A Study on Occupational Noise Exposure of Musicians

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Abstract
The aim of the study was to determine whether or not delivery of live music poses a significant risk to the hearing of musicians involved and to evaluate current practices that are employed (if any) to protect the hearing of musicians. *Method*: consisted of two parts; firstly monitoring of noise exposure levels at four gigs with the application of dose meters, and secondly the completion of a questionnaire process (41 in total) using a convenience sample of musicians. *Results:* Four average 8Hour Leq readings of 102.5, 106, 104.5 and 102 dB(A) were obtained for the two acoustic gigs that were monitored using the dose meters. For the two rock gigs analysed the average 8Hour Leq figures obtained were greater; 110, 110.5, 116.5, and 106.5 dB(A). All 8Hour Leq figures were over 100 dB(A) and substantially greater than the prescribed legislative safe level of 85 dB(A). Analysis of the questionnaire results found that 80.5% of musicians questioned believe that live music can have an adverse affect on a persons hearing. 46.3% believe that they have impaired hearing/a hearing condition. 39% suffer from some form of tinnitus. 39% know what the prescribed safe noise limit is within a music venue, 61% were either unsure or incorrect. 22% wear some form of ear protection. A strong positive correlation exists between the number of years that the individual has been a musician and the incidence of tinnitus. A positive correlation exists between the length of time that an individual has been a professional musician and those who feel that they have impaired hearing/a hearing condition. A correlation exists between the number of hours of live music a week that the musician usually performs and whether they suffer from tinnitus. 78% of those musicians who wear some form of ear protection are aware of what the safe noise limit is in a music venue. 66% of those individuals who do not wear ear protection are unsure as to what the safe noise limit is in a music venue.

Keywords: Occupational, Noise, Musicians, Exposure, Tinnitus, Hearing, Music.

Introduction

Sound

Sound intensity is measured in decibels (dB); the unit A-weighted dB (dBA) is used to indicate how humans hear a sound. Zero dBA is considered the point at which a person begins to hear sound. A soft whisper at 3 feet equals around 30 dBA, whereas a chainsaw can reach 110 dBA or more at operating distance [Ron Chepesiuk, 2005].

Mark Stephenson, (2005) defines hazardous noise as sound that exceeds the time weighted average of 85 dBA, meaning the average noise exposure measured over a typical eight-hour work day. Other measures and definitions are used for other purposes. For example, “sound exposure level” accounts for variations in sound from moment to moment, while “equivalent sound level” determines the value of a steady sound with the same dBA sound energy as that contained in a time varying sound. [Ron Chepesiuk, 2005].

In terms of acoustics, noise was defined by Miriam C. Daum in 1988 as ‘extra’ sound of greater than usual volume. Often the extra sound is unwanted so activities are often described as being “noisy”. As a result noise can be defined as “unwanted sound” [Miriam C. Daum, 1988]. Daphne Gloag (1980) outlined that precisely what constitutes “annoyance” in response to noise was a problem. The US Environmental Protection Agency based its recommendations specifically on interference with

speech and also on complaints; however Gloag felt that annoyance should be taken to include feelings of "bother," interference with activities, and minor psychosomatic symptoms such as headaches, tiredness, and irritability. However annoyance is defined, there is great individual variation, and clearly it does not depend only on the physical feature of the noise; the nature of the source, the circumstances, and the characteristics and attitude of the individual are all important. Gloag (1980) outlined that preventable or unnecessary noises and those that are meaningful tend to be the most disturbing; while a helpful attitude by those concerned may reduce annoyance.

Occupational Noise

In 2005, Deborah Imel Nelson et al completed a study examining Occupational Noise Induced Hearing Loss. The study concluded that a significant proportion of the disabling hearing difficulties around the world-16%-results from excessive exposure to noise in the workplace. They found the burden to be unevenly distributed among all workers, and heaviest among certain occupations (e.g., production workers) and economic sectors (e.g., manufacturing, mining, and construction). A heavier burden is borne by males as compared to females. The implications of hearing loss from any cause are more serious in the developing world, where services, staff, and awareness are in limited supply [Smith, 2004].

The mechanism of noise induced hearing loss (NIHL) involves the destruction of hair cells in the Organ of Corti within the cochlea of the ear. Chronic exposure to loud noise initially damages the hair cells, which are responsible for high frequency sounds. Over time, continued contact with excessive noise may lead to impaired transmission of both low- and high-frequency sounds to the brain. While the average person is born with approximately 16,000 hair cells, up to 30-50% can be damaged or destroyed before any measurable level of hearing loss is detected [Eileen Daniel 2007]. It is very unfortunate that limited ability to detect the initial stages of NIHL means that when a sufficient number of hair cells are destroyed to be noticeable, the damage has been done. While NIHL is most prevalent among individuals over the age of 65 and the incidence is expected to rise as the population increases, the number of children and young adults with hearing loss is increasing. This appears to be correlated to the increase in the amounts of hazardous levels of noise exposure from infancy through early adulthood [Eileen Daniel, 2007]

The Music Profession

The term music-induced hearing loss is now used for a condition akin to NIHL. Both noise- and music-induced hearing loss are linked to a chronic, extended exposure, and progress at a rate proportionate to exposure conditions [Thais C. Morata, 2007]. Noise is defined as unwanted sound; however music is often quite the opposite.

In a scientific literature review concerning hearing impairment among classical music musicians, Palin (1994) found contradictory evidence on whether exposure to music could give hearing impairment. Palin concluded that the studies performed before 1993 had a low scientific level. Palin's study along with a follow up study carried out by Axelsson et al in 1995, which showed surprisingly that rock musicians had fairly well preserved hearing, show that in the past, some findings seemed to follow a trend whereby hearing problems among musicians being related to playing music is dismissed. It appears that in more recent years, the results and conclusions of similar studies, like that of Hagberg et al (2005) show the opposite.

In 2005, Mats Hagberg et al carried out a study with the aim of determining the incidence of tinnitus, impaired hearing and musculoskeletal disorders among musicians. For the purpose of this research project, the incidence of tinnitus and impaired hearing found in the 2005 study was interesting. Hagberg et al's study examined 655 musicians; the mean age for the men examined was 35, and the women, 34. The main result from the study was that a high amount of practicing hours was a risk factor for the incidence of hearing problems.

Aims and Objectives

In recent years more musicians than ever before have voiced their concern about the noise levels that they are exposed to during live performance [Lockwood, A., H., 2001 & Kähäri, K., R., et al 2001]; in particular guitarist Pete Townshend from band 'The Who', has been a leading figure [BBC News, 2006]. One explanation for this trend could be that the noise levels now during live performances are greater than ever before [Kahari et al 2003 & Chung, J., H., 2004]. Also it could be the case that individuals are now more aware of the dangers of excessive exposure to loud noise [The Wellington Press, 2001].

An increase in awareness may well have been brought about by the publishing of studies like that of Hagberg et al in 2005. On the other hand, speculation may have aroused interest; articles relating musicians to NIHL and tinnitus have been published by the media [The Globe and Mail, 2000]. Similarly, companies that produce ear protection equipment have found it to be in their own interest to ensure that awareness of potential dangers increases [Sensorcom, 2006]. The potential influence of legislative guidance, like that of 'The Noise at Work Regulations 1989,' should also be taken into account as musicians within a working environment will find themselves regulated by Environmental Health Officers for example.

The aim of this study was to determine whether or not delivery of live music poses a significant risk to the hearing of musicians involved and to evaluate current practices that are employed (if any) to protect the hearing of musicians. The study has a number of objectives:

- Using noise monitoring equipment, record sound levels on stage during live musical performance.
- Analyse noise levels monitored using appropriate guidance and compare them with specified 'safe' levels outlined in legislation.
- To use a questionnaire aimed at musicians to evaluate their awareness to the potential dangers of excessive noise levels.
- To gage the attitudes of musicians to the theory behind this study.

Methodology

One aim of the study was to collect live performance data, However the scope and the limited time and resources of the study only allowed the selection of four live performances for analysis. These four live musical performances were analysed using two Brüel & Kjær Noise Dose Meters. Both Noise Dose Meters were calibrated using the Brüel & Kjær sound level calibrator before any readings were taken. The four performances comprised of two Acoustic and two Rock performances. Where possible within each genre of music, different musicians in respect of their instrument

were analysed. Each meter was attached to a musician for a 2-hour live musical performance where their personal noise exposure was assessed. Musicianship etiquette meant that a break was taken in-between each two hour performance and therefore one hour was analysed at a time.

The following individuals were analysed:

- 1st Rock Performance – Guitarist and Drummer
- 2nd Rock Performance – Bass Player and Drummer

- 1st Acoustic Performance – Guitarist and Guitarist
- 2nd Acoustic Performance – Guitarist and Guitarist

Each Dose Meter was attached to the waist of the individual by means of a steel clip, and turned on just before performance. Noise was detected by a robust Half Inch Condenser Microphone clipped to the musician's lapel or collar which transferred the data into the device on the Individuals waist via a cable. At the end of each musical performance, 4 separate readings had been obtained, 2 for each musician, 1 for each hour of their performance.

Using the official Brüel & Kjær Instructions and Applications Booklet the readings obtained for each hour were converted into an 8hour Leq figure. A questionnaire process was completed by all musicians involved in each of the live performances, regardless of whether or not their exposure was analysed with the Dose Meter.

A convenience sample of musicians was used to complete 41 questionnaires. As a result, this was not a random sample. The primary aim of the questionnaire process was to determine the awareness of musicians to the dangerous levels of noise they can be exposed to during live performance.

Empirical studies have repeatedly shown that low response rates are often due to participants being unable to read or follow the questionnaire [Boynton, P., M., & Greenhalgh, T., 2004]. Therefore a short questionnaire was developed with predominantly close ended questions for ease of completion [Griffith, L., E., et al 1999]. The close ended questions were useful for determining the awareness level among the convenience sample; one question determined if the individual knows what the prescribed safe noise limit is within a music venue, and another question determined whether or not the individual wears ear protection.

Data analysis of the questionnaire results was done with SPSS; the Pearson coefficient was calculated to test for correlations and further analysis tested for potential cross tabulations.

Results

The table below show the percentage noise exposure readings for each hour analysed converted into an 8 Hour Leq figure. The average 8 Hour Leq figure for each musician involved in the analysis is also given.

Acoustic Gig Number	Musicians	1st Hour – 8 Hour Leq (dBA)	2nd Hour – 8 Hour Leq (dBA)	Average – 8 Hour Leq (dBA)
1	Guitarist	102	103	102.5
1	Guitarist	104	108	106
2	Guitarist	103	103.5	103.5
2	Guitarist	102	102	102

Rock Gig Number	Musicians	1st Hour – 8 Hour Leq (dBA)	2nd Hour – 8 Hour Leq (dBA)	Average – 8 Hour Leq (dBA)
1	Drummer	109	110	110
1	Guitarist	109.5	110.5	110.5
2	Drummer	115	116.5	116.5
2	Bassist	101	106.5	106.5

Following the questionnaire process, the following results were obtained:

- 80.5% of musicians questioned believe that live music can have an adverse affect on a persons hearing.
- 46.3% of musicians questioned believe that they have impaired hearing/a hearing condition.
- 39% of the musicians involved in the questionnaire process suffer from some form of tinnitus.
- When asked what the noise limit is prescribed as within music venues by legislative guidance, 39% of the musicians questioned knew what the limit is. 61% of the musicians either were unsure, or incorrectly answered when asked what the limit is.
- 22% of musicians questioned wear some form of ear protection.
- A strong positive correlation exists between the number of years that the individual has been a musician and the incidence of tinnitus - the correlation is significant at the 0.05 level (2-tailed).
- A strong negative correlation exists between the number of years that the individual has been a musician and the number of hours a week that they practice - the correlation is significant at the 0.05 level (2-tailed).
- A positive correlation exists between those who feel that they have impaired hearing/a hearing condition and those whose perform in pubs and nightclubs - the correlation is significant at the 0.05 level (2-tailed).
- A positive correlation exists between the length of time that an individual has been a professional musician and those who feel that they have impaired

hearing/a hearing condition - the correlation is significant at the 0.05 level (2-tailed).

- A correlation exists between the number of hours of live music a week that the musician usually performs and whether they suffer from tinnitus - the correlation is significant at the 0.05 level (2-tailed).

- 78% of those musicians who wear some form of ear protection are aware of what the safe noise limit is in a music venue.

- 66% of those individuals who do not wear ear protection are unsure as to what the safe noise limit in a music venue

Discussion

In 2003, Laitinen et al carried out a study of the exposure of opera musicians. It was found that within the orchestra, the highest sound exposure levels were found among percussionists, 95 dBA; flute/piccolo players, 95 dBA; and brass players, 92-94 dBA. Among rock and jazz musicians levels between 91 and 109 dBA were measured in 2003 by Kahari et al. The results of Kahari et al's study also showed that rock/jazz musicians had slightly worse hearing thresholds as compared to classical musicians. Within this present study the sound exposure levels range from 102 and 106 dBA for Acoustic musicians, and between 106.5 and 116.5 dBA for Rock musicians; these figures are considerably higher than those found in the two 2003 studies. Taking into account that the two previous studies were of a much grander scale, and neither found levels as large as in this present study, this appears to suggest that either noise levels during performances are increasing further, or in fact noise within gigs in the venues that were analysed is greater than that found in venues analysed in the previous studies.

The table below outlines the safe exposure time limits for various dB levels. The table shows that for an exposure of 85 dB, guidance outlines that an individual can be exposed for 8 hrs without any harm to their hearing. When comparing the results of the dose meter analysis with the table below, a number of revelations are uncovered. By taking the highest acoustic musicians exposure of 106 dB(A), this is substantially greater than the 85 dB(A) which is deemed safe by legislative guidance. The musician examined obtained an 8 Hour leq figure of 106; this clearly shows that there is a very serious problem in relation to the levels that musicians are exposed to when performing. Using the table below, an exposure of 106 dB has a safe exposure limit of just 4 minutes; this again reiterates how dB(A) increases in a logarithmic scale, and as a result an increase from 85 dB to 106 dB is a very substantial increase.

dB(A)	Safe Exposure Time Limit
85	8 Hrs
88	4 Hrs
91	2 Hrs
94	1 Hrs
97	30 Mins
100	15 Mins
103	8 Mins

106	4 Mins
109	2 Mins
112	1 Mins
115	30 Secs

When assessing hearing disorders, (hearing loss, tinnitus, hyperacusis, distortion, diplacusis), Kahari et al (2003) found that a large number of rock/jazz musicians were shown to suffer from different hearing disorders (74%) a significantly larger proportion among men (79%) than women (63%). Hearing loss (52%), tinnitus (45%) and distortion (19%) were significantly more common among men than in women, and hyperacusis (56%) was the most common among women as compared to men. Most of those affected had troublesome combinations of disorders only 27% of the affected musicians had one discrete hearing disorder [Kahari et al, 2003]. As a result evidence does suggest that it may be possible that hazardous noise levels (above 85 dBA) may be present among musicians. Kahari et al found 45% of their subjects to suffer from tinnitus; this present study obtained a similar figure for incidence of tinnitus, i.e. 39%. Both figures are substantially greater than the estimate of 10% for tinnitus sufferers within the adult population in the U.K (figure from British Tinnitus Association). This clearly suggests that musicians are more susceptible to developing tinnitus than the average individual.

Tinnitus occurs in 10-15% of the general population and in 2% causes a significant impairment of daily life [Axelsson and Ringdahl, 1989; Davis, 1995]. The majority of tinnitus patients have hearing loss [Coles et al, 1981; Axelsson and Ringdahl, 1989; Davis, 1989; Holgers and Barrenas, 1996]. Although there is a clinical need for a classification of tinnitus, its accurate categorisation is difficult. One category entitled ‘Sensations associated with hearing and vestibular functions’ includes sensations of ringing in the ears, irritation in the ears, aural pressure and nausea associated with dizziness and vertigo. Tinnitus is a multi-factorial symptom, which can be induced by all types of hearing loss [KM. Holgers, 2003].

The primary aim of the questionnaire process was to determine the awareness of musicians to the dangerous levels of noise they can be exposed to during live performance. When completing the questionnaire process, an opportunity for informal conversation about the potential dangers of loud music arose. Of the 9 musicians who took part in the rock band analysis, 8 of them have some form of tinnitus. As outlined by Holgers in 2003, there are many different types of tinnitus, and this was evident from conversation with some of the band members during completion of the questionnaires; the keyboard player in the first rock band analysed outlined that he only has the condition in his right ear, and like the bassist in the band, explained that he usually sits with his right ear nearest to the drummer, and felt that this had led to his condition. Both the studies of Axelsson and Ringdahl in 1989 and Davis in 1995 outlined that 2% of the general population’s daily life is impaired, however all 9 sufferers of tinnitus within the bands claimed that their daily lives are very heavily impacted upon. It could be the case that these individuals suffer from a more severe level of tinnitus than the average sufferer, or a combination of different hearing conditions.

The results of the questionnaire found that a strong positive correlation existed between the number of years that the individual has been a professional musician and the incidence of tinnitus, i.e. the longer they have been a musician, it appears the more likely they are to have some for of tinnitus. The relationship between the length of time an individual has been a musician and the development of hearing conditions has been documented in previous studies before [Juman, S., et al, 2004]. In the 2004 study none of the 7 musicians who had played steel instruments for less than 10 years had a hearing loss. Four of 10 (40%) who had played between 10 and 19 years had hearing losses, and 9 of 12 (66%) who had played for more than 20 years had hearing losses.

A study entitled "The risk of tinnitus following occupational noise exposure in workers with hearing loss or normal hearing", and carried out in March of 2008 by Tine Rubak et al found that the risk of tinnitus in workers without hearing handicap was not related to the present noise level, the duration of noise exposure, or the cumulative noise exposure. On the other hand, the risk of tinnitus and associated hearing handicap rose by increasing current noise exposure level and duration of noise exposure. They found a consistent dose dependent association between noise exposure and tinnitus with associated hearing handicap, but no such association when hearing was normal.

With the findings of Rubak (2008) in mind, it may be considered that the one musician, who does not have tinnitus, does not have a hearing handicap. It could also be the case that the individual is more protective of his or hers hearing, however all members of the two rock bands analysed do not wear any form of ear protection at present, so this is unlikely. When examining the questionnaire results, focusing on the development of tinnitus and the number of live hours of music performed each week by the musicians, a correlation was found to exist between the two variables, i.e. the more hours performed each week, the apparent greater chance of the individual having tinnitus. It may be the case that as a result of performing more hours of music per week, this led to some form of hearing handicap, and as a result the susceptibility of the individual to developing tinnitus is greater.

In 2001 a study entitled "Hearing development in classical orchestral musicians" was created by Hellström, P., A., (2001). The report was an evaluation of the hearing of classical musicians, measurements of the efficiency of ear protection for such persons, and observations concerning the temporary threshold shifts (TTS) produced by certain music sound energy output. On exposure to noise, the ears sensitivity will decrease as a measure of protection. This process is referred to as a shift in the threshold of hearing, meaning that only sounds louder than a certain level will be heard. The shift may be temporary, chronic or permanent [Hellström, P., A., et al 2001]. The 2001 study found that males showed a tendency toward slightly worse hearing threshold values than the females. One theory was that male musicians tended to play instruments that produce high sound levels, such as woodwind, brass-wind and percussion instruments whereas the females did not play these instruments.

The drummer that wore a dose meter during the 1st rock performance analysed stated that he has had tinnitus from about the age of 20. It was his view that playing drums had caused the development of his condition. The drummer explained that for a number of years he has played very low key jazz and blues music, just so that his ears are not exposed to what he called "ridiculous" levels during a rock performance. He

also stressed that on many occasions it is the noise from the guitarist on stage that he believes is the cause of ringing in his ears after gigs. This is not surprising, considering that a lot of sound that is produced by a guitar amplifier is actually projected out the back of the amp, i.e. usually in the direction of the drummer. He explained that his tinnitus is at its worst when he is tired, ill, or after performing in a loud band. Perhaps the onset of his symptoms post gig is related to a temporary threshold shift as studied by Hellström (2001). The drummer explained that earplugs inhibit his performance, particularly because as a drummer timing is essential and he relies on his hearing. Although he did mention that he has worn earplugs before during a performance and he felt energised after the gig.

All 43 subjects examined by Reddel (1972) reported tinnitus following rehearsal and performances of their musical groups. 10 subjects said that they had chronic hearing difficulty, 8 were uncertain, and the remaining 25 reported no subjective hearing loss. Within this current study a strong negative correlation was found to exist between the numbers of years that the individual has been a professional musician, and the number of hours per week that they practice, i.e. the longer they have been a musician, the less hours they practice per week. This is something that one would expect to find, however it may be suggested that development of tinnitus post practice, even if only temporary, could be a catalyst to the decline in the number of hours each musician spends rehearsing as they get older. Reddell (1972) reported that only six of his subjects had had previous experience with ear protectors, and although his study was completed almost 40 years ago, the results of this present day study state a similar bleak result; 9 out of the 41 subjects questioned wore ear protection.

The bass player of the first rock band that was analysed using the dose meters mentioned that he has in the past been involved in three gigs per day. One day in particular, he found himself positioned to the very close to the drum kit in all three of the gigs. Due to habit he usually positions himself to the left (his right) of the stage, and this means that his left ear is always closest to the drum kit. Following the three gigs he explained that he experienced a ringing in his ears and a general discomfort that lasted about one week. He did not perform music for a couple of weeks. When asked about earplugs, he explained that he has used them in the past, but he feels that they lessen the live experience. He also stressed that his performance was inhibited as he could not hear himself or his band members playing clearly enough. He was aware of the availability of custom made earplugs, but as of yet he has not purchased them, stating that the cost was an issue.

80.5% of musicians questioned believe that live music can have an adverse affect on a persons hearing. However only 22% of the same number of musicians wear some form of ear protection. One would assume that when such a great percentage of individuals feel that playing live music can damage their hearing, surely a greater number of them would wear ear protection. The negative attitude of the bassist in the first rock band towards ear protectors may be the reason for this result. A study in 2007 had the aim of investigating the acceptance of hearing protection aids in members of an instrumental and voice music band. The results of the study found that 56.2% reported not liking hearing protection, and like this present study a high percentage of those questioned stated that music might cause hearing impairment; 77.1% [Mendes, M., H., et al 2007]. Mendes and her peers concluded that although most subjects seemed aware of the risk, few took preventive measures against hearing

loss. One of the recommendations of the 2007 study suggested the need for educational campaigns aimed at musicians. Another study found that musicians as a group were more inclined to use hearing protection when attending concerts and discotheques [Olsen-Widén, S.E., & Erlandsson, S.I., 2004]. The study theorised that musicians, as a group, are dependent on maintaining good hearing to be able to work professionally, and as a result are more likely to wear protection when attending a gig

In this study, 39% of the musicians know what the legislative noise limit within their respective venues; this may be considered to be low. On the other hand, 78% of those musicians who wear some form of ear protection are aware of what the safe noise limit is. This clearly shows that when awareness of the individual is better, there is a greater chance that they will wear earplugs. This link shows the importance of raising awareness, as it should in turn lead to an increase in the number of musicians wearing some form of ear protection. Social differences, both in attitudes towards noise and in health preventive behaviours, i.e. the use of hearing protection in musical settings, have been identified [Widén, S.E., et al 2006]. In the long run, these differences may cause similar inequalities in actual health.

Three of the four members of a heavy metal band (ManOWar), which is billed as the loudest rock music band in the world had pre and post-concert audiograms undertaken using a portable Audiometer with noise excluding headset. The tests were performed after the pre-concert sound checks and after the hall had emptied following the concert which was approximately an hour and a half in duration. None of the band had ear symptoms except for a feeling of blockage and tinnitus temporarily following a concert which usually disappeared by the next morning. The pre-concert audiograms for the three people without a history of ear problems had a 6 kHz dip; suggestive of early noise damage. It was concluded that there is a small but definite risk of developing noise damage with sensorineural hearing loss and tinnitus in rock musicians especially when the music is played loudly as in heavy metal bands that rely on excessive amplification, particularly at low frequencies [Drake-Lee, A., B., 1992]. In this present study pre and post-gig audiograms were not undertaken; however a feeling of general discomfort and heightened tinnitus temporarily after performances was mentioned by the drummer in the first rock band. The 6 kHz dip; suggestive of early noise damage, found by Drake-Lee, may well have been found had the tests been included in this present study.

Pitch is that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high, such as a musical scale. Pitch is primarily dependant on stimulus. In 2004 Mari Tervaniemi et al examined pitch discrimination accuracy in musicians vs. non-musicians. Thirteen professional musicians and 13 non-musicians were presented with frequent standard sounds and rare deviant sounds (0.8, 2, or 4% higher in frequency). Musicians detected the pitch changes faster and more accurately than in non-musicians. Interestingly, the superiority in pitch discrimination accuracy in musicians over non-musicians was observed not only with the o.8% but also with the 2% frequency changes [Mari Tervaniemi, 2004]. Pitch discrimination is something that is vital to a musician for effective performance; particularly classical musicians such as violinists. If a violinist was to incur some form of NIHL, their acquired skill of pitch discrimination could be severely affected. A loss in pitch discrimination appears to be what the bass player in the first rock band was explaining when he outlined that he finds it difficult to wear ear protection and perform live.

Wearing earplugs will mean that the over all level of noise you are exposed to is reduced, however it will also mean that certain pitches of sound, that may even have been difficult to hear without earplugs, will now be unheard. As a result performance is inhibited as the musician may struggle to stay in time for example.

The singer in the first rock band outlined that some musicians he performs with have lost certain ranges of sound in their hearing. Using words ‘base’, ‘middle’ and ‘top,’ he spoke of the different pitches within music in his own words. These three terms are used for describing the tone of a guitar sound for example. Within a CD player like that found in a car, the base, middle and top can be altered for the listeners own preference. He explained to me that two drummers he has played with both have the ‘top-end’ range within their CD players up to the maximum, as they cannot hear this range as clearly as the middle and base. The singers explained that he does not feel the songs sound as they should, and are almost un-listenable. This is perhaps an indication that his ability to hear top-end sound is better. Another drummer that the singer performs with always has the volume up to the maximum level in his car radio, as he simply cannot hear the music. These are examples of the impact that apparent music induced hearing loss has on a sufferer’s life.

Recent research has shown the essential role of reduced blood flow and free radical formation in the cochlea in NIHL. The amount, distribution, and time course of free radical formation have been defined, including a clinically significant late formation 7-10 days following noise exposure, and one mechanism underlying noise-induced reduction in cochlear blood flow has finally been identified. These new insights have led to the formulation of new hypotheses regarding the molecular mechanisms of NIHL; and, from these interventions that prevent NIHL have been identified, even with treatment onset delayed up to 3 days post-noise. Finding safe and effective interventions that attenuate NIHL will provide a compelling scientific rationale to justify human trials to eliminate this single major cause of acquired hearing loss [Colleen G. Le Prell et al, 2006]. This research does mean that there is some hope for those 46.3% of musicians in this study who feel that they incurred hearing loss or developed a hearing condition.

While multiple factors contribute to the occurrence of occupational NIHL, lack of prevention is the major contributor. Most occupational noise exposure can be minimised by the use of engineering controls to reduce the generation of noise at its source. Complete hearing loss prevention programs that include noise assessments, noise controls, audiometric monitoring of workers’ hearing, appropriate use of hearing protectors, worker education, record keeping, and program evaluation are needed to effectively reduce the global burden of occupational NIHL. [Deborah Imel Nelson et al 2005]. The apparent growing burden of Music induced hearing loss is something that like NIHL can be prevented with the use of ear protection, however within this study it was found that only 9 of the 41 musicians who completed a questionnaire wore ear protection, and 66% of these individuals are not aware of the what the safe noise limit is within their respective venues that they perform in.

An example of how recent growing concern for the health of musicians leading to the measurement of noise levels during a performance is that of the New Zealand Symphony Orchestra (NZSO) in September 2001. This was the first time that extensive tests had been carried out with the orchestra, which involved more than

simply measuring noise levels. Ways to reduce risks included placing screens behind some musicians to see if this made a difference to the noise levels they were exposed to. A British report published a month previously to the tests had urged musicians to wear ear plugs or risk hearing damage. Of the NZSO's 86 musicians, 67 intermittently used earplugs during loud passages and five regularly used earplugs [The Wellington Press, 2001]. 78% of musicians within the orchestra use earplugs during loud passages and 6% use earplugs regularly. When these results are compared to the findings of this current study on rock and acoustic musicians, a number of assumptions can be made. The questionnaire process found that 22% of musicians regularly wear earplugs, which is a substantial greater figure than the 6% found within the orchestra. However 78% of the orchestra wear earplugs during the loudest passages of music, this precautionary step may ensure the safety of their hearing. It may be the case that the noise level for the majority of the orchestral performance is lower than 90 dB, and as a result using ear plugs during what is the loudest passages would in some way be an effective precautionary approach.

Pianist Linda Lee Thomas with the Vancouver Symphony Orchestra estimates that 70 percent of her colleagues wear earplugs, a phenomenon that has been on the rise for the last decade. Concerned with certain statistics that show 52% of classical musicians experience permanent hearing loss as compared with 30% of rock musicians, most symphonies now provide generic earplugs, gratis. It is possible that rock musicians simply took steps earlier on to protect their hearing, while classical musicians simply have assumed that they were not as much at risk [The Globe and Mail, 2000]. Within this study, the results show that there is very little evidence to suggest that rock musicians are taking steps earlier on in their careers to protect their hearing; not one member of the two bands analysed using the dose meters wear any form of ear protection.

During the second rock gig, an alarming scene was observed. The drummer during one of the closing, and clearly loudest songs of the night, had one finger in his ear, and played the drum kit with one hand. He explained after the gig that it was the noise being produced from the back of the guitarist's amplifier that was his reason for doing so. This drummer is the musician who was exposed to the greatest noise of all those analysed in the study, i.e. an 8 Hour Leq average of 116 dB(A). A number of times during the gig he asked the guitarist to turn down the amp, but due to the noise of the crowd in the venue the guitarist felt he was forced to turn up his amp to maintain the overall sound of the performance. Within this band it appears that the guitarist is of the belief that maintaining the quality of the overall sound being produced by the band is more important than preserving the condition of his colleagues hearing; a clear sign that lack of communication and clashes of attitudes is a problem within some bands.

Some disturbing consequences of loud noise, including increased aggression, have been found in experiments on social and interpersonal reactions. The response is to the dominant features, to the neglect of the complexities of personal interaction. One study suggested a reduced tolerance of differences among those who were normally tolerant; while another experiment suggested that people became less likely to help others in noisy conditions, possible owing to reduced "peripheral" awareness. There is good evidence of annoyance sufficient to affect wellbeing [Daphne Gloag 1980]. Two of the rock musicians that took part in the study mentioned that they at times find themselves moody and argumentative as a result of their tinnitus.

This second rock band had the loudest noise on stage out of all the gigs that were analysed. The average number of years as professional musicians was a lot greater in the second rock band and when questioned, all members suffered from some form of tinnitus. One member of the band, although deaf in one ear, and with tinnitus in the other ear, he maintained that his hearing problems had nothing to do with performing music on stage. Instead, he explained that he obtained his condition hereditarily. This could be the case, however when exposed to noise levels like that found to exist during the gig analysed, it is more than likely that damage has and is being done to this mans hearing by loud noise on stage. The fact that he questioned the feasibility of the study may also explain the reasoning for his beliefs.

Unlike many other occupational exposures, excessive noise is commonly encountered in non-occupational settings. A variety of recreational activities including listening to music via headphones can cause the same type of injury experienced by workers in excessively noisy working conditions [John J. May, 2000]. The results of this study show that musicians appear to be exposed to dangerous noise levels during their performances, (not one of the 8Hour Leq readings was below 100 dB(A)), however one must take into account that these individuals may be exposed to various non-occupational sources of excessive noise during the remainder of their day; like noise from a car radio for example. Noise exposure is on the increase, especially in the general living environment [Passchier-Vermeer, W., & Passchier, W., F., 2000]. With this in mind, and the likelihood of excessive noise during rehearsals, it must be considered that their total exposure over a full day could potentially be even more harmful.

Within many music venues there is a 'noise limiter' in place. These are fitted to the sound system and can cut the power supply to the plugs around the stage if a pre-set level is breached; this is usually around 90dB. On the other hand, they can automatically reduce the volume being produced by the band at discrete steps [Health and Safety Executive 2007]. Perhaps the revelations of the singer and rhythm guitarist in the 1st rock band analysed are the most intriguing. He explained that in every venue he has ever played in where a noise limiter is in place, the band has been forced to "by-pass" the limiter. This is easily done, by simply running a lead from the stage to obtain power from a socket in behind the bar for example. He explained that all musicians that he has ever performed with are aware of how to by-pass the limiter. It appears that this practice is common knowledge among the profession and almost a formality before each performance. This strongly suggests that there is a very serious problem present within the music profession; one that needs to be addressed for the sake of the health of musicians.

Limitations

41 completed questionnaires formed the basis of the statistical analysis. This is a relatively small number; and as mentioned previously the scope and the limited time and resources of the study only allowed the completion of 41. In theory; the greater the sample, the more reliable the results of a questionnaire process are. Therefore it may be considered that had the sample been greater, not only would there have been more data to analyse, with possible very different conclusions, the results would have been more reliable.

The questionnaire was created with the aim of determining whether or not musicians were aware of the dangers that they can be potentially exposed to during live performance. This included determining whether or not the individual 'felt' they had reduced hearing/a hearing condition. It may be the case that some of the musicians who felt they have reduced hearing or a hearing condition do not actually, however they were considered to have for the purpose of the data analysis. Ideally analysis would have been carried out to test the hearing of each individual. This could have been done before and after each gig, examining potential temporary threshold shifts, like testing completed by A B Drake-Lee in 1992. Having this further analysis of the individuals involved in the questionnaire process, combined with the dose meter analysis, it would have meant that the results of the study would have been much stronger.

Only four gigs were analysed, and with only two dose meters. In the two rock gigs analysed, there was a total of nine musicians involved in the whole performance, but due to only two dose meters being available for the analysis, the noise exposure of only four musicians was obtained. Ideally, the individual noise exposure of all musicians involved in all of the performances should have been obtained. This would have strengthened the results of the study, and possibly provided more evidence for the arguments and conclusions.

In previous studies like that of Laitinen et al in 2003, the exposure of classical musicians formed the basis of the results. Although analysis of classical musicians was initially intended for this study, it proved very difficult to include the genre for analysis. It was the initial intention to include classical musicians but the musicians contacted refused to take part in the study. The range of instruments included in an orchestra from the brass section, to strings and woodwind could have made for a very interesting part of the study. Again, similarly to the small number of gigs analysed, not including classical musicians in the dose meter analysis does mean that the study is somewhat lacking. This lacking is in some way made up for by the inclusion of classical musicians in the questionnaire process; however any potential statistical revelations in relation to musicians from this particular genre of music could not be compared with the findings of the dose meters.

Conclusion

The first aim of this study was to determine whether or not delivery of live music poses a significant risk to the hearing of musicians involved. The results of the dose meter analysis suggest that there is noise levels present during live performances that pose a significant risk to the hearing of the musicians. The second aim of the study was to evaluate current practices that are employed (if any) to protect the hearing of musicians. Less than a quarter of individuals involved in the questionnaire process wear some form of ear protection. Attitudes towards the use of ear protection were found to be negative among some members of the rock bands analysed. This does suggest that either ear plugs are an ineffective form of protection, or that the attitude of some musicians need to be examined.

Although only 4 gigs were analysed, the findings are alarming. Further research is needed and more steps taken to ensure the health protection of professional musicians. Improving safety measures in place should start with a review of the 'Noise limiter' concept currently employed; a system which has been shown to be open to abuse.

Improving awareness will almost certainly be a greater challenge; considering that two thirds of musicians questioned who do not wear ear protection are unaware as to what the safe limit for noise exposure is. An interrelated problem is the fact that individuals have a limited ability to detect the initial stages of noise induced hearing loss, and when symptoms become noticeable the damage has already been done, and the effects are irreversible.

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