 100 dB(A), should be exempted from a need for compliance with the Regulations. A further group for whom exemption has been sought is that of Recording Studio Engineers. These engineers listen to music during recording sessions, again at Sound Levels in excess of 100 dB(A). The reasoning is that the response of the human ear is not "flat" below 100 dB(A) and that Studio Equipment is designed to work best as high Sound Levels.

Whilst it has been known for centuries that noise from gunfire and from hammering can damage hearing, positive measures to protect the hearing of persons employed in heavy industry and exposed to high level noise have only been taken in recent years. In the early 1950's it became clear that Sound Levels as low as the mid-70s could cause temporary threshold shifts at some frequencies and that, in some instances where individuals had ears susceptible to damage, hearing loss of a permanent nature might result from long term exposure to noise at levels not much in excess of 80 dB(A).

The advent of amplified music on a wide scale coupled with Rock and Roll music led to large increases in the Sound Levels to which patrons and employees of Dance Halls were exposed. It was realised that hearing damage might be caused by such high level noise exposure and so attention became focused on noisy pastimes and particularly on music. Flach and Aschoff [3], in 1967, investigated noise levels to which Musicians in a Symphony Orchestra were exposed and coupled this with measurements of Hearing Level. Whilst some slight inner ear loss of hearing was noted in Musicians in the String section, it was concluded that Orchestra Players did not run any risk of occupational

noise trauma in the ordinary sense of the word. In 1968 Lebo and Oliphant [4] reported on a study into Sound Levels during Symphony Concerts and compared the levels with those found from Rock and Roll music. They concluded that, whilst the Damage Risk Criteria were exceeded by Rock and Roll music, the noise levels at Symphony Concerts were well below risk levels.

In a study reported in 1968 Rintelmann and Borus [5] found little Hearing Loss in 40 Musicians from a total of 42 Members of Rock and Roll Groups. The Groups used amplifiers with power outputs in the range from 35 Watt to 300 Watt. One 18 year old was found to have a classical NIHL dip. Flugrath [6], in a 1969 study, measured noise levels from 10 Rock and Roll Bands in a single Dance Hall and concluded that the average levels from some Bands exceeded the Damage Risk Criteria. Rupp and Kock [7] investigated one Rock and Roll Combo of 5 members over a 2½ hour session and found Temporary Threshold Shifts of up to 30 dB at a frequency of 4 kHz. All musicians experienced Tinnitus for several hours or, in some cases, for days after playing.

Axelsson and Lingren [8], in 1977, studied 160 Pop Musicians and, although they found only slight deviations from normal in Hearing Levels, indicated that the Group average Audiogram showed a clear 6 kHz "dip" of about 20 dB. In their conclusions they suggested a Criterion for Pop Music at 95 dB(A).

AIMS & OBJECTIVES

The research reported in this paper is part of a larger study which includes Pop Musicians, Country and Rock Musicians and Folk Groups linked by the use of amplification in their sessions. The study includes an investigation into means of reducing noise exposures of Musicians and of Patrons of Dance Halls. In this preliminary study the aims were confined to:-

1. Measurement of the Sound Levels, and in particular the Leq (8 Hour), to which the Musicians were exposed.

2. Assessment of the Hearing Level of the Musicians.

3. Correlation of the Loss of Hearing and Noise Dose Levels.

INSTRUMENTATION AND METHODS

Subjects were all musicians selected at random from groups playing in selected establishments within a 50 mile radius of the University of Ulster Jordanstown Campus and which had different types of groups performing. As a pre-requisite the establishments chosen were required to have accommodation suitable for Sound Level measurements and audiometric testing. Sound levels and frequency analyses were recorded generally for 2 musicians per event. The data collected and measurements consisted of:-

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1. Sound levels and frequency analyses measured at on stage positions
2. Leq measurement by noise dosimeter on stage
3. Tape recordings of selected passages of music at on stage positions
4. Audiometric testing of selected musicians
5. Proformas for each musician.

1. SOUND LEVEL MEASUREMENTS

Sound measurements on stage were carried out using a Bruel & Kjaer Sound Level Meter Type 2218 complete with 1/3 Octave Band Filter Type 1616. Two Bruel & Kjaer Type 4165 ½" microphones matched to +/- 0.5 dB were connected to the Sound Level Meter via extension leads and could be individually switched. Only musicians who did not move about stage were used for tests. The microphones were placed on boom stands and positioned as close as was practically possible, without affecting performance, to either ear of the musicians.

Measurements recorded included A-weighted Leqs and Octave Band Analysis in the range from 250 Hz to 16 kHz. A variety of musical types, including slow, moderate, fast, beat and rock, was selected for analysis at various stages during the performance.

2. DOSIMETER MEASUREMENTS

Leq readings were obtained using 2 Bruel & Kjaer Type 4428 noise dosimeters with ½" microphones. The Dosimeters were positioned on microphone booms close to the Sound Level Meter microphones so that the two microphones were at the same distance from the subjects and were recording essentially the same sound fields.

3. TAPE RECORDINGS

Uher Typer 4400 Tape Recorder was connected to the AC output of the Sound Level Meter and was used to record sections of music from each of the two measurement positions at intervals throughout the performances. A 30 second calibration signal from the most appropriate of the two Calibrators was recorded at the beginning and end of each 45 minute tape.

4. AUDIOMETRY

All threshold tests were conducted in a room remote from the Dance Hall, from all patrons and other activities within the building. The ambient noise levels in the different rooms were measured on each occasion and were sufficiently low as not to interfere with the threshold measurements. 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 calibrated and a check was carried out before each test session.

Audiograms for each musician were completed before the commencement of the performance, after the musicians had set up their gear but before any sound checks were performed. This eliminated any possible TTS's from sound tests which, although of short duration, were conducted at Sound Levels comparable to those used during the events.

Subjects who had colds, influenza or had been prescribed drugs were excluded from testing as were those musicians who had been exposed to high level noise in the preceding 20 hours. Examples of this were musicians who had performed earlier in the day at, for instance, a wedding or at live recording sessions.

5. PROFORMAS

A proforma was completed for each Musician tested and included details of the subject's noise exposure history 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.

RESULTS

Over a 2 year period Sound Levels to which Musicians from 48 groups were exposed on stage were measured on various occasions at 16 venues throughout Northern Ireland. On each occasion Audiometric tests were also carried out on those Musicians whose noise exposures were measured. In all 192 subjects were involved. In some instances it was impossible to obtain both Audiograms and Sound Level data for the subjects. Again, 2 subjects were rejected on medical grounds. The group remaining totalled 170 Musicians, 164 of which were male and the remaining 6 Musicians were female. The youngest subject was 18 years old and the oldest 63 years old whilst the average age was 35.3 years.

Of the 170 Musicians 95 (56%) were professional (ie full-time with no other employment) and 75 were amateur (ie with other full-time employment) whilst 4 of the 6 female Musicians were professionals, one was a housewife and one was in full-time employment. The range of employments of the amateur Musicians was 27% in Industry, 28% in Offices, 19% in sales with the remainder including several drivers, 1 student, 1 piano tuner and 1 medical doctor (General Practitioner).

Although no known family hearing problems were reported 22 musicians (13%) indicated that they had ear problems ranging from injuries resulting from car accidents to falling down stairs. A further 6 musicians reported having head injuries at some stage in their careers, eg one the result of amateur boxing.

Table 1 shows the distribution of instruments played by the musicians. It will be seen that not all musicians played instruments and indeed, 19 (11.2%) were lead vocals who usually stood at the front of the stage and well away from instruments. Irrespective of the type of music played by the groups, the more popular instruments were drums, bass guitar, keyboards and lead guitar.

Instrument	Number	%
Lead Guitar	28	16.5
Rhythm Guitar	13	7.6
Steel Guitar	3	1.8
Bass Guitar	34	20.0
Drums (acoustic & electric)	36	21.0
Keyboards (including accordion)	31	18.2
Saxophone	5	2.9
Trumpet	1	9.6
Vocals (no instruments)	19	11.2

Table 1 Distribution of Instruments played by Musicians.

1. FREQUENCY ANALYSIS

To verify the spectrum of the sounds to which individual musicians were exposed octave band analyses were performed from the tape recordings. Sample analyses are given in Figure 1 for a Lead Guitar and in Figure 2 for a Bass Guitar. It will be seen that the Lead Guitar had a fairly constant output up to 2 kHz above which frequency there was a sharp fall off. Whilst the Bass Guitar peaked at 250 Hz, its frequency response was within 10 dB of peak amplitude up to 16 kHz.

2. NOISE EXPOSURE MEASUREMENTS

On average performances of groups lasted for 2 hours which, for 50% of the groups, including a majority of the professional groups, was continuous with only short breaks for announcements. The remaining groups took a 20-30 minute rest break in the middle of their programmes. It was noted that these groups also tended to rest longer between sets of tunes (on average 30 seconds per 10 minute set of tunes) than the groups whose performance was continuous. Ambient noise levels during breaks were usually below 85 dB(A).

Sample values of Leq were measured for individual musicians during performances and the distribution of the maximum values of these measured levels are given in Figure 3 for the group of 170 musicians. From the noise dosimeter measurements and from the data summarised in Figure 3, coupled with information on length and frequency of performances, the

noise exposures of subjects were estimated. The distribution of these subjects daily noise dose levels, calculated as Leq (8 Hour) values, is given in Figure 4.

3. AUDIOMETRIC TESTS

The measured values of hearing level at 4 kHz for individual ears of the Musicians are summarised in the histogram given in Figure 5, which includes test results for a total of 337 ears. One ear only was measured for one subject whilst, for another subject, the test was delayed because he had been given an injection prior to dental treatment earlier on the day of the performance and this had affected his hearing. The values of hearing level used were those measured before the commencement of the performances, ie they are permanent hearing levels.

A scattergram showing the distribution of permanent hearing threshold at 4 kHz with the estimated Leq (8 Hour) for individual ears of subjects is given in Figure 6. No attempt has been made to allow for frequency of performances or number of years over which individuals have played in groups. Some measurement points have been highlighted [0] to indicate subjects who had suffered head injuries or had other ear problems.

DISCUSSION

1. LEVELS OF NOISE EXPOSURE

The values of maximum sound levels from groups included in this investigation, in the range from 93 dB(A) to 113 dB(A), and with a distribution as shown in Figure 3, are consistent with the findings of Rintelmann and Borus [5] and of those of Flugrath [6]. The most common sound levels at which members of groups were found to be exposed was from 105 dB(A) to 108 dB(A).

In order to compare the noise exposure of these musicians with employees in industry it is more appropriate to look at the distribution of daily noise exposures for the musicians in terms of Leq (8 Hour) and hence the distribution given in Figure 4 is more likely to be meaningful. From Figure 4 it will be seen that the range of Leq (8 Hour) to which the subjects of the study were exposed is in the range from 85 dB(A) to 105 dB(A). Hence all subjects were exposed to a daily noise dose level above the First Action Level of 85 dB(A), as recommended in the 1990 Regulations.

Further, 154 musicians (90.6%) were exposed to an Leq (8 Hour) of 90 dB(A) or greater. The 1990 Regulations class an Leq (8 Hour) of 90 dB(A) as a Second Action Level above which the wearing of ear defenders is mandatory. The implication is that, to comply with the Regulations, steps should either be taken to reduce sound levels or these musicians should be required to wear ear defenders.

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A small number of musicians were exposed to sound levels, as indicated by a direct Sound Level Meter reading or by the peak excess indicator of the Noise Dosimeters, in excess of 140 dB(A). This sound level is close to the point where there is the possibility of rapid and permanent hearing damage. The new Regulations include a peak sound level of 140 dB as a Peak Action Level above which, even if the Leq (8 Hour) is below 90 dB(A), ear defenders must be worn.

The musicians exposed to peak sound levels in excess of 140 dB were, in each instance, lead guitarists and drummers. Comments from other musicians indicate that they consider the lead guitar to be the loudest instrument played in Groups. Some musicians stated that there were occasions when the lead guitar was so loud that they felt pain in their ears.

2. HEARING LOSS

The data summarised in Figure 5, which includes hearing loss due to ageing, clearly indicate that some musicians have incurred a considerable hearing loss due to noise exposure. Indeed, out of a total of 337 ears tested a hearing loss at 4 kHz of 20 dB or more was found in 105 ears (31.2%). Again, a hearing loss of 30 dB or more was found in 47 ears (13.9%).

The average hearing level at 4 kHz for the subjects, whose average age was 35.3 years, was found to be 15 dB which contrasts with an expected average hearing loss of 5 dB for subjects of this age. Dips in audiograms of 40 dB were common. However, some caution must be exercised in analysis of the data contained in Figure 5. This is made clear in the scattergram (Figure 6) which shows the measured values of hearing level at 4 kHz against estimated daily noise dose or Leq (8 Hour).

In general, whilst Figure 6 indicates that, in spite of high level noise exposure, some musicians still have a hearing level better than the average for non noise exposed persons, it is also clear that most subjects exposed to higher levels also suffer hearing losses. However, it would appear that the hearing losses incurred are relatively small, 15 dB to 25 dB on average. There does not seem to be as large an increase in hearing loss as expected for those musicians exposed to the higher sound levels.

Subjects who were found to have hearing problems are included in Figure 6 for completeness and are highlighted [0]. Whilst it is impossible to arrive at any viable conclusion without further analysis, for example, of other frequencies, or in advance of corrections for ageing, it will be seen that, for the most part, the hearing levels of these subjects stand out from the general spread of hearing levels of subjects who declared no hearing problems.

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CONCLUSIONS

The increase in recent years, in size and sound power, of amplification and the use of multiple loudspeakers by Musicians must inevitably lead to higher noise exposure levels. The sound levels to which Musicians in the Groups investigated in this study are exposed were found to be in the range of L_{max} from 93 dB(A) to 113 dB(A). When exposure time was allowed for the corresponding range of Leq (8 Hour) was found to be from 85 dB(A) to 105 dB(A). Out of a group of 170 musicians it was found that 154 Musicians (90.6%) were exposed to a Daily Noise Dose of 90 dB(A) or more.

Whilst the Hearing Loss of the majority of Musicians was small overall, of the 337 ears tested, 105 ears (31.2%) had a Hearing Loss of 20 dB or more. Again, whilst some Musicians had hearing which was clearly resistant to noise damage, it was evident that, as the level of noise exposure increased there was, as a consequence, a resulting increase in the Hearing Loss of the Musicians.

The demand for the exemption of Musicians from the new Regulations regarding Occupational Noise Exposure is obviously a demand based on the effect which the compulsory wearing of Ear Defenders would have on the ability to perform in the musical sense. However, this study reinforces the results of previous studies - that amplified music causes hearing loss. There is one readily available remedy which is widely used in other spheres of acoustics - that is - attenuate the sound at source.

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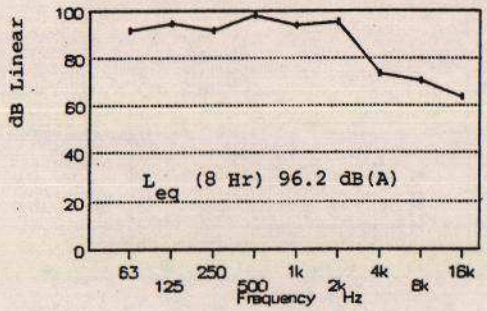

Fig 1. Octave Band Analysis of lead guitar

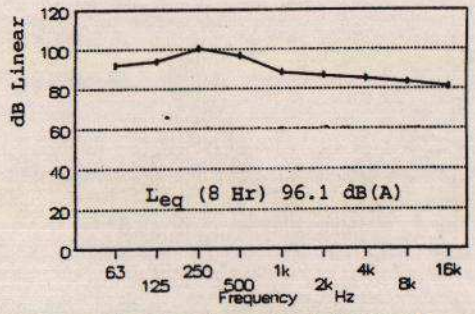

Fig 2. Octave Band Analysis of bass guitar

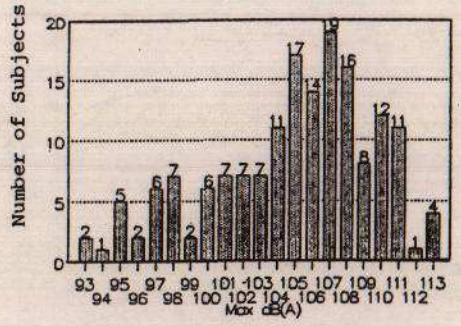

Fig 3. Distribution of Maximum L_{eq} (1s) for 170 musicians

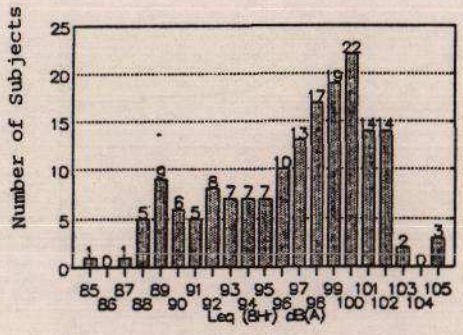

Fig 4. Distribution of L_{eq} (8 Hr) for 170 musicians

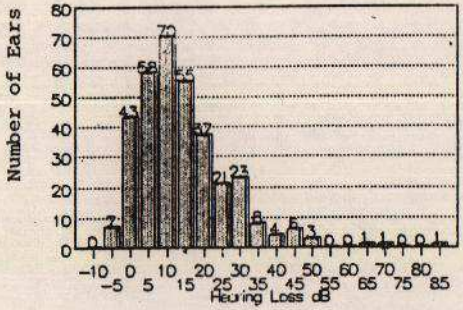

Fig 5. Permanent Threshold Shift at 4 KHz for 337 ears

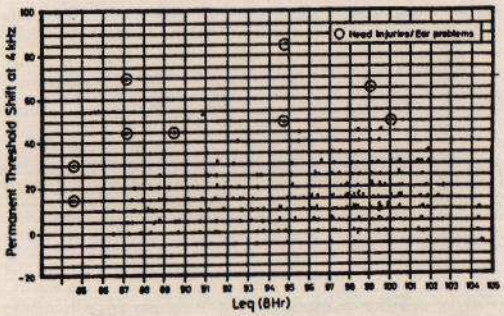

Fig 6. L_{eq} v PTS at 4 KHz for 337 Ears