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Noise-Induced Hearing Loss as a Growing Threat to Society

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NOISE-INDUCED HEARING LOSS AS A GROWING THREAT TO SOCIETY: AN EXPLORATION OF THE DAMAGING EFFECTS OF IPODS AND CONCERTS ON AUDITORY FUNCTION

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ABSTRACT

The purpose of this paper is to determine the exact dangers of leisure music to society, as peoples' hearing can be negatively impacted by excessive exposure to music, in terms of both duration and sound (dB) level. Two types of studies are analyzed. One study analyzes the effects of concert and disco style music on musicians and party guests, primarily through experiments which test pure-tone audiometry, distortion product otoacoustic emissions (DPOAE), and general sound levels of people and places before, during, and after exposure. Another study analyzes the effects of personal listening devices (PLDs) on the population, mainly through studies, questionnaires, hearing tests, and experiments. The results of many studies show that, due to the popularity of personal listening devices, people are listening to more music, more often, in more places, and at higher dB levels than ever before. The results determine that whereas both PLDs and concerts are harmful to society, PLDs pose a greater threat to users' auditory functions.

INTRODUCTION

In America today, over 27 million people suffer from moderate levels of hearing loss, and the numbers are steadily increasing (Daniel 2007; Matusitz and McCormick 2010). About half of these people lose a portion of their hearing due to exposure to loud noise for just a short period of time (Daniel 2007). Many are school-age children and young adults who voluntarily expose themselves to increasingly loud music over time (Matusitz and McCormick 2010). Adults have begun to lose their hearing at earlier ages than ever before, and more young children and teenagers have begun to suffer from hearing loss than in years past. The National Institute for Occupational Safety and Health (NIOSH) has found that 30 million Americans are exposed daily to unsafe levels of noise, and that one out of every eight children shows symptoms of hearing loss (Daniel 2007).

How loud is loud noise? The National Institute for Occupational Safety and Health states that exposure to sound levels above 85 dB over the course of an eight-hour work day is considered hazardous to one's hearing because it can cause damage to hair cells or actually cause temporary hearing loss. Although it is well known that prolonged exposure to loud noise will likely cause damage to one's hearing, studies have shown that even brief exposure to noise levels above 85 dB can potentially damage the hearing (Daniel 2007; Matusitz and McCormick 2010). In this paper, sound volume and length of exposure are highlighted because they are the two exposure factors over which individuals have the most control.

The most common form of hearing loss is noise-induced hearing loss (NIHL). What exactly is noise-induced hearing loss, and how does it occur? In the cochlea, a section of the inner ear, there is a region called the Organ of Corti which contains inner and outer hair cells embedded in a sensory epithelial layer of tissue. The Organ of Corti is situated on top of the basilar membrane which is stiff and wide in some areas and the opposite in others. Sound waves vibrate the basilar membrane; low frequencies vibrate the apical section, and high frequencies vibrate the basal section. The inner hair cells of the cochlea normally transmit the vibrations from the ear to the brain via transduction, which causes an impulse to go from the eighth cranial nerve in the inner ear to the cerebral cortex. The outer hair cells (OHCs) "boost the stimulus by

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electromechanical feedback… it increases both the amplitude and frequency selectivity of basilar-membrane vibrations for low-level sounds" (Mahendrasingam et al. 2010). For this reason, the outer-hair-cell region is also known as the cochlear amplifier and, as such, is extremely important in the discussion of hearing loss. When a person is exposed to extremely loud noise, the hair cells that detect high-frequency noise are damaged (Daniel 2007).

There are two different ways that noise can damage hair cells of the inner ear. The first is when the ear is exposed to noise louder than 140 dB for a short amount of time (for example, an explosion or a bang). The force of the sound's energy can cause such a strong vibration that the Organ of Corti can completely detach itself from the basilar membrane, causing immediate permanent hearing loss. The second way in which the Organ of Corti can be damaged by sound is through high intensity noise (85 dB and above) that the ear is exposed to over a longer period of time. Through prolonged exposure, the stereocilia of outer hair cells can gradually be destroyed, and the mechanical functions of the hair cells can be damaged. This second kind of exposure can, eventually, also lead to inner hair cell damage, causing permanent hearing loss as well (Zhao et al. 2010) (See Figure 1). Noise-induced hearing loss that damages hair cells in the cochlea is irreversible, and even a hearing aid cannot restore that aspect of hearing, because the damaged or destroyed hair cells can no longer transmit sound signals from the inner ear to the brain (Daniel 2007). In addition, a secondary result of sensory cell destruction is the destruction of spiral ganglion cells. Spiral ganglion cells play a key role in the best treatment for hearing loss that is available right now, namely, cochlear implants. Cochlear implants operate by stimulating the spiral ganglion cells of the cochlea. Thus, with the loss of spiral ganglion cells, noise-induced hearing loss can leave lasting and permanent damage to the ear (Watanabe et al. 2010).

Studies suggest that with longer exposure to loud noise, more hair cells are damaged. An incredible observation from scientists has shown that 30-50 % of all hair cells can be destroyed before any degree of hearing loss is even discovered (Daniel 2007; Matusitz and McCormick 2010). For this reason alone, prevention is the most important way to avoid hearing loss.

Since there are noise limit regulations for the workplace, the most common source of NIHL is not due to unsafe work environments but, rather, to recreational sources of noise. There are currently no clear guidelines for the noise levels deemed safe in recreational environments. The main sources of recreational loud noise are amplified music from discos and portable music players. These can cause either temporary or permanent threshold shifts (TTS/ PTS), depending on the intensity of the music and on the duration of exposure to the music. A temporary threshold shift generally lasts for up to two days and then goes away due to "regeneration mechanisms of the inner ear" (Muller et al. 2010). A permanent threshold shift occurs over a longer period of time and

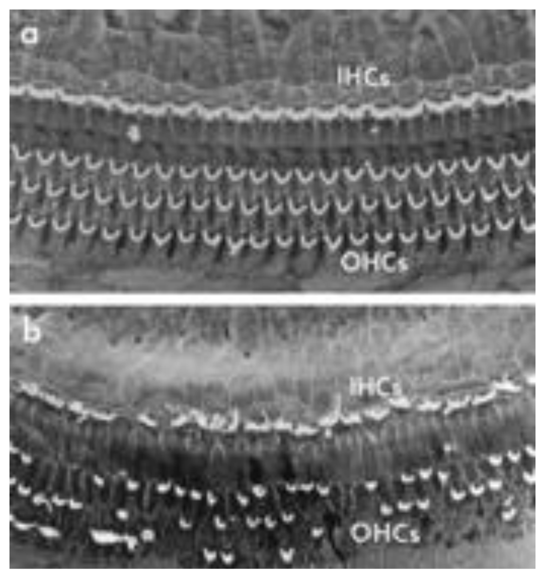

Figure 1: Scanning electron micrographs of the (a) normal and (b) damaged cochlear sensory epithelium. In the normal cochlea, the stereocilia of a single row of inner hair cells and three rows of outer hair cells are present in an orderly array. In the damaged cochlea, hair cells are missing, and stereocilia are abnormal, leading to hearing loss. Source: Ryan 2000

is gradual because it is caused by irreversible outer hair cell damage in the cochlea (Muller et al. 2010). Ringing ears and temporary hearing loss are warnings that if unhealthy noise exposure continues, NIHL may occur (Loftis 2007).

Listening to personal listening devices such as iPods and mp3 players has become one of the most common forms of leisure that exposes people to extremely loud music. Recent studies have shown that the most popular PLDs have the capacity to reach a sound output level of over 100 dB. The sound level is further increased if the recording is at a louder than average dB level to begin with. Those who listen to their PLDs at maximum capacity for just 3-12 minutes exceed safety limits and put themselves at risk for permanent noise-induced hearing loss (McNeill et al. 2010).

This paper considers the impact of excessive duration and volume (dB) of the music that one listens to, in order to determine which source of leisure music—live music at social events or PLDs—is most harmful to society. The desired result is to educate readers when to take extra precautionary measures to protect their hearing.

Dangers of Social Events to the Ear

One category of excessive leisurely noise that poses a large threat to peoples' hearing is social events. This category includes weddings, concerts, and discos. There is a twofold problem that arises regarding social events. The first problem is that the noise levels are generally controlled by musicians and DJs who themselves are often victims of NIHL. In fact, many musicians who perform in rock or jazz bands have been shown to display either one or a number of the most commonly tested for hearing disorders among musicians, namely, tinnitus, hyperacusis, distortion, diplacusis, and temporary threshold shift (Kahari et al. 2003). Due to their difficulty hearing, musicians tend to play the music very loud, exposing their audiences to unsafe sound levels above 85 dB, putting them at risk of NIHL even with short exposure (Santos et al. 2007). Indeed, as has been documented, "Recently there has been rising concern about the prevalence of NIHL caused by excessively amplified sound activities in leisure settings" (El Dib et al. 2008). Studies focusing on musicians at nightclubs and rock bands found that, in many cases, the non-musicians such as bar tenders, waitresses, DJs, and doormen were all exposed to sound levels above 85 dB (Santos et al. 2007).

The second problem tied to social events is that today's generation has grown accustomed to louder volumes of music, and, as such, the younger members of the audience at social events demand louder sound levels from the bands. As a result, the bands and DJs play music at higher dB levels to please their audiences, leading to increased exposure to louder music for more members of the population. Thus, more people are at risk for developing NIHL by attending loud concerts and other social events that feature loud music (Levey et al. 2011).

Dangers of Personal Listening Devices to the Ear

A second category of excessive leisurely noise that poses a serious threat to peoples' hearing is personal listening devices. This category includes iPods and mp3s. Many members of the younger population are listening to PLDs at higher volumes, for longer periods of time, on headphones that send noise directly through the outer ear canal to the eardrum (Levey et al. 2011). Even noise that is at a safe dB level in a free field may not be safe when listened to through in-the-ear headphones because the volume increases in the ear canal due to resonance (Henry and Foots 2012). Increased volume in the ear canal poses greater danger to one's hearing because the noise causes stronger vibrations of the eardrum, leading to excessive movement of the outer hair cells, inner hair cells, and stereocilia. The excessive movement can, in turn, damage them.

Teenagers specifically tend to listen to their PLDs at higher intensities than other members of the population. Many do not realize the extent to which they are endangering their hearing (Levey et al. 2011). In fact, according to one study, since PLDs today can reach a maximum volume of well over 100 dB, close to the sound intensity of a chain saw, the noise emitted by a PLD today is powerful enough to damage the listener's hearing in just five minutes (Matusitz and McCormick 2010). A study done in 2009 found that adolescents who frequently listen to mp3 players are four times more likely to raise the volume and listen to louder music than infrequent listeners (Kahari et al. 2011). As such, the growing danger of noise-induced hearing loss due to PLDs is indeed a true threat to the hearing of today's society as PLD use becomes more and more frequent. In addition, many PLD users tend to listen to their music in settings where there is outside noise interference, such as on the street, subway, and bus. There are reports suggesting that when outside noise increases to 72 dB, the average PLD user raises the device sound level from 69 dB to 85 dB on average. While 85 dB is still not too extreme, due to the current popularity of the Apple iPod, which is conveniently small and contains a large amount of memory and long battery life, people are taking more risks with respect to their hearing by exposing themselves to prolonged periods of 85 dB sounds. This suggests a greater risk of NIHL occurrence in today's population (Levey et al. 2011). PLDs can be particularly dangerous for yet another reason. Being that they are primarily used for private activities in which only the listener is aware of and in control of the sound level, there is little room for third parties, such as teachers and parents, to gauge the amount of noise exposure to which children are exposing themselves (Matusitz and McCormick 2010).

TYPES OF HEARING LOSS

There are several types of hearing loss. This paper, however, focuses on sensorineural hearing loss (SNHL) in particular. Sensorineural hearing loss occurs when the inner ear or auditory nerve is not functioning properly and sound is not being processed as it should be. One of the main causes of sensorineural hearing loss is excessively loud noise. Sensorineural hearing loss that is caused by loud noise is called noise-induced hearing loss.

Other auditory defects that generally come along with NIHL are hyperacusis, diplacusis, tinnitus, and distortion. Hyperacusis is described as hypersensitivity to general sound, which is normally an innoxious stimulus. It occurs when sound that is normally considered of average level suddenly becomes too loud for a person to handle. Diplacusis occurs when one has problems with pitch perception. Tinnitus occurs when one hears buzzing or ringing in the ears, particularly when there is no outside stimulus producing any noise. Distortion occurs when one hears harmonies, frequencies, or other tones as fuzzy, out of tune, unclear, and not in the correct form that the sound was produced (Kahari et al. 2003).

METHODS USED TO MEASURE HEARING LOSS

Hearing loss can be measured in a variety of ways. Different methods target specific sections of the ear, discerning between the effects of differing sounds on various parts of the ear. In the studies analyzed below, the procedures most generally used were pure-tone audiometry, distortion product otoacoustic emissions (DPOAE) testing, and questionnaires. Pure-tone audiometry measures overall hearing loss by determining the lowest tone that is still audible to a person, otherwise known as the pure-tone threshold. Distortion product otoacoustic emissions, which is a type of otoacoustic emissions (OAE) testing, detects the status of the cochlea, measuring the extent of damage to outer hair cells. Because outer hair cells play a large role in auditory functions, when they are damaged, hearing loss occurs. Otoacoustic emissions testing, therefore, is most helpful in measuring NIHL because the outer hair cells are the most vulnerable part of the ear when it comes to loud noise exposure. Otoacoustic emissions are thought to emerge from the ear due to transduction of healthy outer hair cells. Thus, the less otoacoustic emissions that emerge after a given stimulus, the greater the indication that outer hair cell damage has occurred (Muller et al. 2010; Bhagat and Davis 2008).

PURE-TONE THRESHOLD AND OTOACOUSTIC EMISSION MEASUREMENTS AT SOCIAL EVENTS

An experiment was conducted to study the effects of three hours of loud disco music on the audience's hearing, particularly on their pure-tone threshold and on their distortion product otoacoustic emissions. A pure-tone threshold is the lowest audible sound that one can hear, and a distortion product otoacoustic emission is emitted from the ear in response to two tones of one frequency and one sound pressure that are presented into the outer ear canal. Pure-tone threshold testing, as previously explained, measures overall hearing loss, and distortion product otoacoustic emission testing measures the amount of functioning outer hair cells in the cochlea.

In this particular experiment, 15 subjects with a mean age of 25, who were all healthy and had normal hearing levels, were exposed to disco style music of about 104 dB for three hours. Pure-tone threshold and distortion product otoacoustic emission measurements were taken both before and after exposure to the disco music. The stimuli for both measurements were administered and recorded via ear probes and a digital signal processing card. Pure-tone noises were calibrated using in-the-ear simulators. For pure-tone threshold measurements, the stimuli ranged in frequency from 3469 Hz to 4500 Hz, steadily increasing in increments of 47 Hz. This range was used because human hearing is the most sensitive to noises around 4000 Hz. Beginning with 40 dB level noise, the subject was exposed to a pure tone and instructed to press down on a PC mouse until the sound could no longer be heard. The dB level was decreased in increments of 2 dB at a time until an average was reached at which the subject ceased to press down on the PC mouse. The dB level at this point was determined to be the subject's pure-tone threshold. For distortion product otoacoustic emission measurements, the frequency range of the stimuli was similar to the range used in the pure-tone threshold measurements, and the distortion product otoacoustic emissions were detected using ear probe microphones.

Measurements were taken immediately before, immediately after, and one day after exposure to loud music. Pure-tone thresholds shifted dramatically immediately after disco exposure by approximately 8-14 dB. Individually, there was a wide range of deterioration from 0 to 26 dB. After one day, many subjects significantly recovered; however, they did not recover completely. There was an overall deterioration of about 4 dB (max= 9 dB) among all participants in the experiment. All of the participants in the study displayed diminished distortion product otoacoustic emission levels, which recovered somewhat after the first day post-exposure. However, none of the participants recovered completely (Muller et al. 2010) (See Figure 2).

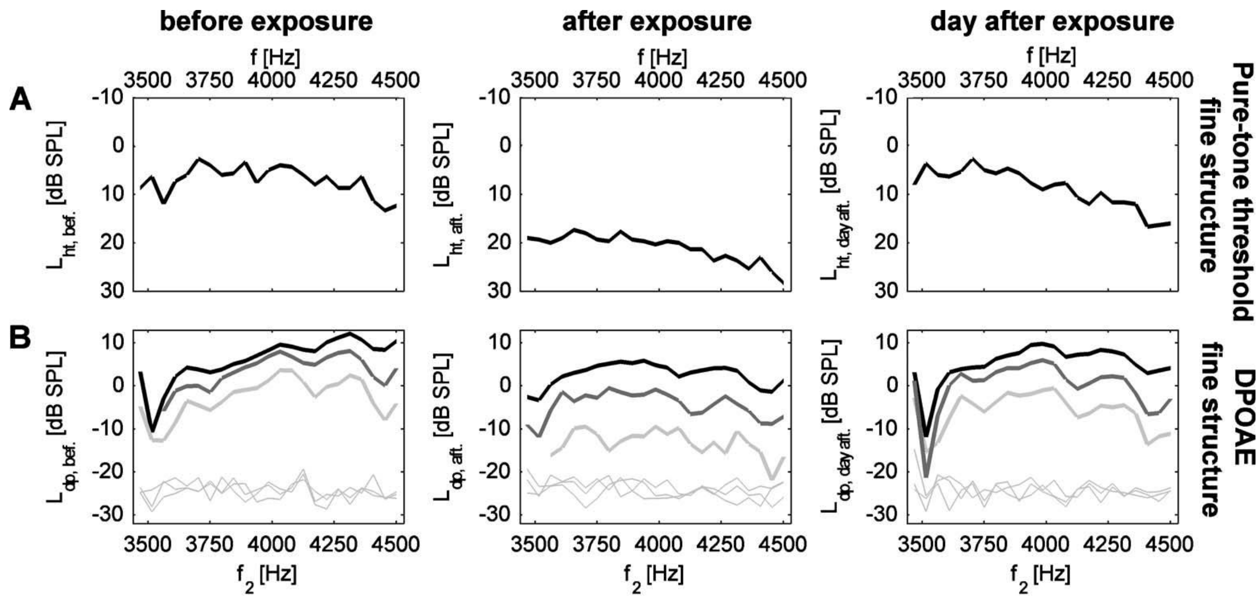

Figure 2: (A) Pure-tone threshold fine structure data taken before (left panel), immediately after (middle panel), and the day after (right panel) discotheque attendance. (B) DPOAE fine structure data for L=40, 30, and 20 dB (from top to bottom). Light gray lines show the particular noise floor; the noise floor is the level of background noise generated by the measuring tools. Source: Muller et al. 2010

Overall, three hours of exposure to music averaging 102 dB caused a clear deterioration in pure-tone thresholds and in distortion product otoacoustic emission levels of the participants. In addition, the decreased distortion product otoacoustic emission levels indicated an increase in distortion product otoacoustic emission threshold, showing that the outer hair cells (i.e. the cochlear amplifier) suffered a loss of sensitivity, particularly at low tone levels. If after only three hours of exposure to 102 dB, outer hair cells and overall hearing capability were clearly impacted, one can infer how much more so would hearing and outer hair cell function be affected by repeated exposure to these high noise levels (Muller et al. 2010).

Another experiment was conducted in Sweden to ascertain the extent of NIHL that rock and jazz musicians suffer from due to their constant environment. This experiment was of particular importance because at social events, such as weddings and discos, the musicians and DJs are generally in charge of the music sound level. If the musicians suffer from NIHL, they may turn up the volume on the amplifiers to their instruments, and this would put all of the party guests at great risk for developing temporary threshold shift or even permanent threshold shift and NIHL due to the excessively loud music.

The participants in this experiment were all musicians who were over the age of 25, had at least five years of experience working in the music industry (i.e. they were exposed to the sound from their instruments directly, not through headphones), and had no preexisting hearing disorders other than possible NIHL due to their daily occupational music exposure. In total, 139 musicians participated. First, pure-tone audiometry was conducted using a calibrated audiometer and headphones, in a soundproof booth. Participants were tested at least eight hours after their last exposure to music in order to avoid temporary threshold shift that would interfere with the data. Next, all participants filled out a questionnaire to determine the presence of any other hearing disorders such as hyperacusis, diplacusis, tinnitus, and distortion. Based on the results of the questionnaire, the musicians were divided into groups of those with no hearing disorders, those with one hearing disorder, and those with two or more hearing disorders.

According to the information collected from the questionnaires, most of the musicians played for four days a week and five hours a day, all in amplified sound environments where music levels exceeded safety limits. The pure-tone audiograms showed that, overall, the female musicians had lower (i.e. better) hearing thresholds than the males. Interestingly, all the musicians who had five different hearing disorders (five being the most) played the drums, with some also playing the saxophone, both of which are very loud instruments. Some had even worn customized protective earplugs during performances. The results of the testing showed that 74% of the 139 musicians displayed affected hearing due to their excessive music exposure, a frightening statistic. However, it is also interesting to note that the sound levels measured in the listeners' positions were only above safety levels 50% of the time (Kahari et al. 2003). That being said, the listeners are apparently at a slightly lower risk than the musicians to develop NIHL

A cross-sectional study similar to the previous experiment was conducted on 177 Brazilian participants in 2007 to determine the prevalence of high-frequency hearing loss due to noise overexposure (i.e. NIHL) among sound technicians as compared to the rest of the members of the population. Non- sound technicians who were exposed regularly to high sound levels due to their occupations were excluded from the study. Of the participants, 50% were sound technicians and 50% were non-sound technicians. All participants filled out questionnaires regarding their specific exposure to music. They had their ear canals inspected and had hearing tests administered via audiometers. The results of the study showed that 50% of the sound technicians had high-frequency hearing loss and only 10.5% of the non-sound technicians displayed signs of high-frequency hearing loss (El Dib et al. 2008)

In the above three studies, the effects of excessively loud music exposure on the hearing of both musician and listener were analyzed and tested. The conclusions gathered from the studies will be discussed below

Pure-Tone Threshold and Otoacoustic Emissions Measurements and Questionnaires From PLD Users

In 2007, a study was conducted to determine the effects of 30 minutes of exposure to PLD noise that is at the maximum safe exposure level of 85 dB. The participants were 20 young adults who had very good hearing thresholds to begin with. Pure-tone threshold and distortion product otoacoustic emission (DPOAE) measurements were taken before, during, and after the music exposure in sound treated booths. Pure-tone threshold measurements were taken using a calibrated audiometer and headphones. Distortion product otoacoustic emission measurements were taken by emitting primary tones to the ear canal using a probe that contained mini loudspeakers and a mini microphone. The participant was exposed to 30 minutes of straight rock music via an ear bud headphone that was inserted into the ear canal. Immediately after the music exposure, DPOAE and pure-tone threshold measurements were taken to assess immediate recovery abilities of the ear. In addition, to test for long-term hearing loss as a result of the music exposure, DPOAE and pure-tone threshold measurements were taken again 48 hours after the noise exposure.

The results of the above study are interesting. The pure-tone threshold measurements showed no long-term significant threshold shifts as a result of the 30-minute rock music exposure of 85 dB. However, there were significant reductions in DPOAE half-octave band levels, specifically in the higher frequency range, for a short period of time. Although the DPOAE levels returned to pre-exposure levels within 48 hours of the music exposure, the results indicate that even at the maximum safe level of music volume, certain parts of the ear can be temporarily affected. The results of this study indicate that DPOAE changes can be possible early warning signs that if exposure continues, real ear damage may occur (Bhagat and Davis 2008).

A field study conducted in Sweden gathered data regarding the listening preferences and habits of PLD users, the prevalence of hearing disorders among the population, and sound exposure differences between males and females. Over the course of a single day, data was collected in the main hall of a central station. Passersby who were listening to PLDs were invited to fill out a questionnaire and then to measure their preferred listening volume. There were 41 participants deemed fit to have their results be part of the study. The questionnaire covered three main topics. The first questions discussed the participant's PLD usage history, addressing the type of PLD and headphones used and the earliest age of usage. The second group of questions covered the participant's general usage habits, addressing length of time, environments, maximum volume, and type of music that the participant generally listened to. This section also questioned whether the participant listened to music when falling asleep at night. The third category of questions discussed the hearing health of the participant, inquiring whether there was tinnitus, distortion, hearing fatigue, ultra sensitivity to noise, and whether the participant had basically good hearing or not.

The sound pressure levels of the PLDs were measured with a KEMAR manikin equipped with a coupler and microphone. The microphone was connected to a preamplifier and to a 3560B Frontend (a system for noise and vibration analysis) that was used together with PULSE software to measure and analyze all of the incoming data. Each participant was asked to pick a preferred song and volume, and after 30 seconds of the music playing, a minute-long sample time was measured. The components observed were mean listening level (L_{Aeq}^{60s}), maximum level, and peak level from 20 Hz-10 kHz. In this field study, both genders had begun to use PLDs in their early 20s. More than half of the participants reported listening to their PLDs every day; they were dubbed frequent listeners. The majority of participants reported listening to their devices in loud environments, namely trains and buses (see Figure 3). In addition, more than half of the participants listened to their PLDs at sound levels 75-100% of the device's maximum volume. In this study, only half of the participants showed no signs of affected hearing (Kahari et al. 2011).

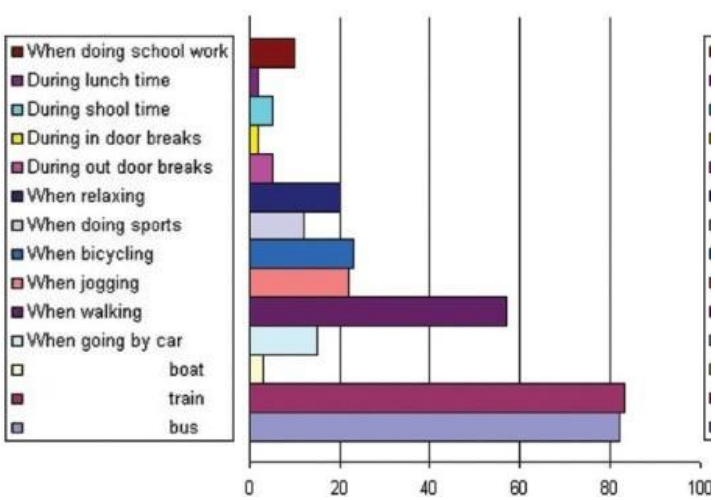

Figure 3: Bar graph plots number of participants per category versus type of environment in which PLD is listened to. The majority of PLD users listen to their devices in loud environments, namely trains and buses. Source: Kahari et al. 2011

ADDITIONAL STUDIES REGARDING PLD USAGE AND DANGERS

In 2006, the American Speech-Language-Hearing Association conducted a survey of 1,000 adults and 301 high school teens in the United States to review the prevalence of hearing difficulties in different parts of the population. The survey showed that a larger percentage of teens than adults displayed three symptoms of noise-induced hearing loss: (1) Television volume was turned up by 28% of teens vs. 26% of adults. (2) During regular conversation, 29% of teens said “what” or “huh” vs. 21% of adults. (3) Tinnitus was experienced by 17% of teens vs. 12% of adults (Levey et al. 2011).

In an unrelated study conducted on 189 college students (average age being 22 years old) using PLDs and walking right out of the subway station onto a CUNY campus, the goal was to determine the percentage of college students at risk for noise-induced hearing loss as a result of their PLDs. The earphones of all participants were measured, and questionnaires were filled out regarding their backgrounds and details surrounding their PLD usage (i.e. recent volume adjustments, type of PLD, frequency of usage, etc). The earphone volumes were measured via a mannequin fitted with a sound level meter that had the microphone situated in the silicon ear canal of the mannequin and was connected to an ER-7C Probe Microphone System via a probe tube that was connected to a computer which recorded the incoming data. The data gathered from the study showed that over 50% of the PLD users were at risk of NIHL due to unhealthy PLD listening habits; too many of the students preferred listening levels above the safe limit (Levey et al. 2011).

Another study, examining 28 undergraduate students, included a questionnaire, hearing health assessment, and measurements of the students’ PLD sound levels. Males were discovered to listen to music at an average of 8 dB higher than females (McNeill et al. 2010).

Yet another study tested the hypothesis that PLD users raise the volume on their devices when in a loud environment. Noise measurements were made using two Etymotic ER-7C probe tube microphones placed in the participants’ ear canals at a safe distance from the eardrum and connected to a PC able to record the data. The hypothesis was proven correct, as the majority of listeners on average raised their dB levels by 10 dB when in noisy environments. In addition, this study also found that male PLD users tended to listen to louder music than females (Henry and Foots 2012).

DISCUSSION: SOCIAL EVENTS VS. PLDS

DANGERS OF MUSIC AT SOCIAL EVENTS

The first issue raised in this paper regarding social events, claiming that those in control of music volume are themselves likely to have NIHL, inclining them to expose their audiences to excessive volumes, has substantial evidence backing it. In one Swedish experiment described above, which analyzed musicians, 74% of the 139 musicians displayed affected hearing due to their excessive music exposure (Kahari et al. 2003). In the Brazilian study described above, 50% of the sound technicians examined had high-frequency hearing loss (El Dib et al. 2008). Additional studies have shown that most musicians who perform in rock or jazz bands display one or more symptoms of hearing loss (Kahari et al. 2003).

The second issue raised regarding social events, claiming that music volumes are often excessively loud, above 85 dB, placing the audience at great risk of developing NIHL, also has substantial backing. Sound level measurements that were carried out at a number of random musical performances, using meters attached to listeners’ and musicians’ collars near the ears, showed that all of the musicians were exposed to volumes that exceeded the country’s safety limits. Even worse, at rock and jazz concerts, the sound levels that the listeners were exposed to ranged from 90 to 150 dB, definitely unsafe according to the universal safety limit of 85 dB (Kahari et al. 2011). In addition, the abovementioned study which examined the effect of three hours of excessively loud music on hearing showed that three hours of 102 dB level music can cause outer hair cell deterioration and general hearing loss (Muller et al. 2010). Clearly, NIHL has the potential to occur as a result of loud concerts.

Minimizing the urgency of this data, however, is El Dib's aforementioned study which, although finding that 50% of the sound technicians had high-frequency hearing loss, found just 10.5% of the non-sound technicians to be significantly affected by the effects of loud music. Another point to consider is that females have been shown to possess better hearing thresholds than males (Kahari et al. 2011).

DANGERS OF MUSIC FROM PLDS

There were a number of issues raised in this paper regarding PLDs. Firstly, since many members of the younger population are listening to PLDs at higher volumes and for longer periods of time, they are putting themselves at risk for developing NIHL (Levey et al. 2011). Secondly, many PLD users tend to listen to their music in settings where there is outside noise interference, such as on the street, subway, or bus. In such settings, where there is a high level of noise interference, the average PLD user raises the listening level to excessively loud and, therefore, unsafe volumes. Thirdly, even noise that is at a safe dB level in a free field may not be safe when listened to through in-the-ear headphones, because the volume increases in the ear canal due to resonance (Henry and Foots 2012).

These issues have validity, as in one study, over 50% of PLD users were shown to be at risk for developing NIHL due to unhealthy PLD listening habits (Levey et al. 2011). Another study found the majority of PLD users listening to their devices in loud environments and at more than 75% of the maximum volume (Kahari et al. 2011). In another study, the majority of PLD users were shown to raise their PLD volume by 10 dB when in noisy environments (Henry and Foots 2012). As for the third issue, ear buds in particular have been shown to be extremely harmful to one's hearing because they are placed in the outer ear canal and project noise towards and within very close proximity to the eardrum. The noise emitted from the ear bud is more concentrated and louder in the ear canal and, as such, can cause greater damage to the ear than free field noise that is heard at concerts and parties. To make matters worse, because most ear buds do not block outside noise, and many PLD users listen to already loud music in loud environments, they tend to turn up the music even louder on their PLDs, leading to greater resonance of noise within the ear canal, which increases the sound intensity by about 10 dB (Henry and Foots 2012).

POSSIBLE IMPROVEMENTS FOR SOCIAL EVENTS AND PLDS

A possible improvement to address excessive sound levels at social events is to set legal limits on the volumes at which bands and DJs are allowed to play music during events. A possible improvement to prevent excessive sound levels in PLDs is to lower their maximum volume capabilities. Devices geared towards the adult population can have two sound-level limits, one at baseline level that limits the user to safe volumes and a second, higher volume that can only be activated consciously (e.g. a password). Devices geared toward children and teens, who tend to use PLDs more recklessly than adults, should have just one maximum volume that is well within the safe range of noise exposure (Kahari et al. 2011). Dr. Brian Fligor, director of diagnostic audiology at Boston Children's Hospital, recommends limiting PLD volume to 50% of its maximum sound level for one who listens all day and to 80% if listening for just 90 minutes (Matusitz and McCormick 2010).

Another possible improvement to prevent NIHL might be to raise awareness of the positive effect that intake of antioxidant-rich foods has on auditory function. Antioxidants help lower radioactive oxygen species (ROS) levels in the body. Within the ear, ROS levels in cochlear tissue are raised due to exposure to loud noise. Raised levels of ROS can cause NIHL. As such, the increased uptake up antioxidant-rich foods would be a possible improvement to help prevent NIHL (Hirose et al. 2008).

CONCLUSION

Whereas social events do pose some auditory health risks to the general audience, the music is in a free field and is not exposed to the general public for nearly as long or as often as PLD sounds are. PLDs are used more often and in more private settings, allowing little regulation by others. Thus, although both can reach equal noise levels, PLDs pose a greater danger than social events in regard to developing NIHL, because the devices are more frequently listened to than social events are attended.

At concerts and discos, although studies show the musicians at great risk of developing NIHL, the audience does not have as great a risk. With PLD use, however, all users, both male and female, are at risk of developing NIHL due to unsafe listening habits (Levey et al. 2011), although males have been shown to be more susceptible to hearing loss than females, and the left ear (in both males and females) has been shown to be more sensitive than the right ear (Zhao et al. 2010). In reality, although both social events and PLDs pose threats to society's hearing, one can be worse than the other depending on the frequency of exposure and the dB levels that each individual listens to. Therefore, everyone should take proper precautions to protect their ears in all settings, regardless of the source of the music.

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