An Investigation of the Effects of Noise Exposure and History of Otitis Media on Hearing Thresholds in a Student Population

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Abstract

Background: In recent years, concern regarding noise-induced hearing loss (NIHL) due to personal listening device (PLD) use has been evident both in academia and mass media. Results of previous research have yielded variable results, suggesting that 5-80% of young adults engage in risky listening behaviour. Few studies have included audiometric examination or considered history of otitis media (OM) in their research design.

Purpose: The objectives of this study were (1) to determine what percentage of participants engages in ‘risky’ listening behaviour, (2) to identify whether a correlation exists between NIHL and the listening habits of PLD users, and (3) to identify whether a positive history of OM is linked to increased hearing thresholds in adult life.

Research Design: This was an experimental study.

Study Sample: Fifty-two adults, 21-34 years of age.

Data Collection and Analysis: Assessment consisted of audiometric examination (pure-tone audiometry and gap detection); measurement of chosen listening levels on three PLDs (Apple iPhone 4S, a Zen X-Fi3 MP3 player, and a Dell N5110 PC); and completion of a questionnaire detailing participants’ aural and medical history and listening habits.

Results: Between 4 and 8% of participants engaged in dangerous listening habits, depending on the risk criteria used. Although 28.8% of participants presented with either Mild or Moderate NIHL, no statistically significant relationship was identified between PLD listening habits or history of OM and NIHL.

Conclusion: Although a substantial number of participants were found to have NIHL, at present it is not possible to identify a direct causal relationship between NIHL and factors such as history of OM or PLD listening habits.

Key Words: Chosen listening levels, iPods, MP3 players, noise-induced hearing loss, personal listening devices, recreational noise exposure

Abbreviations: CLL = chosen listening level; DRC = damage risk criteria; NIHL = noise-induced hearing loss; OM = otitis media; PLD = personal listening device
INTRODUCTION

Since the 1970s, with the commercialization of portable stereos, increased concern around potential noise-induced hearing loss (NIHL) has been evident, both in academia and in the mass media (Henry and Foots 2012). With over 350 million iPod sales alone (Apple 2012b), it is estimated that listening to personal listening devices (PLDs) with earphones is the most popular daily leisure activity among university students (Torre 2008). Thanks to advancements in sound technology, such as increased memory, battery and volume output capabilities, PLDs now offer extended listening times of up to 40 hours and output levels exceeding 120dB, further increasing the potential risk of NIHL (Fligor and Cox 2004; Danhauer et al 2009; Apple 2012a). However, despite this new, music-infused youth culture, the current evidence linking hearing loss to PLD use is limited. The present study investigates the effect of PLD use on the hearing thresholds of an Irish student population, and the long-term impact of a history of otitis media (OM) on hearing acuity.

NIHL & PLDs: A History

NIHL is defined as a gradual sensorineural hearing loss, evident in the higher frequencies (3-6 kHz), caused by exposure to loud noise over an extended period of time (Mosby’s Medical Dictionary 2009). NIHL is the second most common cause of adult sensorineural hearing loss, with prevalence estimated to be between 12 and 17% for the general population (Niskar 2001; NIDCD 2010; Henderson et al 2011; Mahboubi et al 2013). NIHL occurs primarily due to exposure to noise associated with occupational or recreational activities, such as use of loud machinery, firearms, or listening to music (Rabinowitz 2000). This specific type of hearing loss is evidenced in audiograms by a notch maximal at 4 kHz (see Fig. 1), with recovery at 6 and 8 kHz (Doyle 1998; McBride and Williams 2001; Wilson 2011). As Figure 1 illustrates, degree of hearing loss is measured according to decibel loss as follows: normal hearing (-10dB-25dB); mild hearing loss (26dB-40dB); moderate hearing loss (41dB-70dB); severe hearing loss (71dB-90dB); and profound hearing loss (91dB+) (ASHA 2011).
As this type of hearing loss is based solely on noise exposure, both adults and children are susceptible. However, recent studies have asserted that young adults are particularly vulnerable, due to their increased recreational time, listening levels, and durations (Danhauer et al 2009; Portnuff et al 2011). Although a variety of damage-risk criteria (DRC) have been established for occupational noise exposure (OSHA 1981, NIOSH 1998, Council Directive 2003/10/EC), ranging from 80-90dB for approximately 8 hours per day, no such criterion exists for recreational noise exposure. However, a recent mandate by the European Union on safety standards for personal music players states that at 80dB, exposure should be limited to 40hrs/week (EUROPA 2009).

In the 1990s, several studies examined the possible risks associated with PLD use (Wong et al 1990; Turumen-Rise et al 1991; Mostafapour et al 1998). The results of these early studies, and indeed the results of more recent research (Williams 2005; Danhauer et al 2009; Portnuff et al 2011), indicate that the general population is at a relatively low risk for NIHL resulting from PLD use. However, in many of these studies, a small subgroup of the population was identified as engaging in listening behavior that exceeds DRC, placing them at increased risk for NIHL. Interestingly, the percentage of listeners ‘at risk’ varied greatly between studies (Fligor 2009), ranging from approximately 5% to 80%, depending on earphone type and listening environment. The variability between these findings can in part be accounted for by the varying definitions of what constitutes
‘risky’ listening behaviour, as well as the diverse methodologies and sampling methods used across the literature.

**Methodological Variables**

According to Chung et al (2005), the survey method is one of the best means of identifying potentially risky behaviors. As such, much of the present data on NIHL from PLDs is derived from surveys of PLD users (Danhauser et al 2009; Hoover and Krishnamurti 2010). While this method allows researchers access to larger and potentially more diverse samples, as evidenced by Danhauser et al (2009), it also assumes a significant correlation between reported and actual listening levels/durations. However, as Portnuff et al (2011) demonstrated, the correlation between self-reported listening habits and laboratory findings is relatively low ($r < 0.5$). Moreover, in isolation, surveys cannot adequately illustrate cause and effect relationships (Taylor et al 2006).

Several of the studies on NIHL from PLDs employ both survey and laboratory observation methods, using data acquired from measuring users’ chosen listening levels (CLLs) on mannequins (Williams 2005; Portnuff et al 2011; Levey et al 2011; Kahari et al 2011) or within the ear canal itself (Torre 2008). While these methods offer a greater degree of control and specificity than surveys alone, it is important to note that the observer-expectancy effect (i.e. the Rosenthal effect) may partially skew the data collected (Polgar and Thomas 2008). Moreover, sound pressure data measured with mannequins has been noted to conform poorly to levels measured at the eardrum, owing to the large individual differences (Kahari et al 2011).

Lastly, a small number of studies have used pure-tone audiometry to measure the hearing thresholds of their participants (Mostafapour et al 1998; Fligor and Ives 2006; Ahmed et al 2007). Interestingly, however, few studies that incorporated audiometric screening combined this assessment with measurement of CLLs. One notable exception is the study by Ahmed et al (2007), which surveyed 150 university students on their PLD listening habits, and subsequently assessed 24 of these students using high frequency pure-tone audiometry and objective acoustical measures of PLD output (via a mannequin). Results of this study revealed no initial audiometric signs of NIHL and therefore no relationship between CLL and presence of notch. However, due to the small
sample size of this study it is unclear whether their results are representative of the general population.

Although the percentage of the population deemed ‘at risk’ varies considerably among studies, when examined methodologically it was noted that survey studies identified a smaller subgroup, in general, than did mannequin or laboratory observation studies. While Danhauer et al (2009) and Hoover and Krishnamurti (2010) identified a small, unspecified subgroup as at risk for NIHL, Punch et al (2009) estimated that approximately 6% of university students engaged in risky listening behaviour (cited in Punch et al 2011). This stands in stark contrast to mannequin studies such as Williams (2005), who identified 25% as at risk, and Levey et al (2011) who deemed over 50% as at risk. This suggests that surveys are a far less sensitive tool and must therefore be used in conjunction with more specific and objective methods. As such, the present study examined the relationship between PLD use and NIHL through a combination of survey, laboratory observation, and audiometric screening methods.

**Sample Variables**

A review of the present body of literature on NIHL from PLDs revealed a broad range of sampling variables, including participant age, gender, listening habits, and overall sample size. Moreover, the sampling methods used varied markedly from one study to the next. With regard to age, previous studies focused on either adolescents (Portnuff et al 2011), university students (Mostafapour et al 1998; Hoover and Krishnamurti 2010; Danhauer et al 2009; Fligor and Ives 2006), or on a broader, non-specific age range (Williams 2005; Henry and Foots 2012). Within the literature, adolescent participants were identified as having higher CLLs than university-age participants (Portnuff et al 2011), however; university-age participants are noted to have more leisure and study time and therefore greater overall PLD use (Danhauer et al 2009).

A secondary goal of much of the primary research in this area was the identification of discrepancies between the listening habits of men and women. Both Williams (2005) and Fligor and Ives (2006) noted statistically significant differences between male and female listening levels, with men listening approximately 5 dB louder than women. Similarly, Torre (2008) and Henry and Foots (2012) found that men were significantly more likely to report listening for longer durations
and at louder volumes than women were. Conversely, Levey et al (2011) found no gender differences in PLD use, either daily or weekly. However, it is possible that the high degree of background noise in the environment in which this study sampled participants (a busy New York City college campus, near the subway) negated gender differences noted in quieter environments.

**Findings of Previous Studies**

In light of the high volume and memory capacities of modern PLDs, several studies have proposed volume-duration rules. Fligor and Cox (2004) initially proposed the 60-60 Rule, stating that use of PLDs should be restricted to a maximum of 60% of full volume for no more than 60 minutes per day. Portnuff and Fligor (2006) later amended this rule, estimating that PLD users could listen at 70% of full volume for 4.6 hours per day (or 80% for 90 minutes) without significantly increasing their risk for NIHL. Across studies of both college and high school students, it appears that the majority of listeners use PLDs for around 2 hours per day, with approximately 10-15% listening for more than 5 hours per day (Williams 2005; Danhauer et al 2009; Portnuff et al 2011). However, these rules do not account for earphone style or ambient noise levels, which, according to a growing body of literature, will also determine the risk for NIHL (Danhauer et al 2009).

Stock iPod earbuds are often cited as producing higher output levels, with less noise attenuation than many other earphone styles (Fligor and Ives 2006; Danhauer et al 2009; Henry and Foots 2012). As Danhauer et al (2009) noted, as many as 76% of surveyed listeners used stock earbuds, which do not block out ambient noise, thereby necessitating an increase in CLL in noisy environments. Similarly, Fligor and Ives (2006) and Henry and Foots (2012) stated that use of noise attenuating earphones allowed for lower CLLs in the presence of background noise. Given the interaction between these variables, Danhauer et al (2009) suggest that potentially all earbud users may be at risk for NIHL. Therefore, although earphone style does, in part, determine the CLL, it does so in concert with the level of ambient noise.

Numerous studies have demonstrated that PLD users increase their volume settings by 3-20dB in the presence of background noise (Torre 2008; Fligor and Ives 2006; Hodgetts et al 2007). Fligor and Ives (2006) also illustrated the relationship between earphone style and background noise, noting that in a quiet environment, using 85dB as the cut-off for risky behaviour, approximately 6%
of participants were deemed at risk. However, in a noisy environment, between 20% and 80% of participants were at risk, depending on the degree of earphone attenuation. Due to the consistent findings of previous studies in this area, variations in listening level according to background noise and earphone type will not be explored by the present study.

As Fligor (2009) asserts, whether PLDs are capable of causing NIHL is not a matter for debate. However, it remains unclear whether PLDs are, in fact, used at high enough levels, for long enough durations, and in loud enough environments to pose a substantial risk to hearing. At present, there have been no studies that focus on the Irish population, and which combine hearing measures, survey methods and PLD output measurements in order to examine the relationship between PLD use and increased hearing thresholds. The present study will explore this relationship by utilizing two hearing measures: pure-tone audiometry and gap detection. The former measure will provide information regarding participants’ hearing thresholds, while the latter measure will assess participants’ temporal resolution skills (i.e. their ability to segregate auditory events), which are essential for verbal information processing (Samelli and Schochat 2008).

**Otitis Media & Long-term Hearing Loss**

Otitis Media (OM) is an acute inflammation of the middle ear, commonly occurring in children, which causes severe pain and transient conductive hearing loss (Kumar and Clark 2009). While acute OM will often resolve within 72 hours (ibid.), thereby decreasing the risk of more permanent hearing loss, chronic OM and serous OM (also known as otitis media with effusion) may persist for several months or even years, typically accompanied by fluid effusion (Doyle 1998). According to WHO estimates, 65-330 million individuals worldwide develop chronic suppurative OM (2 weeks of persistent ear discharge), 60% of whom will experience fluctuating conductive hearing loss (cited in Vergison et al 2010).

Although myriad studies have investigated the effects of childhood OM (and its attendant fluctuating hearing loss) on language and literacy development (Zumach et al 2010; Roberts et al 2004; Paradise and Feldman 2007), at present, few studies have focused longitudinally on the relationship between OM and reduced hearing thresholds in later life. The scarce information on the long-term implications of early life OM results from the (generally) retrospective research
designs of many studies, wherein hearing thresholds were not regularly assessed (Zumach et al 2010). Moreover, few studies have examined the effects of OM after the age of 7-12 years.

One pertinent study, by Al-Muhaimeed (1996), examined the prevalence and aetiology of hearing impairment of ‘at risk’ children aged 2 months to 12 years in Saudi Arabia. Results of this study indicated that, of the children noted to have any form of hearing loss, 66% were the result of OM (either secretory or suppurative). However, this study did not provide longitudinal data on the hearing (or PLD habits) of these children in later life. Owing to the paucity of information on the long-term effects of OM on adult hearing thresholds, the present study aimed to investigate a possible correlation between a history of OM and the CLLs of university-age individuals.

**The Present Study: Aims and Objectives**

Based on the aforementioned results of previous research, the goals of the current study were to determine if a correlation exists between increased hearing thresholds and the listening habits of PLD users, and to identify whether a positive history of OM is linked to increased hearing thresholds in adult life. The following hypotheses were tested:

**Hypothesis 1:** A small subgroup of participants (10-25%) will select sufficiently high listening levels that will place them at risk for NIHL.

**Hypothesis 2:** The increased CLLs of this group will be reflected in their audiograms by a traditional NIHL ‘notch’ in the 3-6 kHz range.

**Hypothesis 3:** There will be a statistically significant relationship between a history of OM and increased hearing thresholds.
METHOD

Ethical Approval & Consent
Ethical approval for this study was granted by the University of Limerick, Faculty of Education and Health Sciences Research Ethics Committee. Informed written consent was obtained from all participants prior to their participation, and all relevant ethical guidelines, codes of practice and protocol were followed in the implementation of this experimental research project (Appendix A).

Study Design & Variables
This study followed a quantitative, experimental design, in which participants were assessed on multiple hearing measures in a controlled clinical environment (Burns and Grove 2007). Participants completed a quantitative survey detailing their PLD listening habits and selected their preferred listening levels on three PLD devices. Hearing measures, specifically pure-tone audiometry and gap detection, were used as dependent variables. Analyses were conducted using IBM SPSS Statistics 20.0 software to establish whether the dependent measures differed according to the levels of the different aspects of the questionnaire findings (independent variables), using independent samples t-tests, Mann-Whitney U tests, Pearson R correlations, Spearman Rank Order correlations, or single factor ANOVAs as appropriate.

Subjects
Fifty-two university students, comprising 17 males and 35 females between the ages of 21 and 34 years (mean age: 25.8yr), were recruited from the University of Limerick via volunteer and convenience sampling (Parahoo 2006). Volunteers were recruited via posters placed throughout the campus area (see Appendix A – Recruitment Flyer) and through personal contacts of the investigators (i.e. friends and acquaintances). Inclusionary criteria specified participants must be between 18 and 35 years of age and studying full or part-time at university level. Due to the limited number of volunteers during the first weeks of assessment, the latter criterion was later amended to include non-students. Exclusionary criteria (established via the questionnaire) included developmental history of hearing loss, any medical history of aural pathology, and usage of ototoxic medications. Only one participant was excluded under these criteria, as he fell outside the required age range, therefore his results were not used as part of the analysis.
**Procedure**
Audiologic examination took place in the Speech and Language Therapy Clinic within the Health Sciences Building at the University of Limerick over a period of 4 weeks. Sound pressure levels were recorded in each clinic room, prior to participant assessment, using the PrecisionGold N05CC sound pressure level meter. Ambient noise levels ranged from 32dB to 42dB. Each participant was assessed using four distinct measures: A quantitative questionnaire; pure-tone audiometry; gap detection; and selection of chosen listening levels on various PLDs. The duration of each assessment ranged from 30 to 40 minutes.

**Questionnaire**
A 25-item questionnaire was created (see Appendix B) in order to identify participants’ demographic information, relevant medical history, and PLD listening habits. Questionnaire items relating to PLD use were developed on the basis of issues raised in previous studies (Danhauer et al 2009; Hoover and Krishnamurti 2010). Specific items queried family history of hearing loss, history of ear infections and grommet usage, frequency of attendance at bars and concerts, and PLD listening behaviour.

**Audiologic Examination**
Pure-tone audiometry with Telephonics 296D000-1 earphones, using a Kamplex KS 8 audiometer was performed bilaterally on each subject at the following frequencies: 0.5, 1, 2, 3, 4, 6, and 8 kHz. The resulting audiograms were inspected by both investigators and coded for the presence of nonmonotonic patterns (notches) in the pure-tone threshold pattern. Disagreements in coding were resolved via discussion and review. Consistent with Mostafapour et al (1998), notches of 10dB were designated ‘small’ and notches of 15dB or greater were considered ‘large’. The notches of each participant were therefore coded between 0-5, as having no notch, small unilateral notch, small bilateral notch, large unilateral notch, large bilateral notch, or small and large notch, respectively:

0) Participants were considered to have ‘no notch’ when a difference of no more than 5dB existed between 3 kHz and 6 kHz
1) Participants were considered to have a ‘small unilateral notch’ when a difference of 10dB was identified, between the 3 and 6 kHz frequencies, in either the left or the right ear

2) Participants were considered to have a ‘small bilateral notch’ when a difference of 10dB was identified, between the 3 and 6 kHz frequencies, in both the left and the right ear

3) Participants were considered to have a ‘large unilateral notch’ when a difference of 15dB or greater was identified, between the 3 and 6 kHz frequencies, in either the left or the right ear

4) Participants were considered to have a ‘large bilateral notch’ when a difference of 15dB or greater was identified, between the 3 and 6 kHz frequencies, in both the left and the right ear

5) Participants were considered to have a ‘small and large notch’ when a difference of 10dB was identified in one ear (either left or right) and a difference of 15dB or greater was identified in the other ear, between the 3 and 6 kHz frequencies

Notches were coded as above, regardless of whether or not the dip in hearing thresholds fell within the normal hearing range (-10 to 25dB). However, each participant’s audiograms were also described qualitatively, based on the degree of hearing loss (i.e. normal to profound hearing loss – see Figure 1). Additionally, the average hearing threshold (PTA5) of each participant was calculated by taking the average of thresholds across the following frequencies: 0.5, 1, 2, 4, and 8 kHz. This is an expansion of the 4 Frequency Pure-Tone Average (PTA4), adding the highest frequency (8 kHz) in order to obtain a more detailed picture.

Following pure-tone audiometric examination, gap detection was administered on either a Dell N5110 PC or a MacBook OS X 10.8.2. In a two-alternative, forced choice procedure, participants were instructed to listen to 60 sets of paired stimuli and identify whether one of the sounds contained a temporal gap and was therefore ‘different’ (Ross et al 2010). Participants recorded their own responses (see Appendix C), which were subsequently analyzed according to total number of errors.
Chosen Listening Level

Lastly, each participant was required to select their CLLs on three devices: an Apple iPhone 4S, a Zen X-Fi 3 MP3 player, and a Dell N5110 PC. Stock earphones were used with each of the above devices. Each device was loaded with a 3-song playlist, selected from iTunes Charts Top Songs (see Appendix D) on February 11, 2013 in the genres of “pop/hip-hop”, “dance” and “singer/songwriter”. On each device, the volume level was set to zero at the start of each song, and the participant was requested to increase the volume until their normal listening level was reached. The display of all three devices was obscured from the view of the participant in order to obviate the observer-expectancy effect. This is consistent with the methods utilized by Henry and Foots (2012).

Unlike the Zen X-Fi3 MP3 Player, which measures volume numerically (from 0-31), the Apple and Dell devices display volume levels visually. As such, it was necessary to transpose the visual output onto a numeric system. This was done by creating a 100mm line, onto which the visual output could subsequently be plotted, thereby yielding a number from 1-100, representing the percentage of maximum volume that each participant selected (see Appendix E). After the 9 percentages were calculated (3 songs x 3 devices), an average CLL was obtained and it is this average that was utilized in the analysis.

Post-Hoc Procedures

Due to the inherent difficulty in obtaining concrete PLD output measures (in decibels) (Worthington et al 2009), following the assessment period, the investigators utilized DeafHear Limerick’s sound level mannequin (a bespoke model based loosely on the Jolene Mannequin – see Martin and Martin 2007) in order to determine at what level (i.e. what percentage of maximum volume) each device exceeded DRC (see Fig. 2). The mannequin head contained 10 coloured sensors indicating different A-weighted volume levels: Green (82dB or less), Orange (82-84dB), and Red (85dB or greater). For each of the aforementioned PLDs, earphones were held against the mannequin’s ears (which contained sound pressure level meters) and the volume was increased until the red light illuminated, indicating that DRC (85dB+) had been exceeded.
RESULTS

In order to explore the relationship between pure-tone audiometry results and gap detection responses (dependent variables), and factors such as CLL, history of OM, and demographics such as age and gender (independent variables), a variety of statistical analyses were conducted. These included nonparametric independent t-tests, bivariate correlations, and one-way ANOVAs. All statistical tests were considered significant at a p-value of < .05. Results will be discussed according to the hypotheses outlined in the introduction.

Hypothesis 1: A small subgroup of participants (10-25%) will select sufficiently high listening levels that will place them at risk for NIHL.

In the present study, participants selected listening levels ranging from 20-76% of full volume (mean: 42.36%), as averaged across the three PLDs and three songs. However, as DRC is comprised of both listening level and duration, these listening levels must also be compared against the duration of listening. Four participants (7.69%) exceeded the 60-60 rule, while 2 participants (3.84%) engaged in risky listening behaviour based on the amended 70-40 rule (Table 1). In other words 3.84-7.69% of participants were found to engage in potentially risky listening behaviour.
As previous studies have yielded contradictory results with regard to whether CLL varies according to gender, in the present study, an independent-samples t-test was conducted to compare the CLLs of male and female participants. There was no significant difference in the scores for males (M=42.50, SD=14.656) and females (M=42.29, SD=13.472); t (48)= .049, p=.962 (two-tailed).

The relationship between CLL (as measured in percentage of maximum volume) and age was investigated using a Pearson R nonparametric correlation (Fig. 3). No significant correlation was detected between the two variables (r= -.025, p=.863).

<table>
<thead>
<tr>
<th>Weekly PLD Use</th>
<th>0-1 hr</th>
<th>2-4 hr</th>
<th>4-6 hr</th>
<th>6 + hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Maximum Volume</td>
<td>20-29%</td>
<td>30-39%</td>
<td>40-49%</td>
<td>50-59%</td>
</tr>
<tr>
<td>0-1 hr</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
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<td>4</td>
</tr>
<tr>
<td>4-6 hr</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>6 + hr</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1. PLD Listening Habits: Hours per Week Compared with Percentage of Full Volume

Figure 3. Chosen listening level as a function of participant age
Hypothesis 2: The increased CLLs of this group will be reflected in their audiograms by a characteristic NIHL ‘notch’ in the 3-6 kHz range.

Notch

In the present study, 80.8% \((n=42)\) of participants were identified as having a NIHL notch, as reflected by either a 10db or 15dB+ dip in their audiograms. However, only 28.8% of these fell above the 25dB threshold, indicating a mild \((n=12)\) or moderate \((n=3)\) hearing loss.

In order to examine the relationship between notch and CLL, a one-way between groups analysis of variance (ANOVA) was conducted. Subjects were divided into six groups according to type of notch (Group 1: no notch; Group 2: small unilateral notch; Group 3: small bilateral notch; Group 4: large unilateral notch; Group 5: large bilateral notch; Group 6: small and large notch). As Figure 4 indicates, despite the ubiquity of notches in participants’ audiograms, no statistically significant difference was identified between the CLLs of the different notch types \((F(5, 44)= .421; p=.832)\). Post-hoc comparisons were not performed, as at least one group had fewer than two cases.

Figure 4. Distribution of Participant Notches by Average CLL

<table>
<thead>
<tr>
<th>Notch Type</th>
<th>Average CLL per Notch Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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An independent samples Mann-Whitney U test was conducted in order to determine whether there was a difference in the notches of male and female participants. Results revealed no significant difference in the notches of males and females ($p= .920$). The relationship between notch and age was investigated using a Spearman’s Rank Order nonparametric correlation. No significant correlation was detected between the two variables ($n= 51, r= -.204, p= .151$).

As previous studies have proposed that certain PLD types are more detrimental to listener’s hearing (Fligor and Cox 2004; Portnuff and Fligor 2006), the present study examined the relationship between notch and earphone type using an independent samples Mann-Whitney U test, examining each type of device independently. No statistically significant difference was identified between the distribution of notch across the different types of PLDs used: iPod/MP3 player ($p= .955$), PC/Laptop ($p= .718$), and mobile phone ($p= .738$). Similarly, no statistically significant difference was noted in the notches of subjects who reported no PLD ownership ($p= .192$).

In the present study, due to the homogeneity of type of earphones used by participants (94% of participants used earbuds), it was not appropriate to conduct statistical analyses to compare means for this type of earphone. However, an independent samples Mann-Whitney U test was conducted in order to identify whether the distribution of notch was the same for subjects who use over the ear noise-reducing earphones. Results indicate no significant difference between subjects ($p= .323$).

**Pure-Tone Average Hearing Threshold (PTA5)**

In addition to examining participants’ audiograms for evidence of NIHL (i.e. notch), a 5 frequency Pure Tone Average (PTA5) hearing threshold was calculated for each participant’s left and right ear, as discussed in the methodology. Having conducted a bivariate correlation analysis, a small negative association was detected between hearing threshold and CLL but this did not reach statistical significance ($r= -.200, p= .163$ for right ear; $r= -.105, p= .467$ for the left ear). Similarly, no significant relationship was noted between PTA5 and age ($r= -.060, p= .675$ for right ear; $r= .158, p= .264$ for the left ear). The relationship between PTA5 and notch was explored via a one-way between groups ANOVA. Results indicate no statistically significant difference between hearing
thresholds and notches (Right Ear – $F(5, 46)= 2.013; p=.095$; Left ear – $F(5, 46)= .862; p= .514$).

Lastly, an independent samples t-test was conducted to compare the PTA5s of male and female participants. There was no significant difference in the scores for males (Right ear: $M=8.01$, $SD=4.68$; Left ear: $M=8.45$, $SD=5.59$) and females (Right ear: $M=7.50$, $SD=4.06$; Left Ear: $M=9.29$, $SD=4.01$); $t(50)= .408, p=.701$ (Right Ear); $t(50)= -.613, p=.590$ (Left Ear).

**Gap Detection**

The relationship between PTA5 and gap detection (as measured in total number of correct responses) was investigated using a Pearson R nonparametric correlation. Results of PTA5 in the right ear vs. gap detection approach significance ($r=.254, p=.070$). A statistically significant relationship was identified between PTA5 in the left ear and gap detection responses ($r=.398, p=.004$).

An independent samples t-test was conducted to compare the gap detection responses of male and female subjects. Results revealed no statistically significant difference in the scores of males ($M=36.82$, $SD=6.858$) and females ($M=34.29$, $SD=7.748$); $t(50)= 1.148, p=.239$. A one-way ANOVA was conducted in order to identify whether gap detection responses differed based on age bracket. Results indicate that there is, in fact, a statistically significant difference ($F(3, 48)= 2.813; p=.049$). However, it was not possible to run post-hoc analyses to determine specific, between-group differences, as one group had fewer than two cases.

Finally, using a one-way ANOVA, the relationship between gap detection responses and notch was explored. Results revealed no statistical significance ($F(5, 46)=.387, p=.855$).

**Hypothesis 3: There will be a statistically significant relationship between a history of OM and increased hearing thresholds.**

In the quantitative questionnaire, subjects provided information on personal and family history of ear infections, grommet usage, and hearing loss. This information was subsequently compared against hearing measures (i.e. pure-tone audiometry and gap detection) in order to determine whether history of OM results in reduced hearing thresholds in later life. Results of the
independent samples Mann-Whitney U tests indicate that personal history of ear infections does not result in significant differences in notch \((p= .413)\), PTA5 (Left \(p= .638\); Right \(p= .224\)), or gap detection responses \((p= 575)\). While there was no significance between personal history of ear infections and hearing thresholds \((p= .517\) for right ear, \(p= .268\) for left ear), a large number of participants \((N=11)\) who had between 2-4 ear infections during childhood presented with a large bilateral notch on their audiogram.

Similarly, independent samples Mann-Whitney U tests confirm that the independent variables of familial ear infections, grommet use and hearing loss do not result in significantly different distribution of notches, PTA5 average hearing thresholds, or gap detection responses \((p< .05)\).

**DISCUSSION**

Although many investigators have asserted that PLDs present a substantial risk to hearing over time, the current literature on NIHL does not provide a consensus view regarding a causative relationship between PLD use and hearing loss. In light of the highly variable findings of current research, the present study was undertaken to identify whether a causal relationship exists between NIHL and factors such as OM and PLD listening habits.

**Damage Risk Criteria: Who is Actually at Risk?**

In line with the results of previous research (Punch et al 2009; Danhauer et al 2009; Portnuff et al 2011), and consistent with Hypothesis 1, the present study has identified that a small subset of the population \((4-8%)\) selects potentially dangerous listening levels \((i.e. \geq 60-70\% \text{ of maximum volume})\). Post-hoc mannequin-based measurement of the three PLDs’ volume output confirms that approximately 60% of maximum volume equates to 85dB (A-weighted). As such, based solely on listening level, a small subgroup of participants listen to music at volumes that might increase their risk for NIHL. However, decades of research have revealed that risk for NIHL is determined in tandem by both listening level and duration (Punch et al 2011). In the present study, 40% of participants \((n= 21)\) reported listening durations of one hour or less per week, with the majority of participants reporting individual listening sessions of less than 30 minutes. Only two participants \((3.8%)\) reported weekly listening durations greater than six hours. This data suggests that the
The majority of PLD users are listening at safe volumes, and for short enough durations that they are not at risk for NIHL. However, as the questionnaire utilized in the present study primarily investigated total weekly listening duration, it is not possible to conclusively state whether participants exceeded the DRC for daily PLD use. Additionally, a number of participants (n=8) reported experiencing tinnitus (ringing in the ears), which has been identified as a possible symptom of NIHL (Doyle 1998; Punch et al 2011). Therefore, deleterious effects of PLD use may be occurring, which are not reflected audiometrically.

These findings are consistent with the results of Torre (2008) and Hoover and Krishnamurti (2010), who found that the majority of their participants listened for 1-3 hours daily and at safe volume levels (<60% of maximum volume). Similarly, in a survey of college students, Punch et al (2009) estimated that only 6% of participants listened to PLDs at volume levels sufficiently high to put them at risk for NIHL. Using objective measurement of PLD volume output, Fligor and Ives (2006) also identified that, in a quiet environment, 6% of PLD users engage in dangerous listening behaviour. Lastly, in a study by Ahmed et al (2007), which employed a similar research design to the present study (incorporating survey methods, objective PLD output measurement, and pure-tone audiometry), it was found that the pattern of PLD usage was hazardous for only a minority of participants. Despite the consistent findings of these studies, several experimental studies have identified a far greater percentage of listeners at risk for NIHL, such as Williams (2005) and Levey et al (2011), who identified 25% and 50% of participants as at risk, respectively. However, as both of these studies were conducted outdoors, in admittedly noisy environments, it is likely that the ambient noise resulted in increased participant listening levels.

In accord with the findings of Levey et al (2011), no significant differences were identified in the listening levels of male and female participants. Although previous research has reported that males listen at louder volumes and for longer durations than their female counterparts (Ahmed et al 2007; Torre 2008; Henry and Foots 2012), due to the high variation in methods used across these studies it remains unclear whether a true discrepancy exists. Moreover, due to the disproportionate number of male (n=17) and female (n=35) participants in the present study, it is not possible to state conclusively whether or not listening level varies according to gender.
**Notch Prevalence & Configuration**

Results of the present study reveal that the majority of participants (80.8%) had initial audiometric indications of NIHL, evidenced by high frequency, unilateral or bilateral notching below 25dB. Specifically, 28.8% of participants ($n=15$) were identified as having either mild or moderate NIHL, evidenced by high frequency notching above 25dB. However, only two participants (3.8%) could be described as having mild or moderate NIHL on the basis of bilateral notching (see Appendix F) (Mostafapour et al 1998). Although these results are consistent with current estimates of prevalence, it is difficult to accurately compare these findings with general prevalence reports, as the prevalence of notched audiograms depends not only on the definition of the notch but also on the population under study (Wilson 2011).

When compared against previous studies that have incorporated audiometric assessment, the present study identified audiometric indications of NIHL in a far greater percentage of participants. Shah et al (2009) identified only a small percentage of their sample as having hearing loss. Similarly, Ahmed et al (2007) found no audiometric indication of early hearing loss, including no indication of the characteristic 4 kHz NIHL notch, in any of their participants. However, Ahmed et al (2007) tested only the self-reported ‘worse’ ear for each participant. As it is unclear whether there is a strong correlation between self-reported hearing acuity and hearing thresholds, it is possible that the use of unilateral audiometry resulted in the oversight of participant notches. Moreover, Ahmed et al (2007) assessed a smaller sample ($n=24$) comprised of younger participants (16-25 years of age). As NIHL is a cumulative process, it is possible that in a few years time, these same participants may show audiometric evidence of NIHL. As Mostafapour et al (1998) elucidate, the presence or absence of a notch is not *prima facie* evidence for or against noise exposure.

Consistent with the findings of Niskar et al (2001), the majority of notched audiograms (96%) indicate only a singular affected frequency, with 86% of notches maximal at 6 kHz. Although NIHL is more commonly observed at 4 kHz than at 6 kHz (McBride and Williams 2001; Schlauch and Carney 2011; Wilson 2011), several studies have suggested that the 6 kHz notch may in fact be a precursor to the 4 kHz notch, as the audiometric notch begins at 6 kHz twice as frequently as it begins at 4 kHz (Salmivalli 1979; Axelsson 1979). However, given the reported lack of association between 6 kHz notches and noise exposure, researches have asserted that 6 kHz notches may be transient
(McBride and Williams 2001). Moreover, Schlauch and Carney (2011) proposed that with supra-aural audiometry earphones, such as those used in the present study, thresholds obtained at 6 kHz are much less precise than those obtained at 4 kHz. Therefore, it is difficult to confirm whether the audiometric notches identified in the present study are indicative of NIHL, or whether they are the result of a systematic calibration error at 6 kHz.

**CLL and Audiogram Notch**

Despite the ubiquity of notched audiograms in the present study, contrary to Hypothesis 2, results reveal that differences in CLL are not reflected audiometrically. Thus, CLL does not appear to play a causal role in hearing loss. Shah et al (2009) similarly identified a lack of association between hearing sensitivity and the number of PLDs used, the duration of PLD use, and hearing-related symptoms. As Ahmed et al (2007) did not identify initial signs of NIHL in any of their participants, they were unable to affirm or deny a causal relationship between PLD use and audiometric results. Conversely, a study by Peng (2007), which used conventional and extended high frequency audiometry to assess PLD users and non-users, found that high frequency thresholds were significantly increased in PLD users. However, owing to the paucity of research incorporating both audiometric examination and PLD listening levels, in addition to the high variability in participants’ listening environments, it is difficult to assert the validity and reliability of the present study’s findings.

**Gap Detection: An Incidental Finding**

As Samelli and Schochat (2008) assert, a critical aspect of verbal information processing is the ability to process and categorize brief, rapid fluctuations in auditory stimuli. In order to assess an individual’s temporal resolution skills, the psychoacoustic method of gap detection is often utilized (Shinn 2003; Samelli and Schochat 2008). Although no statistically significant relationship was identified between gap detection responses and participant notch, a significant relationship between average hearing thresholds and gap detection responses was noted. These findings are consistent with those of Lister and Roberts (2005), who found that listener’s degree of hearing loss (i.e. average hearing threshold) influenced their temporal resolution for frequency-disparate and dichotic stimuli. This finding is potentially important for the resolution of timing cues in speech, as
individuals with increased hearing thresholds will have difficulty resolving frequency-disparate and dichotic stimuli presented in ongoing speech, particularly in degraded acoustic environments (ibid).

Additionally, results of the present study indicate that there is a statistically significant relationship between gap detection responses and participant age. The present study is not the first to identify such a correlation, as deficits in temporal resolution are purported to underlie part of the speech understanding difficulties experienced by older listeners (Strouse et al 1998; Lister et al 2000; Lister et al 2002; Lister and Roberts 2005).

**OM & Hearing Acuity in Later Life**

Results of the present study indicate that neither personal history of ear infections or grommet usage, nor family history of ear infections or hearing loss, influence hearing thresholds in adult life. Although no studies have examined the effects of childhood OM on adult hearing thresholds, one study, by da Costa et al (2009), noted that chronic OM in individuals aged 3-55 years can be associated with sensorineural hearing loss. Previous follow-up studies have assessed the hearing thresholds of children (aged 2-12 years) with a history of OM (either recurrent acute or secretory) (Sorri et al 1995; Al-Muhaimeed 1996). In a study by Sorri and colleagues (1995), pure-tone audiometry was performed on 298 children at the age of 7, and identified that children with a history of OM more often had hearing thresholds exceeding 20dB. Similarly, Al-Muhaimeed (1996) noted that 66% of children assessed (n= 232) had conductive hearing loss associated with OM.

These findings suggest that although OM may result in increased hearing thresholds for several years post-infection, there are no residual effects in adult life. In other words, the short-term, conductive hearing loss that results from childhood OM does not appear to predispose individuals to sensorineural hearing loss in adult life. However, it is worth noting that although no statistically significant relationship was identified between history of OM and hearing thresholds, a large number of participants (n= 11) who had between 2-4 ear infections during childhood presented with a large bilateral notch on their audiogram. Therefore, further studies incorporating audiometric assessment are required in order to examine more closely the relationship between childhood OM and adult hearing thresholds.
Limitations

This study had several limitations, primarily due to the sampling methods and research design used. Although convenience sampling predominates much of healthcare research, it is widely regarded as methodologically weak, since it provides little opportunity to control for biases (Burns and Grove 2007). As such, the representativeness of convenience samples is questionable (Polgar and Thomas 2008). In the present study, it is unlikely that the sample is representative of the general population, owing to the disproportionate number of female volunteers. Moreover, as the nature of participation in the study was voluntary, it is possible that this may have resulted in the self-selection of those who were biased in a certain opinion (e.g. participants who were more concerned about their hearing) (Griffin et al 2009). This may account, in part, for the high number of notched audiograms identified in the present study.

In order to limit the assessment period to 40 minutes or less, the questionnaire used in the present study was restricted to 25 items, which covered a range of topics relating to aural and medical history in addition to PLD use. However, a more comprehensive questionnaire, examining daily as well as weekly listening durations in greater detail, would have yielded more specific results regarding damage risk criteria. Moreover, with regard to duration of PLD use, the present study relied entirely on the participants’ accurate report of their PLD listening behaviour. As Chung et al (2005) noted, surveys that allow contact between the respondent and the surveyor may result in biased over-reporting of socially desirable responses (i.e. the observer-expectancy effect). As every participant was provided with an information sheet detailing the aims of the study prior to assessment, it is possible that they reported greater/lesser listening durations in order to satisfy the investigators’ criteria. An additional limitation of the present questionnaire was the reliance on self-report regarding history of OM. The majority of participants were unable to recall whether or not they had ear infections as a child and if so, how many. Only one participant recalled having grommets inserted. As such, it is recommended that future studies utilize self-administered surveys (Chung et al 2005), and that participants contact their general practitioner prior to assessment in order to establish a more detailed and accurate aural history.

With regard to evaluation of CLL, mannequins are frequently identified as the superior method of measurement, as they provide sound pressure level readings in decibels, and afford life-like test
conditions and experimental flexibility (G.R.A.S. 2006; Martin and Martin 2007; Levey et al 2011). Although it was not possible to obtain or build a mannequin for the purposes of this study, current research indicates that mannequins provide a more accurate picture of PLD users’ listening behaviour. Moreover, using a single observation of CLL to represent PLD users’ consistent listening levels is tenuous (Levey et al 2011). However, in the absence of technical solutions to monitor participants’ durations and levels of PLD use, self-report and laboratory selection of CLL are effective measures for surveying PLD use en masse (Griffin et al 2009). Finally, owing to the purported ‘transient’ nature of 6 kHz notches (McBride and Williams 2001; Schlauch and Carney 2011), a test/retest research design would have been beneficial in order to establish whether the observed threshold shifts were temporary or permanent.

CONCLUSIONS

In a 2008 study, Torre estimated that approximately 90% of university students own a PLD. In the five years since Torre’s study, an additional 200 million iPods alone have been sold (Apple 2008; Apple 2012b), which suggests that this figure may now be closer to 95 or 100%. As such, NIHL may present a greater risk now than ever before, particularly if these devices are used for excessive durations and at high volumes (Ahmed et al 2007). However, despite the concern expressed within academia and the mass media, the findings of the present study and prior research indicate that the general population is at relatively low risk for NIHL, based on their PLD listening habits. Only a small subgroup of PLD users listens to music at high enough levels and for long enough durations that they are at increased risk for NIHL.

Although the present study identified a substantial number of participants with audiometric notches, results indicate that there is no significant relationship between participants’ CLLs and their audiometric results. Moreover, the presence or absence of a notch is not conclusive evidence for or against NIHL, as a notch may exist in the absence of noise exposure and vice versa (Mostafapour et al 1998). Additionally, as the majority of notches noted in the present study affected the 6 kHz frequency, rather than the characteristic 4 kHz frequency, it is unclear whether participants can be conclusively identified as having NIHL. Due to the insidious and cumulative
nature of NIHL, and the purported transiency of 6 kHz notches, longitudinal studies are needed to monitor audiometric changes over many years of PLD use.

Results of the present study indicate that history of OM does not result in increased hearing thresholds in adult life. However, due to the reliance on self-report and the inability of many participants to recall how many ear infections they experienced as a child, further investigation of the long-term effects of childhood OM is required. Owing to the scarcity of research in this area, as well as the paucity of research incorporating audiometric assessment, objective measurement of CLLs, and qualitative data on PLD use and aural history, the present study uniquely contributes to the growing body of literature on NIHL. Further investigation, utilizing multi-faceted research designs such as this one, are required to examine the complex relationship between NIHL and factors such as PLD listening habits and history of OM.
References


Appendix A

Participant Information Sheet, Consent Form & Recruitment Flyer
Title of the study: An investigation of the effects of noise exposure and history of otitis media on hearing thresholds in a student population.

Introduction
We are students on the Masters in Speech & Language Therapy degree at the University of Limerick. This research aims to explore the effects of earphone usage and history of ear infection on hearing among students aged 18-35 years.

- Researchers who study hearing loss have found that a person who is exposed to noise levels at 85 decibels or higher for a prolonged period of time is at risk for hearing loss. Many devices that we use today have noise levels much higher than 85 decibels. For example, an MP3 player at maximum level is roughly 105 decibels- that's 100 times more intense than 85 decibels.
- Children with recurrent episodes of ear infection have higher risks of developing hearing loss during childhood. It is not known whether or not a history of ear infection in childhood can have long term effects on hearing.

What is the purpose of this investigation?
This research aims to explore the effects of both earphone usage and history of ear infection on hearing levels in the student population.

Why have you been invited to take part?
We would like to interview and test 35 male and 35 female students aged 18-35 years.

Do you have to take part?
Your participation is completely voluntary. If you decide to take part you will be given this information sheet to keep and you will be asked to sign a consent form. If you do decide to take part you are free withdraw from the research at any point without giving a reason and without fear of prejudice.

What will you do in the project?
If you decide to take part in this research, you will be asked questions about: your use of earphones; history of ear infection and/or hearing difficulties; family history of hearing loss; and environmental exposure to high levels of noise. Your hearing will then be tested using 3 different types of test: you will be asked to respond to noises hear through headphones; and to tell the difference between sets of different sounds. The total time taken for questions and hearing testing will be approximately one hour. Testing will take place in the Health Sciences Building in the University of Limerick.

What are the potential risks to you in taking part?
All information that is collected about you during the course of the research will be kept strictly confidential
and anonymous. Only members of the research team will have access to it. Your name or any other contact details will not be recorded on any transcripts or test forms.

All data collection, storage and processing will comply with the principles of the Data Protection Act 1998 and the EU Directive 95/46 on Data Protection. In accordance with University policy, data generated from the research must be kept securely in paper form for a period of seven years after the completion of the project, after which it will be destroyed. Under no circumstances will identifiable responses be made available to any third party. Information from the research will only be made public in a completely anonymised format or at an aggregate level in order to ensure that no participant can be identified. The hearing assessments used are completely safe and risk free.

**What happens to the information in the project?**

The results of this research will be used in our Final Year Project and will be published on the Department of Clinical Therapies website. Anonymity and confidentiality are ensured at all times. Additionally, this research may be presented at academic and professional conferences and in academic journals.

Thank you for reading this information – please ask any questions if you are unsure about what is written here.

**What happens next?**

If you decide that you would like to take part in this research, you can contact us by email at the addresses below. We will explain what the research is about, what is involved in the interview and testing process, and answer any questions you may have. You can then decide if you want to go ahead and we can arrange a suitable time and location. The location will be in a private room in the Health Sciences Building.

We will also ask you to sign a consent form to confirm that you wish to take part in the research.

If you do not wish to take part in this research, we would like to thank you for your time and attention.

**Researcher Contact Details:**

Kelly Schuster: ULStudent:KELLY.SCHUSTER [11146982@studentmail.ul.ie]  
Shevon Walker: ULStudent:SHEVON.WALKER [11002352@studentmail.ul.ie]

**Chief Investigator Details:**

Tara Kearns, Department of Clinical Therapies, Health Sciences Building, University of Limerick.

email:tara.kearns@ul.ie. Tel: 061-234604.

If you have any questions/concerns, during or after the investigation, or wish to contact an independent person to whom any questions may be directed or further information may be sought from, please contact: 

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*This research has received ethical approval from the University of Limerick Research Ethics Committee. If you have concerns regarding this study, please contact: Chairman, Education and Health Sciences, Research Ethics Committee, EHS Faculty Office, University of Limerick, Tel (061) 234101 Email: ehsresearchethics@ul.ie*
Title of the study: An investigation of the effects of noise exposure and history of otitis media on hearing thresholds in a student population.

- I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, without having to give a reason and without any consequences.
- I understand that I can withdraw my data from the study at any time.
- I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.

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Email: ehsresearchethics@ul.ie
Would like to have your hearing tested?

We are doing research on hearing levels in the student population. We are looking for volunteers aged between 18 and 35 years to participate in hearing screening for our final year project.

Further information is available from:

Kelly Schuster, ULStudent:KELLY.SCHUSTER [11146982@studentmail.ul.ie]
Shevon Walker, ULStudent:SHEVON.WALKER [11002352@studentmail.ul.ie]

Supervised by Tara Kearns, Department of Clinical Therapies.

This research has received ethical approval from the University of Limerick Research Ethics Committee. If you have concerns regarding this study, please contact: Chairman, Education and Health Sciences, Research Ethics Committee, EHS Faculty Office, University of Limerick, Tel (061) 234101

Email: ehsresearchethics@ul.ie
Appendix B

Case History Questionnaire
### Case History Questionnaire

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<td>Gender</td>
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**Have you been exposed to loud music/noise in the past 24 hours?**
*Please circle: Yes/No*
*If yes, please give details*

__________________________

__________________________

**Have you ever had an ear infection, either recently, or as a child?**
*Please circle: Yes/No*
*If yes, approximately how many*

__________________________

And, when?

__________________________

**Is there a family history of ear infections?**
*Please circle: Yes/No*
*If yes, please give details*

__________________________

__________________________

**Is there a family history of grommet usage?**
*Please circle: Yes/No*
*If yes, please give details*

__________________________

__________________________

**Have you ever experienced a hearing loss?**
*Please circle: Yes/No*
*If yes, please give details*

__________________________

__________________________

**Is there a family history of hearing loss?**
*Please circle: Yes/No*
*If yes, please give details*

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__________________________

**Please circle all/any answers that apply.**
Which of the following do you use?
*IPod/MP3 Player  PC/Laptop  Mobile Phone  None*

**What kind of headphones do you use?**
*Earbuds  Over the ear  Over the ear noise reduction  None*

**In which environments do you use your headphones?**
How many hours per week do you listen to music with headphones?

0-1 hour  |  2-4 hours  |  4-6 hours  |  6 or more hours (if more; please specify)  

6 or more hours (if more; please specify)  

Please give a number for each of the following:

How many concerts/gigs have you attended in the past month?

How many clubs/parties have you been to in the past month?

Thank you for your time and consideration in completing this questionnaire

This research has received ethical approval from the University of Limerick Research Ethics Committee. If you have concerns regarding this study, please contact: Chairman, Education and Health Sciences, Research Ethics Committee, EHS Faculty Office, University of Limerick, Tel (061) 234101 Email: ehsresearchethics@ul.ie
Please indicate whether the sounds you hear are the same or different by circling the correct response.

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The following songs were chosen from Apple iTunes Charts - Top Songs ([https://www.apple.com/itunes/charts/songs/](https://www.apple.com/itunes/charts/songs/)) on 11 February 2013:

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<tr>
<th>Song</th>
<th>Artist</th>
<th>Genre(s)</th>
<th>Link</th>
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The above songs were selected as they represented diverse genres and therefore incorporated various volume levels, tempos, instruments, and singing styles.
Appendix E

CLL Score Sheet
Participant Chosen Listening Levels Score Sheet

Device #1: Apple iPhone

Song 1 – ‘The A Team’

[-------------------------------------------------------------]

Song 2 – ‘Gangnam Style’

[-------------------------------------------------------------]

Song 3 – ‘Locked out of Heaven’

[-------------------------------------------------------------]

Device #2: Zen X-Fi 3

Song 1 – ‘The A Team’ /31

Song 2 – ‘Gangnam Style’ /31

Song 3 – ‘Locked out of Heaven’ /31

Device #3: Dell PC

Song 1 – ‘The A Team’ /100

Song 2 – ‘Gangnam Style’ /100

Song 3 – ‘Locked out of Heaven’ /100

This research has received ethical approval from the University of Limerick Research Ethics Committee. If you have concerns regarding this study, please contact: Chairman, Education and Health Sciences, Research Ethics Committee, EHS Faculty Office, University of Limerick, Tel (061) 234101 Email: ehsresearchethics@ul.ie
Appendix F

Examples of Participant Notches
The above audiogram (representing participant 21) is one of only two cases of bilateral notching above 25dB identified in the present study. As the audiogram reflects, participant 21 has bilateral notching at the 6 kHz frequency. In the right ear, the quietest sound participant 21 can hear is at 35dB, and at 50dB in the left ear. This indicates that this individual has a 10dB loss in the right ear (resulting in mild NIHL) and a 25dB loss in the left (resulting in moderate NIHL).
Figure 6. Notched audiogram indicating mild bilateral NIHL

The above audiogram (representing participant 44) is the second of the two cases of bilateral notching above 25dB identified in the present study. As with participant 21, participant 44 has bilateral notching at the 6 kHz frequency. In the right ear, the quietest sound participant 44 can hear is at 30dB, and at 35dB in the left ear. This indicates that this individual has a 5dB loss in the right ear and a 10dB loss in the left (resulting in mild bilateral NIHL).
Figure 7. Notched audiogram indicating early bilateral NIHL

The above audiogram (representing participant 4) is presented here to illustrate early NIHL (below 25dB). As the audiogram reflects, participant 4 has early bilateral notching at the 6 kHz frequency. In the right ear, the quietest sound participant 44 can hear is at 15dB, and at 20dB in the left ear. This indicates that this individual’s hearing is presently below the 25dB threshold and is therefore normal. However, due to the insidious and additive nature of NIHL, it is possible that audiometric re-evaluation in several years time may indicate hearing thresholds above 25dB.