University of Alberta

The Effects of Ambient Noise and Physical Exertion on User-Preferred Listening Levels While Using a Personal MP3 Player

by ©

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Abstract:

This study investigated the influence of physical activity and background noise typical of busy exercise facilities on the preferred-listening levels (PLLs) selected by participants using a portable listening device (MP3 player). Twenty-four participants aged 18 to 30 selected loudness levels on the MP3 player in the presence and absence of background noise while exercising and at rest. PLLs were measured in participants' ear canals and were used to calculate the permissible listening duration to reach 100% daily noise dose based on occupational health and safety standards. Participants also completed a 40-item, listening-habits survey designed to provide information on their listening-device-use patterns. Significant increases in PLLs in the presence of noise while resting and exercising were noted. The implications with respect to noise-induced damage risk are explored.

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1 INTRODUCTION

Noise-induced hearing loss (NIHL) is considered one of the most pervasive occupational hazards by most national workplace safety advisory organizations, including the Workplace Hazardous Materials Information System (WHMIS) in Canada and the National Institute for Occupational Safety and Health (NIOSH) in the United States (WHMIS, NIOSH, 2006). Maximum noise dosages for continuous, free-field, occupational noise set by the National Institute for Occupational Safety and Health (NIOSH, 1998) indicate that, for every increase in 3 decibels (dB) above 85 dB SPL, the length of exposure time before damage can occur is halved. For example, while a continuous noise of 91 dB SPL affords the listener 2 hours of safe listening time, safe-exposure time is cut to 1 hour at 94 dB SPL and 30 minutes at 97 dB SPL (NIOSH, 1998). In general, depending on the duration of exposure, levels above 85 dB SPL have the potential to create conditions in which hearing damage is likely to occur (NIOSH, 1998).

While NIHL that occurs as a result of noisy workplace environments has been studied and documented for some time, NIHL caused by leisure activities, such as listening to loud music, has proven to be less transparent and more difficult to prove. In particular, researchers and clinicians have not formed a consensus on whether or not the use of personal listening devices (PLDs), such as CD players or MPEG audio layer 3 (MP3) players contribute to NIHL.

1.1 BACKGROUND

1.1.1 The Risks Associated with PLD Use

The widespread use of portable CD players and the recent popularization of portable MPEGaudio layer 3 (MP3) audio devices have engendered renewed public and clinical concern about the potential for hearing impairment caused by their use. Recent studies have demonstrated that personal listening devices (PLDs), including many popular CD and MP3 player systems, are able to generate maximum sound pressure levels that would cause listeners to reach the maximum allowable daily noise dose within a few minutes.

A recent study by Fligor and Cox (2004) measured the peak output levels of 9 commercially-available CD player/headphone combinations and found transient peak sound pressure levels as high as 139 dB SPL as well as root-mean-square (RMS) average levels as high as 123 dB(A). Similarly, Hodgetts, Rieger and Szarko (2006) measured the output capabilities of a popular MP3 player device combined with various headphone types and recorded average levels as high as 110 dB(A). Clearly, at sound pressure levels as high as these, maximum noise doses are reached in relatively short periods of time and the potential for NIHL becomes apparent. It is important to note that these maximal levels are only of concern for those individuals who choose to listen to their PLDs at or near full volume.

Although the maximal output capabilities of commercial personal listening devices are alarming, it is important to reiterate that, like workplace-related NIHL, music-related NIHL is a function of the duration of exposure to the music as well as the level at which it is played through the device. As sound levels increase, the maximum allowable duration decreases. Given the fact that popular MP3 devices, such as Apple Corporation's iPod, have long battery lives and storage capacities that enable the listener to carry thousands of songs in very compact and portable units, such convenience could increase the time spent using the device to durations that could be hazardous at even non-maximal sound levels. In a recent market research poll commissioned by the American Speech-Language-Hearing Association (ASHA) to survey adults and high school students as to their use of MP3 player systems, 43% of adults reported listening to their MP3 player between 1 to 4 hours per session. Nine percent of these adults reported listening for more than 4 hours per session (Zogby, 2006). Depending on the output levels selected, such prolonged listening durations could generate conditions under which NIHL will occur.

Given the mounting research evidence regarding output capabilities of devices and typical listening behaviors of PLD users, it is clear that certain patterns of PLD use can involve high sound levels over periods of time long enough to cause hearing damage. However, despite the theoretical risk associated with PLD use, the actual risk caused by real patterns of use has proven difficult to quantify, and the results of research that examines these issues have been equivocal.

More than 30 years ago, Kuras and Findlay (1974) studied the listening patterns of self-identified rock music listeners and found that, while two-thirds of subjects selected preferred listening levels that might result in NIHL if listening persisted over sufficiently long periods of time, most subjects found it difficult to estimate typical listening durations or the time elapsed between exposures. As a result, the researchers were unable to estimate actual risk of NIHL and concluded that the risk of hearing impairment as a result of headphone use could vary considerably among listeners, depending on length and regularity of exposure. However, of note is their finding that, of 25 subjects, 2 subjects selected levels that exceeded occupational health and safety criteria for damage risk for any length of exposure time (Kuras & Findlay, 1974). Katz , Gerstman, Sanderson, and Buchanan (1982) measured the maximum output levels of 3 portable stereo systems using a sound-level meter coupled to an artificial ear and recorded intensities that ranged from 93 dB A at volume level 4 (half volume) to 115 dB A at 8 and above (full volume). They concluded that portable stereo units have the potential to induce permanent bilateral sensorineural hearing loss. Catalano and Levin (1985) surveyed 190 college students regarding preferred volume settings and weekly exposure in hours for portable cassette player use. Basing their permissible noise dose criteria on OSHA workplace standards, the authors determined that 31.4% of students met or exceeded the maximum allowable dose. Further, the authors found that, of these "at risk" students, 50% exceeded the risk criteria by more than 100%. Based on extrapolated, 10-year "auditory risk criteria", and the fact that their study only included students between the ages of 18 and 22 years, the authors speculated that those at greatest risk may be younger than 18 and that the proportion of people at risk for PLD - induced NIHL could exceed the 31.4% of the population suggested by their study. While the authors admitted that the subjective, self-reporting nature of the study left room for bias, they nevertheless concluded that PLDs posed a potential threat to hearing in young users of "Walkman" type portable stereos.

Lending support to such results are population surveys that examined the prevalence of hearing health issues in young people. A nation-wide, 10-year, cross-sectional survey of 5249 children aged 6 to 19 years that included standard audiometric and compliance testing determined that the prevalence of noise-induced hearing threshold shifts (NITS) among young people in the United States was 12.5 % (an estimated 5.2 million children) (Niskar et al. 2001). While the authors of this study did not specify the noise sources to which these children are most likely being exposed, they speculated that portable stereo use was among the more likely sources of potentially hazardous sound levels for young people. Support for such speculation may be found in surveys such as those of Zogby's International, (2006), which indicated that the majority of American high school MP3 player listeners selected "loud" to "very loud" listening levels and that 51% of these students report experiencing symptoms of hearing loss. Similarly, in a review of the literature on leisure-noise-induced NIHL, Borchgrevink (2003) quotes risk estimates of occurrence of NIHL in young people as high as 10%, and cites the results of recent audiometric surveys from various countries that place median hearing thresholds of 18-20 year-olds around +5 dB HL, not the usual 0 dB HL that would be expected in people this young (Borchgrevink, 2003).

A number of studies that measured the actual hearing impairment resulting from leisure-noise exposure seem to substantiate the disturbing trends uncovered in survey-based research. Lee et al. (1985) found temporary threshold shifts (TTS) of up to 10 dB HL in 6 of 16 subjects and 30 dB HL in one subject after listening to self-selected intensity levels for 3 hours. The fact that measurable TTS occurred after such short exposures, coupled with the finding that, across subjects, an average PLD exposure time of approximately 3 hours per day was reported, led the authors to conclude that typical listening patterns can easily exceed safe exposure times and cause noise-induced symptoms such as TTS that may precede the occurrence of NIHL.

Meyer-Bisch (1996) compared the hearing health of 54 personal cassette player users who used their devices more than 7 hours per week to 195 users who used theirs from 2 to 7 hours per week and a control group of 358 non-users. Using high-definition audiometry and a questionnaire that assessed "auditory suffering," the author found a statistically significant worsening of hearing thresholds in those young people who used a PLD more than 7 hours per week as compared to those who used PLDs 2-7 hours per week and non-users. Interestingly, no differences were found between the audiometric results of these last two groups; however, 22.5% of those subjects whose PLD use equaled or exceeded 2 hours per week reported symptoms of "auditory suffering" such as tinnitus and hearing fatigue compared to only 11.5 % of controls. Based on these results, the author indicated a moderate, but significant, hearing health risk posed by PLD use, particularly for those listeners whose PLD use exceeded 7 hours per week.

1.1.2 Overestimation of Risk?

In contrast to such findings are a series of studies reporting that the hearing risk posed by personal stereo system use is relatively minor and that risk estimates based on occupational noise dosages tend to overestimate the risk posed by the typically intermittent, short-duration noise-exposure patterns involved in PLD use. Rice, Breslin & Roper (1987) and Rice, Rossi & Olina (1987) compiled data from a series of related studies in order to examine the listening behaviours of PLD users and estimate the damage risk involved in PLD use. In the first of these studies, Breslin (1985) used a Knowles Electronics Mannikin for Acoustical Research (KEMAR) to measure the chosen output levels of 20 PLD users who listened to music in quiet and in a 70 dB (A) continuous traffic noise background. In the second study, Roper (1986) measured output levels of 41 PLD users in a variety of naturally-occurring background noise situations and interviewed subjects as to their use habits, including weekly usage estimates. A concurrent study by Rice, Rossi & Olina (1987) surveyed approx 159 Italian school children and reported average PLD usage rates of 4 hours and 3 hours per week for males and females, respectively. After pooling the data from these studies, the researchers generated individual estimations of noise dose that could be compared to free-field equivalents used in occupational noise-dosage standards. To do this, they converted raw output levels and average weekly exposures into 40-hour, work-week equivalents and calculated equivalent daily noise exposures in dB L_{Aeq} (dB L_{Aeq} takes into account both the intensity and duration of noise exposure). The resulting mean exposure level of 85 dB L_{Aeq} was found to be 10% lower than the unconverted, mean listening level measured using KEMAR. The authors considered this relatively conservative exposure level to be indicative of generally safe exposure levels for most PLD users. Additionally, the authors concluded that, although increases in mean listening levels due to the presence of background noise were significant (from 80.7 dB L_{Aeq} to 85.1 dB L_{Aeq}), background noise did not raise chosen output levels past acceptable noise dosages, and is, therefore, unlikely to increase the risk of hearing damage substantially.

Despite these generally reassuring results, the Rice, Breslin & Roper (1987) study indicated that 5% of subjects experienced levels of at least 90 dB L_{Aeq}, which was the maximum recommended daily exposure level according to occupational health standards at the time. Further, the Rice, Rossi & Olina (1987) study found that 26% of respondents reported dullness of hearing or ringing in their ears after using their PLDs. Taken in sum, the data from these studies led the authors to conclude that the adverse effects of PLD use were not grounds for serious concern for the majority of PLD users; however, they did estimate that, based on continued PLD use over a 10 year period, 1 in 1500 PCP users were at risk for hearing decrement.

In a survey of weekly hours of personal cassette player use chosen by 1443 11-18 year-old students, Bradley et al. (1987) revealed that duration of use was quite conservative, on average (75% listened < 8.75 hours/ week). A second part of this study asked 11 PLD users and 14 non-users to set their preferred listening levels for a piece of music under three conditions: as a background while reading, as the main item of interest and at the loudest level that they would regard as uncomfortably loud for 1 hour of use. Sound levels were recorded using a KEMAR artificial head and were converted into their free-field equivalents using Rice and Breslin's (1985) 1/3 octave band transfer ratio. The researchers found that subjects were relatively conservative in terms of levels selected (mean: 65 and 74 dB(A) for the background and main item of interest conditions, respectively), and that even those levels set under the "uncomfortably loud" condition were surprisingly low, (mean: 87 dB(A)). Based on these data and the typical durations of use reported in the survey, the researchers determined that average PLD levels set by youths did not approach hazardous noise dosages as determined by occupational criteria.

In research that supports the findings of the Bradley et al. and Rice et al. studies, Turanen-Rise, Flottorp and Tvete (1991) measured the output levels of five commercial PLD systems over a range of volume control settings and music types. Using free-field conversion calculations similar to those devised by Rice et al., Turanen-Rise et al. determined that, in addition to being, on average, 10 dB lower than unconverted, raw output levels, the range of free-field equivalent SPLs rarely exceeded exposure limits for industrial noise. This study also measured the TTS induced in 6 subjects after a 1 hour exposure to pop music selections that produced the highest free-field equivalent SPL (95 dB SPL) during the output level experiment. The majority of subjects recovered their pre-experimental thresholds within 20-40 minutes and all subjects had fully recovered by the next day. These findings led the researchers to conclude that occupational noise criteria contain a greater margin of safety for noise exposure incurred while listening to music through PLD devices than for industrial noise.

In a recent study of the listening levels selected by MP3 player users, Hodgetts, Rieger and Szarko (2007) reported mean ear-canal SPLs of approximately 78, 89 and 87 dB(A) for quiet, street noise and multi-talker babble noise environments, respectively (values obtained using in-ear headphones). The authors noted that, at such conservative listening levels, subjects could listen to their MP3 players for reasonably long periods of time (approximately 0-42 hours at 78 dB(A), 0-3 hours at 89 dB(A), and 0-5 hours at 87 dB(A)) before approaching maximum noise dosages. As such, the authors concluded that the preferred listening levels chosen by MP3 player users may not constitute as significant a risk to hearing as suggested by some research and popular concern.

While the aforementioned studies investigated real-life listener behaviours such as preferred listening levels and typical listening durations and environments, other studies involving audiometric testing of regular PLD users have yielded similar results that seem to indicate a minimal risk of developing NIHL as a result of PLD use. Wong, Van Hasselt, Tang and Yiu (1990) interviewed 487 youths regarding their PCP use patterns and found a mean duration of exposure of 4.5 hours per week among regular users. Mean ear canal sound levels of 70.4 dB (A) were measured and further audiometric testing of 103 of these subjects revealed no significant difference in the mean hearing threshold of users compared to non-users. Despite these reassuring results, the authors cited the 4kHz, unilateral notch found in one subject who had been listening to his PLD for 7 years for 7 hours per week at 116 dB A as possible evidence that NIHL is progressive and usually detectable only after years of exposure.

Mostafapour, Laharogoue and Gates (1996) conducted a retrospective study of the previous recreational noise exposure of 50 college students aged 18-30 years. All subjects had used a PLD for at least 1 hour per day, with an average estimated lifetime exposure of 2394 hours. After extensive audiological examination including pure tone, speech, and word recognition audiometry, the authors discovered no evidence of NIHL from PLD use in the majority of subjects. Of those subjects in whom a high-frequency audiometric "notch" indicating possible NIHL was found, the presence of notches did not correlate with histories of extensive noise exposure; as such, the notches could not be taken as unequivocal evidence of early-onset NIHL. Based on these findings, the authors speculated that noise exposure from PLDs is regulated by the self-selection of listening levels and durations that are not harmful.

1.1.3 Evidence of Hearing Damage

It is important to note that, while the audiometric findings of such studies are encouraging, other studies have used more sensitive measures of inner ear function, such as transient evoked otoacoustric emissions (TEOAEs), to assess subclinical signs of cochlear damage associated with excessive PLD listening (LePage & Murray, 1998; Mansfield, Baghurst and Newton 1999; Emmerich et al., 2002; Rosankowski, Eysholdt and Hoppe 2006). The findings of these studies lead to further concern regarding the potential for NIHL with recreational PLD use as damage incurred may be undetectable using standard pure-tone audiometry. In a 1998 investigation into the audiological records of 1724 Australians tested as part of an eight-year national research initiative, LePage & Murray used TEOAE data to determine whether cochlear damage was more prevalent in personal stereo users than non users. They found that, although declines in OAE strength were greater for older individuals, males and those exposed to industrial noise, the greatest declines in OAE strength were associated with PLD use. Surprisingly, the researchers discovered that OAE strength declined significantly, even among a "moderate" use group whose PLD exposure amounted to less than 6 hours per week. Based on such evidence, the authors concluded that even moderate use of PLDs is associated with preclinical signs of rapid cochlear aging that are comparable to those induced by industrial noise trauma. Further, based on rates of decline observed in their study, the authors estimated an accelerated decline in hearing acuity of 20% per decade, and predict an increase in the number of young adults with premature hearing loss.

Similarly disturbing trends emerged in studies by Emmerich et al. (2002), Mansfield et al. (1999) and Rosankowski et al. (2006), which demonstrated impaired outer hair cell function as evidenced by reduced TEOAE strength, as well as increased occurrence of tinnitus, in young adults who attended loud nightclubs regularly. While they did not measure the effects of PLD exposure specifically, the authors of these studies suggested that weaker TEOAEs and persistent tinnitus are signs of acoustic micro injuries to outer hair cells that occur as a result of exposure to any excessively amplified musical source, including noise exposure through the headphones of personal listening devices. Given that such acoustic "predamage" cannot be assessed using standard pure-tone audiometry (West & Evans 1990; Rosankowski et al. 2006), it is possible that many of the aforementioned studies that relied on standard audiometry to determine the presence of PLD-related NIHL have underestimated the deleterious effects of habitual PLD use by overlooking the subtler hearing decrements that occur as a result of acoustic micro injuries. In fact, such subclinical damage may even be caught by more sensitive audiometric techniques, such as those employed in a study by West & Evans (1990), in which high-resolution Bekesy tracking, rather than fixed-frequency audiometry, was used to reveal 10-15% wider bandwidths in subjects with greater degrees of exposure to amplified music.

Recent research using animal models has revealed that insidious auditory predamage can accumulate with chronic noise exposure to accelerate age-related hearing loss. Kujawa and Liberman (2006) exposed mice of varying ages to 100 dB SPL broadband noise for two hours and assessed their hearing at 2 weeks post-exposure. Surprisingly, younger mice exhibited maximum threshold shifts of 40-50 dB while older animals exhibited no change in hearing threshold, although all exposed mice demonstrated histopathology unlike unexposed mice. These findings suggest that young animals are more susceptible to noise-induced hearing damage than old and that noise exposure at an early age can cause hearing decrements that progress for extended periods of time following exposure. Applied to humans, these results may have important implications for young PLD users who listen at increased sound intensities; acoustic damage sustained following noise exposure at an early age may render the ear more vulnerable to aging, resulting in an accelerated, cumulative hearing decrement over one's lifetime.

1.2 The Current Study

The potentially detrimental effects of PLD use on the hearing health of users have been studied and debated for decades. Unfortunately, to date, the results of research examining the risks associated with PLD use are often discordant and a consensus regarding damage risk estimates continues to elude researchers. Despite the lack of unanimity regarding damage risk estimates, the majority of PLD research cites at least two factors that have the potential to generate conditions in which noise-induced hearing damage may occur: the selection of high output sound levels and listening for prolonged durations. The current study addressed the first of these factors by investigating the effects of background noise and exercise on output level selection and addressed the second of these factors by collecting PLD users' self-reported listening durations.

1.2.1 RESEARCH OBJECTIVES

The current study investigated the influence of ambient noise and exercise on listener-preferred output levels for participants using a popular, commercially-available, digital music player. All participants listened to a song in three conditions: (1) no exercise in quiet, (2) no exercise in noise, and (3) exercise in noise. The noise presented to each participant was of a type and intensity typical of busy exercise facilities and level of physical exertion was determined by maintaining target heart rate zones calculated for each participant. Sound pressure levels (SPL) in dBA were measured directly inside participants' ear canals after the output stage of the headphone drivers in each of the 3 conditions. The following research questions were of interest:

1. In comparison to a quiet condition, does the presence of ambient noise levels found in exercise facilities cause users to select higher preferred listening levels (PLLs) as measured in the participants' ear canals while at rest?

2. In comparison to a quiet condition, does the presence of exercise facility noise cause users to select higher preferred listening levels (PLLs) as measured in the participants' ear canals while exercising at 60-80% of maximum heart rate?

A secondary, qualitative component of this study investigated possible relationships between participants' answers on a listening-habits survey and the output levels they selected. The survey collected information regarding participants' pastimes, musical preferences, previous noise exposure, and digital-music player use patterns. As such, one further research question was posed:

3. Is the selection of objective output levels related to specific listening habits as reported on the survey?

2 METHODS

2.1 Subjects

Twenty-four young adults (12 males, 12 females), ranging in age from 18 to 30 (mean age: 23.4 years), responded to word-of-mouth advertising and to recruitment posters that were placed across the University of Alberta campus and sent to student email list serves. All subjects had pure-tone hearing levels better than 20 dB HL at 500, 1000, 2000, 4000 and 6000 Hz. All subjects were regular users (2 hrs +/week) of personal, portable digital music systems.

2.2 Instrumentation

2.2.1 MP3 Player and Song

A 4GB Apple iPod Nano (Markham, Ontario, Canada) was used for this study. The headphones used were those that came with the device (non-sealing ear buds). The song, “Music Sounds Better With You (radio edit)” by Stardust (Roulé, 1998), was converted from CD into MPEG1 Layer 3 (MP3) format at a bit rate of 192 kbps and was uploaded to the iPod from a computer. The song was edited by the researchers to eliminate the song’s “break down”, during which its amplitude is temporarily reduced. This song was chosen because it contains minimal amplitude fluctuations and its fast-paced, high-energy character was deemed appropriately motivating for exercise. Further, it was hoped that its immense popularity with a broad section of music listeners (as determined by Billboard charts and its ubiquitous presence on exercise facility play lists) would reduce the possibility of listeners selecting higher or lower levels based on musical preference.

2.2.2 Determining Amplitude Variation of Song

Following the technique of Hodgetts et al. (2007), the 1/12 octave band levels of the chosen song were analyzed using real-time signal analyzer software (Audioscan Verifit, Dorchester, Ontario, Canada) in order to determine the amplitude-by-frequency content of the song. The spectrum that was produced depicted a narrow range between the levels exceeded 70% of the time and the levels exceeded 1% of the time, indicating that the song's amplitude fluctuates no more than +/- 10 dB SPL on average (Figure 1). Although overall amplitude would have changed depending on the output level selected by each participant, the song's narrow dynamic range reduced the possibility of participants needing to make adjustments throughout the song to accommodate amplitude variability.

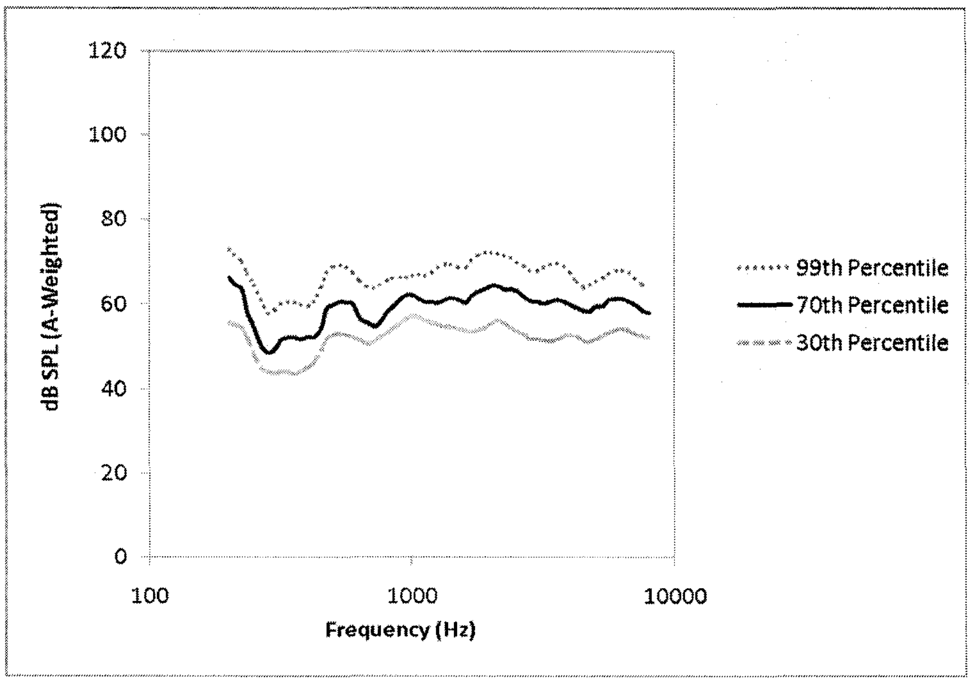

Figure 1. Amplitude-by-frequency content of the stimulus song in 1/12 octave band levels measured in dB (A). From top to bottom, lines depict the range of amplitudes that were exceeded 1%, 30% and 70% of the time.

2.2.3 Environmental Noise

Ambient noise recordings and sound level measurements were collected from the University of Alberta's Fitness & Lifestyle Centre during peak times (as determined by monthly, averaged, peak-use data made available to the experimenters). This large facility was selected because it is the busiest on campus and features a wide variety of cardiovascular training machines (including stationary bicycles, treadmills and ellipticals), weight machines and free weights that contribute to significant noise levels.

The noise was recorded in stereo wave format using an M-Audio MicroTrack 24/96 portable digital recorder and stereo electret microphone (M-Audio, Irwindale, USA). The noise sample selected for the experiment was recorded in the centre of a bank of cardio machines while seated on an exercise bicycle (which was in use while recording). It was presented to participants as a 10 second, repeating loop with no breaks or drops in amplitude. This sample was selected because of its minimum amplitude variability and because it was most representative of the noise recorded throughout the gym on various occasions.

Sound level measurements in the gyms were made using a Larson Davis System 824, integrating-averaging, digital sound level meter set to A-weighting (Larson-Davis, Provo, USA). The use of this sound level meter enabled levels to be measured continuously for 3 minutes at each location, providing the average level in dB SPL for each 3-minute span. Noise data were collected at two separate times between the peak-use hours of 17:00 and 18:00. Noise was recorded and levels were measured in seven different locations where people would most typically be found exercising: amongst cardio machines, free weights and weight machines. At each location, three separate, 3-minute measurements were taken to ensure representative data. Although locations nearest to the banks of cardio machines tended to be slightly more intense, noise levels for five of the seven locations were within 4 dB SPL of each other and averaged to approximately 75 dB SPL. The two most intense measurements were 7 and 17 dB SPL higher than the other locations; however, as they were located nearest the speakers of the gym's stereo system and on the periphery of the main exercise areas, they were not included in the average recorded noise level.

To ensure that the noise levels recorded in the Fitness & Lifestyle Centre were comparable to those of other exercise facilities, sound level measurements were made at two off-campus, public gyms and one private-membership gym during similar peak hours. SPLs measured at various locations within each of these facilities were all found to be within 5 dB SPL of the average of those collected at the Fitness & Lifestyle Centre; therefore, the average SPL taken from the latter facility was used for this study.

2.2.4 Determining Exercise Intensity Level:

The exercise condition involved pedalling a stationary exercise bicycle at 60-80% of the participant's calculated maximum heart rate for approximately 5 minutes (the duration of the song). Each participant's maximum heart rate was calculated using the following standard, widely-used formula: Max HR = 217 - (0.85 × age) (Miller et al., 1993). These calculated heart rate zones provided a rough estimate of exercise intensity that was corroborated by participants' verbal reports of perceived exertion. A Cardiosport GO15 heart rate monitor and G2 digital transmitter (Waterlooville, Hampshire, UK) were used to measure resting heart rates. During exercise, participants' heart rates were continually monitored via the Cardiosport to ensure that they were exercising at a level that was neither too easy, nor too hard (approximately 60-80% of calculated max HR).

2.2.5 Measuring Ear Canal SPL:

To measure ear canal SPL, a flexible, rubber, probe microphone was inserted into the right ear canal of each participant. The probe tube from the probe microphone was marked 30mm from the tip for adult males and 28 mm for adult females. The probe was inserted until the mark rested in each participants' inter-tragal notch; otoscopy was performed to ensure that the probe tube tip was within approximately 5mm of the tympanic membrane for all subjects. The probe microphone was connected to a real-time signal analyzer (Audioscan Verifit) that measured the user-preferred SPL in dBA for each condition. Before each experimental session, the probe microphone was calibrated according to manufacturer specifications (Audioscan, 2005) to avoid the effects of probe tube resonances, which would preclude the possibility of a flat spectrum. This calibration correction was stored in the Verifit and was applied to all subsequent microphone measures. The Verifit was set to function as a real-ear sound level meter that analyzed the input spectrum (in dB A-weighted RMS SPL) over a period of 15 seconds (Audioscan 2007).

2.2.6 Other Instrumentation

The experiment took place within a double-walled, sound-treated, audiometric booth. An Electrovoice S-40 speaker system (Burnsville, Minnesota, USA) wired to a Sony CDP-295 CD player (Toronto, Ontario, Canada) and Technics SU-V460 (Secaucus, New Jersey, USA) stereo amplifier was used to broadcast the recorded sample of gym noise. For the exercise conditions, participants pedaled a Tunturi Pro

Ergometer stationary exercise bicycle that incorporated friction resistance; riders adjusted the level of resistance by turning a dial that tightened, or loosened, a band placed around the wheel. A non-motorized exercise bicycle was chosen because it was relatively quiet compared to other exercise machines, such as motorized treadmills, ellipticals and exercise bicycles. It was hoped that a quieter exercise machine would minimize the effects of bike noise on selected listening levels in the 'exercise-in-noise' condition.

2.2.7 Survey

A 40-item (35 main questions, 5 sub-questions) listening-habits survey was administered to participants to acquire information that might relate noise-induced hearing loss to the type and degree of use of portable audio devices. Following the example of Ahmed, Fallah, Garrido, et al. (2006), items were designed to investigate a number of topics, including demographic characteristics, musical preferences, device-use habits while at rest, exercising and in different noise environments, and previous noise exposure from recreational activities (attendance at bars, movies, concerts and sporting events). Two items gave participants an opportunity to estimate the volume levels at which they typically listen to their devices while exercising and at rest. The survey in its entirety is provided in Appendix A.

2.3 PROCEDURES

2.3.1 Screening, Surveys and Instructions

Permission for all experimental procedures and documents was received from the University of Alberta's Health and Research Ethics Board and all participants signed a consent form prior to the experiment. Documents are included in the appendices. Prior to participation, a hearing screening at 20dB HL was completed for all subjects. Following this, participants were required to complete the listening habits survey. After placement of the probe microphone, participants were given the following instructions:

"The purpose of this experiment is to find your preferred listening level in noise and quiet, and while exercising in noise. You will adjust the volume on the iPod in each of four trials: while resting in the presence of noise, while resting in quiet, while exercising in noise, and while exercising in quiet. For all trials, you will hear the same song. All you have to do is adjust the volume control on the MP3 player up or down until the song sounds best to you. Do not worry about what the researchers might think of the levels you choose; there are no 'wrong' choices."

2.3.2 Listening Level Selection and Measurement

For each of the two exercise conditions, (rest and 60-80% of max intensity), participants set the output level of the iPod under two environment conditions: quiet and noise). This amounted to three conditions in total: 1. quiet without exercise, 2. gym noise without exercise, 3. gym noise with exercise. Participants proceeded through each of the 3 conditions randomly; that is, the order of the environments was counterbalanced to minimize the possibility of order effects.

Participants listened to, and selected listening levels for, the same song for each of the three conditions. The actual volume setting on the MP3 player was obscured with a plastic hood to ensure that participants were unable to use the volume display as a visual cue to determine loudness. Before each trial, the probe microphone placement was checked to ensure that it had not been dislodged and was still inserted to the appropriate depth. After each participant selected his/her listening level in each listening condition, they handed the MP3 player to one of the researchers, who then jogged the track to the same location at which he had taken measurements for all participants. Taking SPL measurements during the same point in the song for each trial ensured that measured output levels would be directly comparable across conditions and participants. At approximately 1 minute, 39 seconds into the song, the Verifit was set to begin measuring RMS ear-canal SPLs for a period of 15 seconds. This RMS amplitude measurement technique reduced the chances of obtaining an SPL value that was increased or decreased due to a momentary change in song amplitude.

2.3.3 Broadcasting Noise Sample

The noise conditions involved broadcasting the recording of the gym noise sample through a speaker placed 2 metres from, and 0 degrees azimuth to, the participant in such a way that each ear was equally exposed to the noise. The small dimensions of the audiometric booth diffused the noise in such a way as to give the impression of non-directional, ambient noise typical of gym environments. The noise sample was broadcast at an A-weighted SPL of 75 dB SPL (+/- 2 dB), which was equivalent to the average of sound levels measured at various times, in various locations in four exercise facilities. Before beginning any trials with a given participant, sound levels of the broadcasted noise sample were measured by placing a sound level meter near where the participant's head was located while seated on the bicycle. This ensured that each participant was exposed to 75 dB SPL (+/- 2dB) of noise, regardless of where his/her head was located in relation to the noise source.

2.3.4 Exercise Conditions

Prior to trials, participants were fitted with a heart rate monitor, their resting heart rates were taken and their target heart rate zones were calculated. For the exercise condition, participants were given the opportunity to warm up for a few minutes before beginning to exert themselves to achieve their target heart rate zones. As participants increased their levels of exertion by increasing the resistance on the bicycle, heart rates were checked periodically using the heart rate monitor. Once achieved, target heart rate zones were maintained by closely monitoring participants' heart rates and keeping the resistance on the bicycle consistent. Once participants were settled into their zones, the iPod was turned on with volume at 0 and they were instructed to adjust the output level of the iPod to suit them.

2.3.5 Rest Conditions

During rest conditions, as in the exercise conditions, participants listened and selected levels while seated on the bike with their heads facing forward. This ensured that their heads occupied the same space in relation to the noise source and also minimized movement that might have dislodged the microphone. Depending on the randomly-selected order of trials, it was necessary for some participants to cool down and rest for several minutes after an exercise trial to ensure that a resting heart rate and composure had returned. Before proceeding with a rest trial, participants were asked if they felt calm and at rest; this verbal report was confirmed by taking another heart rate monitor reading and comparing it to their recorded resting heart rate.

2.3.6 Outcome Measures

The study's main purposes were to collect in-ear intensity measurements and qualitative device-use data, not to detect and quantify any hearing decrement resulting from PLD use. Accordingly, no such outcome measures were used. However, as recent research has demonstrated that exposure to loud music can cause at least a temporary reduction in hearing acuity (Santos et al., 2007), it is possible that a hearing assessment administered directly after the experiment might have revealed hearing threshold shifts in some participants.

2.4 STATISTICAL DESIGN AND ANALYSIS:

2.4.1 Data Distribution

As data distributions for all conditions exhibited some positive skew, both non-parametric and parametric analyses were conducted to determine whether separate results were obtained with both types of analyses. To this end, a K-Related Samples Friedman test and a 2-related samples Wilcoxon test were performed on the data. These analyses were not discrepant with results obtained from the parametric analyses, so, for ease of comprehension, only parametric results are presented here.

2.4.2 Quantitative Data

All statistical analyses were performed using SPSS (Version 14.0, 2005). A one-way, within-subjects, repeated-measures ANOVA was conducted to analyze the data. There was one independent variable, CONDITION, with three levels: 1. quiet, 2. gym noise, 3. gym noise while exercising at 60-80% max intensity. The dependent variable was dB A-weighted RMS, ear canal SPL. The repeated-measures ANOVA was used to determine if there was a main effect for condition on selected listening levels. Prior to running the ANOVA, an independent-samples t-test was used to explore whether participants' gender influenced their PLLs. Similarly, a Pearson's correlational analysis was used to determine whether there was a relationship between participants' ages and their PLLs.

Based on the research questions listed earlier, there were three post-hoc, pairwise comparisons of interest: 1. rest-in-quiet vs. rest-in-noise, 2. rest-in-quiet vs. exercise-in-noise 3. rest-in-noise vs. exercise-in-noise. In order to test the significance of these contrasts and avoid the possibility of a Type-1 error, a Bonferonni correction was applied to the p-value of 0.05, which was divided by the number of post-hoc contrasts (3). A p-value lower than 0.017 was necessary for pairwise t-tests to be significant.

2.4.3 Qualitative Data

Descriptive statistics were calculated for responses to survey questions of particular interest. To reveal any relationships that may have existed between participants' responses and their selected output levels, participants whose responses to certain survey items were similar were grouped together. Mean PLLs were compared between these groups for each item of interest using independent samples tests with appropriate Bonferroni corrections where applicable.

3 RESULTS and DISCUSSION:

3.1 Quantitative Data

Univariate test results indicated that the main effect of CONDITION on ear canal SPL was significant; however, the assumption of sphericity was violated and the use of an epsilon correction was necessary. The Greenhouse-Geisser epsilon correction is a conservative calculation suitable for small sample sizes. The p-value resulting from this correction indicated that CONDITION had a significant effect on PLLs ($F_{(1.289, 28.359)}$ = 157.615, $p < 0.001$; partial eta squared = .873). This p-value did not differ from that of the univariate results for the sphericity-assumed calculation. The presence of 75 (+/- 2) dBA SPL gym noise presented while participants were at rest resulted in significantly higher PLLs (M = 89.3, 95% CI = 87.2 to 91.3) compared to PLLs obtained for participants at rest in the absence of noise (M = 72.1, 95% CI = 68.3 to 75.9). PLLs obtained while participants exercised in the presence of noise were significantly higher than either of those obtained for participants at rest in noise and in quiet (M = 91.8, 95% CI = 89.9 to 93.8). This information is summarized in Table 1. Figure 3 depicts the data distribution. The three pairwise contrasts and their associated significance levels are summarized in Table 2. All three of the contrasts were significant at the $p < 0.001$ level, with the greatest mean difference occurring between the rest-in-quiet and exercise-in-noise conditions.

An independent-samples t-test did not reveal any significant differences in PLLs between genders for any of the experimental conditions. A Pearson's r analysis revealed that age was not significantly correlated with PLLs in the rest-in-quiet, rest-in-noise, nor in the exercise-in-noise conditions.

Table 1. Mean Ear Canal Levels, 95% Confidence Intervals and Maximum Levels in dB A

Condition	Mean (dB A)	95% Confidence Intervals		Maximum (dB A)
		lower bound	upper bound	
Rest, Quiet	72.1 (SD=9.1)	68.3	75.9	94.4
Rest, Noise	89.3 (SD=4.9)	87.2	91.3	100.0
Exercise, Noise	91.8 (SD=4.6)	89.9	93.8	103.0

Table 2. Mean Differences (in dB A SPL), 95% Confidence Intervals and 2-Tailed Significance for Planned Pairwise Comparisons.

Pair	Mean Difference (dB A SPL)	95% CI of Difference		Sig. (2-tailed)
		Lower Bound	Upper Bound	
rest-in-quiet - exercise-in-noise	-19.78	-22.82	-16.75	<0.001
rest-in-quiet - rest-in-noise	-17.17	-20.00	-14.35	<0.001
rest-in-noise - exercise-in-noise	-2.61	-3.89	-1.33	<0.001

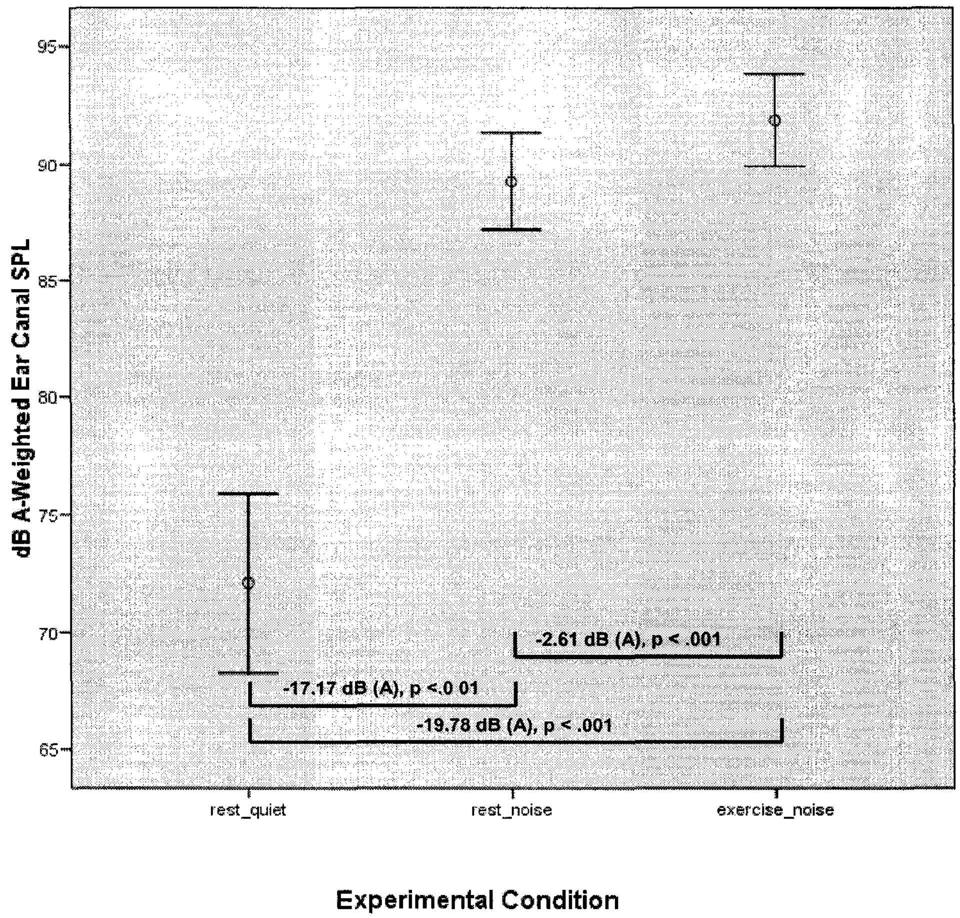

Figure 2. Means, mean differences and 95% confidence intervals for PLLs in all conditions

3.1.1 Effect Size Calculations

Effect sizes were calculated to give an indication of the strength of the experimental results using Cohen's *d* formula (Cohen, 1988):

$$d = \frac{\mathrm{mean}_1 - \mathrm{mean}_2}{\sqrt{(\mathrm{SD}_1^2 + \mathrm{SD}_2^2)/2}}$$

Using this formula, outcomes of 0.2, 0.5 and 0.8 are indicative of small, medium and large effect sizes, respectively. Large effect sizes were noted when comparing PLLs recorded in exercise-in-noise with rest-in-quiet conditions (1.9), and rest-in-noise with rest-in-quiet conditions (1.6). A smaller effect size was noted when PLLs recorded in exercise-in-noise and rest-in-noise were compared (0.4).

3.1.2 Noise Dose Calculations and Maximum Values

The mean PLLs obtained in each of the 3 conditions were used to calculate the permissible listening duration to reach 100% daily noise dose according to the following equation (NIOSH; OSHA; American Academy of Audiology, 2003):

$$T\ (\text{min}) = 480/2^{(L-85)/3}$$

Where T equals the number of minutes that can be spent at that level of exposure (L) before reaching 100% daily noise dose. For PLLs measured during experimental conditions, durations to reach maximum noise dose ranged from 157 hours, 53 minutes for the rest-in-quiet condition, to as little as 1 hour, 38 minutes for the exercise in noise condition. Table 3 lists the means, 95% confidence intervals and number of hours required to reach maximum noise dose.

Table 3. Mean Ear Canal Levels and 95% Confidence Intervals in dB A and Maximum Permissible Noise Dose in Hours.

Condition	Mean (dB A)	95% Confidence Intervals		Maximum permissible noise dose (hours)
		Lower Bound	Upper Bound	
Rest, Quiet	72.1	68.3	75.9	157.88
Rest, Noise	89.3	87.2	91.3	2.99
Exercise, Noise	91.8	89.9	93.8	1.63

Daily noise dose calculations were also performed for the highest PLLs measured during each condition. Table 4 summarizes these results.

Table 4. Maximum Ear Canal Levels Obtained for each Condition in dB A and Maximum Permissible Noise Dose in Minutes.

Condition	Maximum ear canal SPL obtained	Maximum permissible noise dose (minutes)
Rest, Quiet	94.4	60
Rest, Noise	100.0	15
Exercise, Noise	103.0	7.5

Using reported, average, single-session listening durations, it was determined how many participants would have, theoretically, met or exceeded their maximum daily noise doses given their recorded PLLs in each condition. These data are summarized in Table 5. For the rest-in-quiet condition, 1 participant would have exceeded his maximum noise dose by 30 minutes if he had continued to listen at the PLL he had chosen for his typical, reported listening durations. For the rest-in-noise condition, 7 participants would have exceeded their maximum noise doses by as much as 2.75 hours. For the exercise-in-noise condition, 8 participants would have exceeded their maximum noise doses by as much as 90 minutes. For both of the latter two conditions, 1 participant would have met, but not exceeded, her maximum allowable noise dose had she continued listening at her chosen PLL for her reported average listening duration.

Table 5. Participants Who Would Have Met or Exceeded Their Maximum Noise Doses as Calculated from Their Recorded PLLs and Self- Reported Average Listening Durations.

Condition/ Participant #	Measured PLL (dB A SPL)	Max Noise Dose (hours)	Avg. Reported Listening Duration (non-exercise) (hours)	Amount by which Noise Dose would be Exceeded (hours)
Rest-in-quiet				
Participant #20	94	1	1.5	0.5 (30 min)
Rest-in-noise				
Participant #8	96	0.6 (36 min)	1.5	0.9 (54 min)
Participant #9	95	0.8 (48 min)	1	0.2 (12 min)
Participant #10	95	0.8 (48 min)	1	0.2 (12 min)
Participant #11	95	0.8 (48 min)	1	0.2 (12 min)
Participant #12	94	1	1	0
Participant #20	100	0.25 (15 min)	3	2.75
Participant #23	91	2	3	1
Exercise-in-noise				
Participant #3	89	3.2 (192 min)	3.5	0.3 (18 min)
Participant #8	103	0.13 (7.5 min)	1.5	1.4 (82.5 min)

Participant #9	95	0.8 (48 min)	1	0.2 (12 min)
Participant #10	95	0.8 (48 min)	1	0.2 (12 min)
Participant #11	95	0.8 (48 min)	1	0.2 (12 min)
Participant #12	94	1	1	0
Participant #18	90	2.5 (150 min)	4	1.5 (90 min)
Participant #20	99	0.3 (18 min)	1.5	1.2 (72 min)

3.2 Qualitative Data

3.2.1 Portable Audio Device Use Patterns

a. Device Type:

The most popular portable audio devices amongst participants were iPods (67%), MP3 players of a variety of brands (25%), CD players (4%) and laptop computers (4%). The most common headphones used by participants were in-the-ear (67%), followed by in-canal (33%), over-the-ear (17%), on-the-ear (13%) and active-noise-cancellation (4%).

b. Frequency and Duration of Use:

In terms of weekly device usage, 13% of device users reported using their devices for ≥ 20 hours per week, 17% reported usage between 10 and 20 hours per week, 33% reported usage between 5 and 10 hours per week, 13% reported usage between 3 and 5 hours per week and 25% reported usage ≤ 2.5 hours per week. In terms of length of listening session, 13% of device users reported using their devices for ≥ 3.0 hours per session, 29% reported usage between 1.5 and 3.0 hours per session, 29% reported usage between 1 and 1.5 hours per session, and 29% reported usage ≤ 0.75 hours per session. On average, participants reported using their devices for 8 hours/week for 1.4 hours per listening session with maximum reported listening frequencies of 25 hours per week (N=1) and 4 hours per session (N=1).

21 of the 24 participants (87.5%) reported using their devices while exercising and reported listening to their devices while exercising for an average of 3.2 hours per week for 0.8 hours per listening session with maximum values of 22.5 hours per week and 1.5 hours per listening session.

c. Listening Environments

75% of all respondents reported listening to their devices while on public transit, 45% reported listening while studying or sitting in quiet, 17% listened while sleeping and 21% reported listening during other activities. 81% of exercising respondents (N=21) reported that they were most likely to use their devices while exercising in both quiet and noisy environments; 19% indicated that they exercised in noisy environments exclusively.

d. Reasons for Use

Of the exercising participants, 83% indicated that they use music played on their devices to motivate them to exercise harder; 63% use music to alleviate boredom; 58% use music to drown out background noise; 58% use music to distract them from the physical discomfort associated with exercise; 17% use music to drown out physiological noise, such as heavy breathing or a pounding heart.

e. Subjective Volume Ratings

Using a visual analogue scale (VAS) on which 0 cm equaled 0%, and 10 cm equaled 100%, of maximum "volume", participants were asked to mark where they would typically set the volume of their devices during exercise and at rest. The mean reported listening level for the "at rest" item was 48% of maximum volume (SD=20, min=12%, max=88% %). The mean reported listening level for the "exercise" item was 66% of maximum volume (SD=15%, min=26%, max=90%). In order to compare objective in-ear SPL measurements to subjective estimations of listening level, in-ear measurements were converted to percentages of the maximum measured iPod output of 103 dB SPL (with stimulus song). While the survey items did not specify whether or not listening at rest and during exercise included the presence of background noise, comparisons were made for PLLs measured in all experimental conditions based on survey data that suggested that typical device use often occurs in noisy environments (see section C. "Listening Environments"). Figure 3 depicts these comparisons as percentages of the maximum output capabilities of the device.

A Pearson's r analysis was done to determine whether subjective volume ratings were correlated with measured, ear canal PLLs. Volume ratings for device use at rest were not correlated with PLLs for any condition: rest-in-quiet (r=.259, n= 23, p=0.232, two-tailed); rest-in-noise (r=.096, n= 23, p=0.663, two-tailed); exercise-in-noise (r= -.032, n= 23, p=0.885, two-tailed). Similarly volume ratings for device use during exercise were not correlated with PLLs for any condition: rest-in-quiet (r=.136, n= 21, p=0.557, two-tailed); rest-in-noise (r= -.096, n= 21, p=0.690, two-tailed); exercise-in-noise (r= -.163, n= 21, p=0.481, two-tailed).

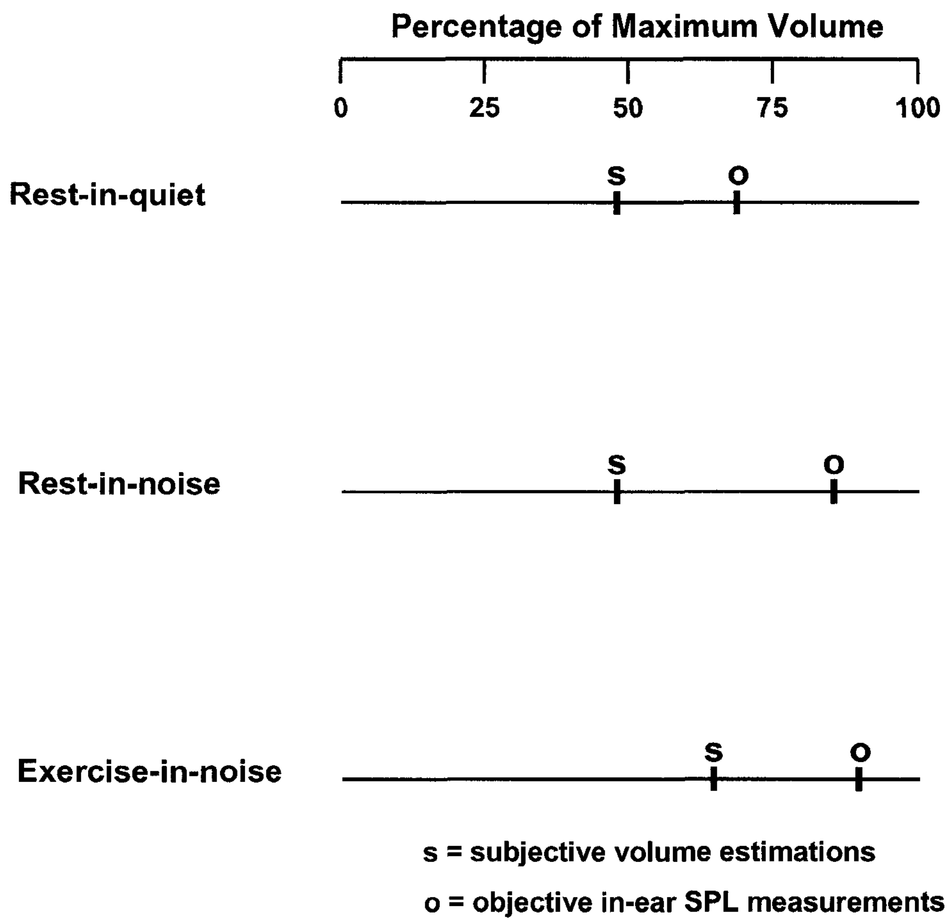

Figure 3. Comparison of average subjective estimation of volume to average objective measurement of ear-canal SPLs as percentages of maximum volume for each condition

3.2.2 Hearing Health

a. Subjective Assessment of Hearing Health

21% of all participants reported that their hearing was slightly worse than it was five years ago and 25% felt that they had a hearing loss. Of those who thought they had a hearing loss, 8% felt that it hampers their personal, social lives. It is interesting to note the discrepancy between perceived hearing deficits and actual hearing health (all participants successfully passed a hearing screening prior to participation in this experiment.)

b. Deleterious Effects of Device Use While Exercising

21 of 24 participants responded to survey items designed to probe potentially deleterious effects of audio device use during exercise. Participants were asked whether, after using their audio device while exercising, they needed to reduce the volume because it sounded too loud while at rest. 52% of these participants reported reducing the volume occasionally and 48% reported that this happened frequently. After using their device while exercising, 24% of participants reported experiencing a dull, fuzzy feeling in their ears, 19% reported that their ears felt full, 14% reported that it was hard to hear conversations, 5% reported ringing in their ears, and 5% indicated other hearing issues.

c. Noisy Recreational Activities

8 of 24 participants reported engaging in activities that involve loud sounds for an average of 3 days per week. The average duration of involvement in such activities was 4 hours at a time as reported by 7 of 24 participants. 63% of participants reported attending loud sporting events occasionally and 4% reported attending frequently. 75% of participants attended the cinema occasionally, while 17% attended frequently. 83% of participants reported attending noisy clubs for ≤ 4 hours per week, with the remainder attending more than 4 hours per week. 75% of club-goers indicated that they stayed in noisy clubs for ≤ 4 hours at a time with the remainder staying for durations of more than 4 hours. Noise levels in clubs were reported to be somewhat uncomfortable by 54% of

participants, quite uncomfortable by 29% of participants and unbearable by 4% of participants.

3.2.3 Mean Comparisons amongst Participant Groups Based on Response Patterns

Participant response patterns to survey questions enabled the authors to generate groups that could be compared using independent samples t-tests. Some of the categories used to compare participant groups were as follows: those participants who rated themselves as unfit, moderately fit and very fit; those who played in a band and those who did not; those who exercised at varying intensities; and those who differed in the levels of education they had attained. These between-group comparisons revealed no significant differences in PLLs collected during all experimental conditions. Comparisons of PLLs were also made amongst groups defined by stated musical preference; no significant differences in PLLs were found, suggesting that musical preference did not have a significant impact on selected listening levels. When the PLLs of those who engaged in loud recreational activities were compared with PLLs of those who did not, no significant differences were found, with the exception of participants who attended clubs weekly. An independent-samples t-test revealed that PLLs for the exercise-in-noise condition were significantly higher for participants who attended clubs >4 hours per week (N=4, M = 95.1, SD 2.5) than those who attended clubs <4 hours per week (N=20, M = 91.2, SD 4.7). An effect size of 0.7 was calculated for this difference using Cohen's d formula.

3.2.4 Effects of Noise

The results of this study revealed that significant increases in subject-selected output levels, or PLLs, were caused by the addition of background noise of a type and intensity similar to that of real exercise facilities. Interestingly, the variability in PLLs was significantly reduced in the noise conditions compared to that of the quiet condition, suggesting that the presence of background noise tended to increase PLLs to within a similar range, regardless of personal, idiosyncratic loudness preferences that might be indulged in quiet environments. The fact that ranges for each of the noise conditions (36, 23 and 17 dB(A) for rest-in-quiet, rest-in-noise and exercise-in-noise, respectively) were narrow compared to that of the non-noise condition suggests that the presence of background noise is capable of causing selected output levels loud enough to overcome ambient noise, regardless of what an individual's loudness preference may be in quiet. The relevance of this evidence lays in the fact that even those PLD users who would preferentially select relatively low output intensities may be "forced" into selecting much higher intensities to compete with noise intruding from their surroundings.

3.2.5 Effects of Exercise

With only two exceptions, participants selected higher output levels while exercising in noise than while resting in noise. It is important to note that the higher PLLs in the exercise-in-noise condition were not simply a function of increased ambient noise levels caused by adding bicycle-generated noise to broadcasted gym noise. This confound was avoided by taking sound level meter measurements while participants pedaled vigorously in the presence of gym noise to ensure a constant, 75 dB A SPL, ambient noise level, regardless of noise coming from the bicycle. This, in itself, can be taken as evidence that exercise alone may have some effect on increased PLLs, as PLLs for the exercise-in-noise condition should have been no higher than those for the noise alone condition if noise (which was held constant) was the only variable that had an effect. However, the effect size calculated for a means comparison between the rest-in-noise and exercise-in-noise conditions was small to medium (0.4) indicating a less robust exercise effect when compared to noise effect sizes. Some possibilities for why exercise could cause users to select higher PLLs can be found in participants' survey responses reported in the "Reasons for Use" section of the qualitative data results. Participants may have, consciously or unconsciously, increased the output of their MP3 players to provide increased motivation to exercise harder, distract themselves from physical discomfort, relieve boredom and/or overcome physiological noise associated with increased rate/depth of breathing and blood flow. To determine the reasons why exercise may cause increased PLLs, future studies will need to devise methods of quantifying abstract psychological phenomena such as motivation, boredom and discomfort and will need to find ways to isolate the physiological noises associated with vigorous activity.

3.2.6 Effects of Club Attendance

PLLs were significantly higher for participants who attended clubs for more than 4 hours per week than those who attended clubs less than 4 hours per week, but only in the exercise-in-noise condition. If increased PLLs due to subtle hearing decrements or acclimatization to loud noise are related to club attendance, it is uncertain why increased PLLs were noted in only one noise condition. Also of interest is the fact that duration of single visits to clubs did not appear to be related to increased PLLs. Increased club attendance may influence PLL selection in ways that could not be investigated in the current study.

3.2.7 Gender

Although gender differences might be expected and were observed in survey results such as those of Ahmed et al. (2006), in which more males than females preferred the highest and lowest output levels, there were no significant differences in the PLLs that each gender selected in the current study.

3.2.8 Subjective and Objective Output Levels

When measured ear canal SPLs were converted to percentages of the maximum measured iPod output (with stimulus song), it was noted that subjective estimations of volume level were discrepant with objective ear canal measurements for all experimental conditions (see Figure 3). While using their PLDs in the absence of exercise, participants reported an average subjective listening level of 48% of maximum volume, compared to the objective, ear canal means measured during the rest-in-quiet condition and rest-in-noise conditions, which were 70% and 86% of the iPod's maximum output respectively. Subjective and objective values for PLD use during exercise were similarly discrepant: participants reported an average subjective listening level of 66% of maximum volume while using their PLDs during exercise, compared to the objective mean measured during the exercise-in-noise condition, which was 89% of the iPod's maximum output.

This underestimation of loudness levels is further borne out by the fact that, regardless of condition, 20 out of 24 subjects judged their iPod volume settings to be quieter than their actual, recorded PLLs, some by as much as 50%. Such conspicuous lack of agreement between qualitative estimations and quantifiable measurements of listening levels may indicate that PLD users typically underestimate how loud they are listening to their devices. A tendency to underestimate loudness settings may lead users to base decisions regarding how long and loud they will listen to their devices on unrealistic judgments, and may cause them to neglect to exercise the caution that would otherwise prevent them from exceeding maximum noise doses.

3.2.9 Damage Risk Estimates

a. Maximum Noise Dose Calculations

Although the results of this study indicate that PLLs increase dramatically in the presence of noise and/or exercise; these results do not, in themselves, provide evidence of a potential threat to the hearing health of PLD listeners as they do not take into account listening duration. To provide such a risk estimate, duration of exposure to selected listening levels must be taken into consideration. In order to provide a rough estimate of potential risk, maximum permissible noise doses were calculated to determine at what durations listeners could safely use their PLDs given the PLLs they selected. However, as Hodgetts et al. (2006) have noted, using occupational noise dose calculations designed for free-field sound levels may not be appropriate for use with the near-field, ear canal SPLs measured in this study. Because ear canals amplify the mid-high frequencies of an incoming signal, it is possible that the maximum noise doses calculated for A-weighted levels collected in this study underestimate safe listening durations. Previous research by Rice, Breslin & Roper (1987) and Turanen-Rise, Flottorp and Tvete (1991) has suggested that raw near-field output levels are, on average, 7-10 dB (A) SPL higher than their free-field equivalents, which were generated by the application of a transfer function that corrected for the effects of ear-canal resonance. If the near-field PLL means collected in this study are equivalent to free-field means that are several dB SPL lower, noise dose calculations that assume free-field levels may overestimate the potential risk for NIHL. As such, caution should be used when considering the damage risk estimates made in this paper, which are only intended to provide a sense of the conditions under which PLD-related NIHL could occur.

b. Noise Dose Calculations for Mean PLLs

A noise dose of 158 hours was calculated for the mean PLL collected in the rest-in-quiet condition (72 dBA SPL). This does not appear to be a realistic duration for a single session of PLD use given that survey respondents reported average non-exercise and exercise listening sessions of 1.4 hours and 48 minutes, respectively. Similarly, when compared with these average reported listening durations, the noise dose of 3 hours calculated for the mean PLL collected in the rest-in-noise condition (89 dB A SPL) is only approached by 21% (n =5) of the sample who report average, non-exercise listening sessions of 2.5 hours or greater.

The noise dose calculated for the mean PLL collected in the exercise-in-noise condition (92 dB A SPL) was 1.6 hours, a duration that could be of greater concern for some PLD users. Although the average exercise session of exercising participants was reported to be only 48 minutes, a listening duration of around 1.6 hours is not entirely unrealistic when one considers that 57% of exercising participants (N=12) reported using their devices while exercising for 1 hour or more, 3 of these individuals reported 1.5 hour-long use durations, and the reported non-exercise, average listening session was 1.4 hours.

c. Above-Mean PLLs

If the possibility of reaching maximum daily noise doses with relatively low mean-output levels seems unlikely, the noise dose calculations completed for the above-mean PLLs measured during each experimental condition may provide more reasonable cause for concern. 42% (n=10) of participants selected PLLs above the means of 89 dB A SPL and 92 dB SPL for rest-in-noise and exercise-in-noise conditions, respectively. Six of these participants in the rest-in-noise condition, and all ten in the exercise-in-noise condition, chose PLLS between 93 and 103 dB A SPL, a range which corresponds to noise doses between 1.3 hours and 7.5 minutes that are within the reported average listening session of 1.4 hours. The brevity of these exposure periods suggests that thresholds for noise-induced hearing damage could be reached relatively rapidly in noisy conditions.

d. Participants Exceeding Maximum Nose Dose Criteria

As mentioned above, it is uncertain whether maximum noise doses calculated with near-field SPLs using a formula designed for free-field SPLs can be used to accurately quantify risk of NIHL. However, these calculated doses are reported to illuminate the possibility that some PLD users may reach and exceed their maximum noise doses when listening at increased sound intensities. As summarized in Table 5, for PLLs recorded in the rest-in-noise condition, seven participants would have met or exceeded their extrapolated allowable noise dose durations by an average of 31 minutes (minimum = 12 min, maximum = 165 min) had they been allowed to continue listening as long as their reported typical listening durations. For PLLs recorded in exercise-in-noise, eight participants would have met or exceeded their allowable noise dose durations by an average of 40 minutes (minimum = 12 min, maximum = 90 min). For PLLs recorded in rest-in-quiet, one participant would have exceeded his noise-dose duration by 30 minutes. While it is important to note that these damage risk estimates were calculated using self-reported estimations of average PLD-use sessions, the average reported listening durations of these "above-mean" individuals were not extreme. Excepting the three individuals who reported sessions longer than 3 hours, participants who met or exceeded maximum-noise-dose criteria reported an average PLD-use session of 1.3 hours, which is well within the total average reported listening duration of 1.4 hours. Such realistic timeframes indicate that many PLD users could reach their maximum noise doses just by using their devices in noisy environments without increasing the length of their exposure.

3.3 Study Limitations and Future Research

3.3.1 Overestimation of Risk

An occupational noise dose formula that assumes free-field levels was used to provide a rough estimate of the duration PLD users would have to listen at specified amplitudes before incurring potential hearing damage. As discussed in Results section A. "Maximum Noise Dose Calculations," noise doses calculated for near-field levels collected in this study may inaccurately portray the length of time before the potential for NIHL is present. However, this study's main purpose was to determine how the presence of exercise and/or background noise affects selected listening levels, not to generate decisive statements regarding risk. Follow-up research could replicate the research of Rice et al. (1987) and employ a transfer function derived from measurements made on a KEMAR artificial ear. Once converted into their free-field equivalents, the in-ear levels collected in this study could be used to calculate more accurate estimations of the extent to which noise doses were reached or exceeded in this experiment.

3.3.2 Homogeneity of Sample and Absence of Age Effects

Despite advertising at a number of off-campus locations, 23 of the 24 individuals who responded to the call for participants were enrolled in, or had completed, at least one year of post-secondary education. Further, all participants fell within the relatively compressed age range of 18-30 years. Given these sample attributes, it is fair to consider the possibility that this well-educated sample population obscured the variation in PLL selection. A more heterogenous sample that included a wider age-range of individuals with more varied levels of education may have yielded different results. In particular, it is interesting to conjecture whether the inclusion of younger participants would have altered mean listening levels and reported listening habits. The results of some PLD-use surveys have implied that younger individuals are more likely to listen to their PLDs at higher output intensities. For example, Ahmed et al. (2006) found that, on average, undergraduates used their devices for less time and at lower levels than high school students. Similarly, a market research survey conducted by Zogby (2006) indicated that high-school-aged students were twice as likely as adults to listen at “very loud” output levels and that adults were twice as likely as high-school students to play the volume at “low” levels. Even some of the earliest PLD researchers have speculated that the PLD users at greatest risk may be those younger than 18 (Catalano & Levin, 1985).

In light of such findings, it is noteworthy that the current study did not reveal a correlation between age and PLLs. In fact, the 9 youngest participants (age range: 18-21) selected average levels that were only slightly higher than the overall group averages (rest-in-quiet: group mean=72 dB A SPL, <22 y.o. mean= 75 dB A SPL; rest-in-noise: group mean=89 dB A SPL, <22 y.o. mean= 91 dB A SPL; exercise-in-noise: group mean=92 dB A SPL, <22 y.o. mean= 94 dB A SPL). However, although this study did not reveal a significant age effect, it is possible that the small sample size and relatively homogenous, adult age range (18-30) did not capture the variability that may be apparent in larger samples of a younger population. It is interesting to note that the three highest PLLs measured in both noise conditions were those collected from the same three participants who were all among the youngest age range (19-21 years). Future studies could investigate a possible upward trend in PLLs as age decreases by sampling from a broader age range that includes individuals younger than 18 years old.

3.3.3 Isolating Exercise Effects

Originally, the authors had hoped to isolate the effects of exercise by having participants select levels while exercising in quiet. However, pilot testing revealed that finding a suitable physical activity that generated little or no noise was very difficult. Thus, no truly noiseless, exercise-only, condition could be simulated. In lieu of finding and using a noiseless exercise activity, future studies of this kind could run another experimental condition to isolate the effects of exercise. This could be achieved by, first, measuring the noise levels generated by the exercise method for each participant, second, recording a sample of the exercise-generated noise and, third, broadcasting this sample to participants while they selected PLLs without exercising. If non-exercising participants exposed to exercise-generated noise selected levels lower than those they selected while exercising in the same noise, the results would suggest that exercise had an independent effect on PLLs. Future work should include this condition.

3.3.4 Noise Dose Calculations Based on Maximum Output

Authors 1 and 2 of this paper tested the maximum sound pressure levels achievable with this study's iPod/headphone/song combination in their own ears and noted that the maximum PLL selected in the exercise-in-noise condition corresponded to the authors' ear canal SPLs measured with the iPod's 'volume' set to maximum (103 dB A SPL). In fact, three individuals in the exercise-in-noise condition, and one in the rest-in-noise condition, selected PLLs within 4 dB of the iPod's maximum output capabilities for the stimulus song. Further, the fact that one individual listened at the iPod's maximum output raises the question of whether a ceiling effect inhibited this individual's PLL selection. As a result, the authors were curious as to whether it was possible that even higher SPLs could be obtained at maximum output for pieces of music exhibiting higher amplitudes and/or greater amplitude variability. To determine this, ear canal SPLs were measured in each experimenter's ear, with the iPod/speaker output set to maximum, for two other popular songs belonging to the same era as that used in the experiment. The maximum levels obtained for these songs were considerably louder than the level obtained for the experimental song, leading to dramatically reduced permissible noise dose durations. For the stimulus song, "Music Sounds Better With You (radio edit)" by Stardust, (Roulé, 1998), a maximum, ear canal SPL of 103 dB SPL was obtained, at which intensity, maximum permissible noise dose would be reached in 7 min, 30 sec. For the other two songs, "Clocks" by Coldplay (Parlophone, 2003) and "Beautiful Day" by U2 (Interscope, 2000), the maximum ear canal SPLs obtained were 108 dB SPL and 111 dB SPL, respectively. The durations to reach maximum noise dose calculated for each of these ear canal levels were 0.04 hrs (2 min, 39 sec) and 0.02 (1 min, 11 sec), respectively.

Given such increased loudness and reduced lengths of duration to reach maximum noise doses, one can only speculate that, had songs with higher RMS amplitudes been used for this experiment, individuals who preferred listening to the iPod at, or very near, its maximum output capabilities might have registered even higher ear canal SPLs across all experimental conditions. Future research should use songs with varying RMS amplitudes to determine whether some individuals will listen at maximum device output regardless of loudness level.

4 CONCLUSIONS

It is, perhaps, inevitable that at least some of the PLD-using population will use their devices excessively to the detriment of their hearing health and this study may have identified several such "extreme" PLD users. A number of users selected lower volumes under quiet conditions, but increased their volume settings under gym-noise conditions to the extent that they could have reached their maximum noise doses had they been allowed to continue listening for the average durations they reported on the survey. Remember that, as in-ear loudness levels increase, the length of time required to reach maximum noise dose thresholds decrease. This study identified 4% (n=1) of participants in rest-in-quiet, 30% (n=7) of participants in rest-in-noise and 33% (n=8) of participants in exercise-in-noise who might be at risk of reaching or exceeding their maximum noise doses if they had continued to listen at their selected PLLs for the session durations they reported on the survey. If these percentages can be extrapolated to the general PLD-using population, considerable percentages of listeners might be at risk of reaching maximum noise doses if they listen in noisy environments typical of exercise facilities.

Importantly, the effects of noisy environments on PLLs are not limited to users who choose above-average PLLs and/or listening durations. All participants increased their PLLs from those they selected while at rest in quiet when exposed to gym noise by an average of 17 dB A SPL and all but 2 increased their PLLs by an average of 20 dB A SPL when exposed to gym noise while exercising. Further, it is important to note that using a PLD in a gym is only one example of a noisy environment that may be encountered while using PLDs. Other PLD-use scenarios, such as listening while at work, commuting or engaged in other leisure activities, may constitute environments in which noise levels may approach or exceed those found in typical exercise facilities. If this is the case, the average reported "non-exercise" listening duration of 1.4 hours may be of concern if PLD users are choosing levels similar to those they chose in the presence of gym noise. As 1.4 hours is a safe listening duration only for loudness levels below 92.5, it is concerning that 30-40% of participants listened above this level under noise conditions. Extrapolated to the general population, this finding may suggest that a considerable percentage of PLD-users may be at risk of reaching maximum noise doses if they listen in noisy environments similar to those found in exercise facilities, regardless of whether or not they are exercising.

That PLD users may be placing themselves at risk of NIHL in noisy exercise environments is cause for concern, particularly when one considers the percentages of participants who reported deleterious effects after using their devices. Recall that, after using their devices while exercising, 24% of participants reported experiencing a dull, fuzzy feeling in their ears, 19% reported that their ears felt full, 14% reported that it was hard to hear conversations, 5% reported ringing in their ears, and 5% indicated other hearing issues. Coupled with the fact that 25% of participants felt they had a hearing loss (8% of whom report that it hampers their social lives), a disturbing picture of potential NIHL in PLD-users begins to emerge. Given the typical durations of use, the in-ear amplitudes these devices can generate and the types of noisy environments in which use often occurs, PLD users need to be made aware of the potential for NIHL that these devices present. The widespread popularity of PLDs may indicate a need for an equally widespread education campaign regarding the listening levels and noisy environments that have the potential to compromise hearing health when using these devices.

4 REFERENCES

Ahmed, S., Fallah, S., Garrido, B., Gross, A., King, M., Morrish, T., et al. (2006). Use of portable audio devices by university students. Submitted for publication.

American Academy of Audiology. Position Statement: Preventing noise-induced hearing occupational hearing loss. October, 2003. Available at http://www.audiology.org/professional/positions/niohlprevention.pdf. Accessed February,15, 2006.

Audioscan. (2005). Verifit® VF-1 real-ear hearing aid analyzer user's guide: Version 2.4.1. Dorchester, Ontario.

Biassoni, E. C., Serra, M. R., Richter, U., Joekes, S., Yacci, M. R., Carignani, J. A., et al. (2005). Recreational noise exposure and its effects on the hearing of adolescents.Part II: Development of hearing disorders. *International Journal of Audiology, 44,*74-85.

Borchgrevink, H. M. (2003). Does health promotion work in relation to noise? *Noise & Health, 5*(18), 25-30.

Bradley, R., Fortnum, H., & Coles, R. (1987). Research note: patterns of exposure of schoolchildren to amplified music. *British Journal of Audiology, 21,* 119-125.

Carter, N., Murray, N., & Bulteau, V. (2000). Amplified music, recreational noise and hearing in people aged 16-21 and 28-33 years. *Australian Journal of Audiology, 7*(2), 79-83.

Carter, N. L., Waugh, R. L., Keen, K., Murray, N., & Bultrau, V.G. (1982). Amplified music and young people's hearing. *The Medical Journal of Australia, 2,* 125-128.

Catalano, P. J., & Levin, S. M. (1985). Noise-induced hearing loss and portable radios with headphones. *International Journal of Pediatric Otorhinolaryngology, 9,* 59-67.

Chung, J. H., Des Roches, C. M., Meunier, J., & Eavey, R. D. (2005). Evaluation of noise-induced hearing loss in young people using a web-based survey technique. *Pediatrics, 115,* 861-867.

Clark, W. W. (1991). Noise exposure from leisure activities: A review. *Journal of the Acoustical Society of America, 90*(1), 175-179.

Clark, W. W. (1992). Hearing: the effects of noise. *Otolaryngology-Head & NeckSurgery, 106*(6), 669-675.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Erlbaum

Crandell, C., Mills, T. L., & Gauthier, R. (2004). Knowledge, behaviors, and attitudes about hearing loss and hearing protection among racial/ethnically diverse young adults. *Journal of the National Medical Association, 96*(2), 176-186.

Emmerich, E., Richter, F., Hagner, H., Giessler, F., Gehrlein, S., & Dieroff, H. (2002). Effects of discotheque music on audiometric results and central acoustic evoked neuromagnetic responses. *International Tinnitus Journal, 8*(1), 13-19.

Fligor, B. J., & Cox, L. C. (2004). Output levels of commercially available portable compact disc players and the potential risk to hearing. *Ear & Hearing*, 25(6), 513-527.

Ferrari, J. R., & Chan, L. M. (1991). Interventions to reduce high volume portableheadsets: “Turn down the sound.” *Journal of Applied Behavior Analysis, 24,* 695-704.

Hodgetts, W. E., Reiger, J.M., Szarko, R.A. (2007). The effects of listening environment and earphone style on preferred listening levels of normal hearing adults using an MP3 player. *Ear and Hearing*, 28(3), 290-297.

Katz, A.E., Gerstman, H.L, Sanderson, R.G, Buchanan, R. (1982). Stereo headphones and hearing loss. *New England Journal of Medicine*, 307, 1460-1.

Kujawa, S. G., & Liberman, M. C. (2006). Acceleration of age-related hearing loss by early noise exposure: Evidence of a misspent youth. *The Journal of Neuroscience, 26*(7), 2115-2123.

Kuras, J. E., & Findlay, R. C. (1974). Listening patterns of self-identified rock music listeners to rock music presented via earphones. *Journal of Auditory Research,14,* 51-56.

Lee, P. C., Senders, C. W., Gantz, B. J., & Otto, S. R. (1985). Transient sensorineural hearing loss after overuse of portable headphone cassette radios. *Otolaryngology Head and Neck Surgery, 93*(5), 622-625.

Lees, R. E. M., Hatcher Roberts, J., & Wald, Z. (1985). Noise induced hearing loss and leisure activities for young people: A pilot study. *Canadian Journal of Public Health, 76,* 171-173.

LePage, E. L., & Murray, N. M. (1998). Latent cochlear damage in personal stereo users: A study based on click-evoked otoacoustic emissions. *Medical Journal of Australia*, 169(11-12), 588-592.

Mansfield, J. D., Baghurst, P. A., & Newton, V. E. (1999). Otoacoustic emissions in 28 young adults exposed to amplified music. *British Journal of Audiology, 33,* 211-222.

Meyer-Bisch, C. (1996), Epidemiological evaluation of hearing damage related to strongly amplified music (personal cassette players, discotheques, rock concerts) – high definition audiometric survey on 1364 subjects. *Audiology*, 35, 121-142.

Mostafapour, S. P., Lahargoue, K., & Gates, G. A. (1998). *The Laryngoscope, 108*(12), 1832-1839.

National Institute for Occupational Safety and Health (NIOSH). Criteria for a recommended standard: Occupational noise exposure, revised criteria. Pub. No.98-126; Cincinatti: NIOSH; 1998.

Niskar, A.S., Kiesak, S.M., Holmes, A.E., Esteban, E. Rubin, C., Brody, D.J., et al. (2001) Estimated Prevalence of Noise-Induced Hearing Threshold Shifts Among Children 6 to 19 Years of Age: The Third National Health and Nutrition Examination Survey, 1988-1994, United States. *Pediatrics,* 108; 40-43.

Rice, C. G., Breslin, M., & Roper, R. G. (1987a). Sound levels from personal cassette players. *British Journal of Audiology*, 21(4), 273-278.

Rice, C. G., Rossi, G., & Olina, M. (1987). Damage risk from personal cassette players. *British Journal of Audiology, 21,* 279-288.

Sadhra, S., Jackson, C. A., Ryder, T., & Brown, M. J. (2002). Noise exposure and hearing loss among student employees working in university entertainment venues. *Annals of Occupational Hygiene, 46*(5), 455-463.

Santos, L., Morata, T.C., Jacob, L. C., Albizu, E., Marques, J.M., Paini, M. (2007). Music exposure and audiological findings in Brazilian disc jockeys. *International Journal of Audiology*, 46, 223-231.

Serra, M. R., Biassoni, E. C., Richter, U., Minoldo, G., Franco, G., Abraham, S., et al. (2005). Recreational noise exposure and its effects on the hearing of adolescents. Part I: An interdisciplinary long-term study. *International Journal of Audiology, 44,* 65-73.

Turunen-Rise, I., Flottorp, G., & Tvete, O. (1991). Personal cassette players ('walkman'). Do they cause noise-induced hearing loss? *Scandinavian Audiology, 20*, 239-244.

West, P. D. B., & Evans, E. F. (1990). Early detection of hearing damage in young listeners resulting from exposure to amplified music. *British Journal of Audiology, 24,* 89-103.

Williams, W. (2005). Noise exposure levels from personal stereo use. *International Journal of Audiology, 44,* 231-236.

Wong, T. W., Van Hasselt, C. A., Tnag, L. S., & Yiu, P. C. (1990). The use of personal cassette players among youths and its effects on hearing. *Public Health, 104*, 327-330.

Zogby International. Survey of Teens and Adults about the Use of Personal Electronic Devices and Head Phones. March 14, 2006. Available at: *http://www.asha.org/NR/rdonlyres/10B67FA1-002C-4C7B-BA0B-1C0A3AF98A63/0/zogby_survey2006.pdf.* Accessed March 20, 2006.

Appendix A. Portable music player use and listening habits survey.

The following survey is designed to gather information regarding your hearing health, exposure to noise and music/ MP3-player listening habits. Information collected here will be used for the purposes of this experiment alone and will be kept confidential.

NAME: ____

BASIC DEMOGRAPHIC INFORMATION:

1. What is your gender? (please circle)

- Male
- Female

2. What is your age? __________

3. What level of education have you had? (please circle)

- Less than high school
- High school
- Post Secondary Undergraduate (please circle how many years)

  1 yr   2 yrs   3 yrs   4 yrs   >4 yrs

- Post secondary graduate (please circle)

  Master's   PhD.

4. Have you ever received any training or information about factors that cause hearing loss and/or unsafe noise levels? If so, what?

____

____

HEARING HISTORY:

5. After being exposed to loud sound, do you ever experience the following:

(circle all that apply)

- "dull" or "fuzzy" feeling in your ears?
- A feeling like your ears are full?
- A ringing in your ears?
- That it is hard to hear what people are saying?
- Other hearing issues? ___________________

6. Do you have persistent ringing in your ears, even when you haven't been exposed to recent loud sounds? (please circle) YES NO

7. How do you rate your hearing compared to five years ago? (please circle)

Much Worse Slightly Worse Same Much Better

8. Do you think you have a hearing loss? (please circle) YES NO

If you answered NO to question # 8, proceed to question # 11.

9. If you think you do have a hearing loss, what do you think is the cause?

(please circle)

- Noise-induced
- Present at birth
- Illness or drug side effect
- Age-related
- Other ______________

10. If you think you have a hearing loss, do you feel that your difficulty with hearing limits or hampers your personal or social life? (please circle)

Never Occasionally Frequently

LEISURE ACTIVITIES:

11. a) Do you participate in activities that involve loud sounds, such as using firearms, power tools, driving ATVs, snowmobiles, etc? If so, please specify which activities:

____

b) How many days of the week are you typically engaged in such activities?

____

c) For how long at a given time? ____________

12. How often do you attend professional sporting events? (please circle)

Never Occasionally Frequently

13. How often do you attend the cinema? (please circle)

Never Occasionally Frequently

14. a) Please estimate how often you attend clubs, bars or concerts in which loud music is played? ____________hours/week

b) How long do you typically stay in these clubs and/or bars at one time?

____

c) Would you characterize the noise level in the clubs/ bars you attend as uncomfortably loud? (please circle)

Not at all Somewhat Quite uncomfortable Unbearable

15. a) Do you play an instrument or sing in a music band? YES NO

b) If so, what instrument?___________ c) What type of music?___________

d) How often do you practice or perform with the band? ______hours/ week

16. a) While attending clubs/ bars, sporting events, playing in a band or engaging in any other activity that involves loud sounds, how often do you use hearing protection, such as foam earplugs? (please circle)

Never Occasionally Frequently

b) If yes, in what situations do you most use hearing protection?

(please circle)

- Concerts
- Sporting events
- Clubs/ bars
- Other __________

PORTABLE MUSIC PLAYER USE:

17. What genres of music do you listen to most frequently while using your portable music player? (please circle)

- Hip Hop
- Electronic
- Jazz
- Rock
- Pop
- Alternative
- Punk
- Heavy Metal
- Other _______________

18. What brand/ model of portable music player do you use? _______________

19. What type of earphones do you use? (circle all that apply)

- Over the ear (covers the entire ear)
- On the ear (sits on top of the ear)
- In the ear (rests inside the ear, but not in the canal)
- In the ear canal (rests inside the canal itself)
- Earphones with active noise cancellation technology
- Other_______________

20. a) Do you ever use the equalizer settings on your portable audio device?

YES NO

b) If yes, please indicate what setting you use or how you modify the sound (i.e. turn up/ down the bass, etc.)___________________

21. How often do you use your portable music player? __________hours/ week

22. In a typical listening session, how long do you use your portable music player continuously? ______________

23. Please specify the environments in which you use your portable music player:

- Public transportation/ commuting
- While exercising
- While studying or sitting in quiet
- While sleeping
- Other______________

24. If you use your portable music player while exercising, please indicate in which of the following situations you would most likely use your portable music player: (circle all that apply)

- While exercising in relative quiet
- While exercising in busy exercise facilities or other noisy environments
- While exercising in quiet environments
- Other_______________

25. If you use your portable music player while exercising, how long is your average listening session? ____________

26. How many hours per week do you listen to your player while exercising?

____________hours/ week

27. Do you listen to different genres of music on your portable music player while exercising than when not exercising? If so, which ones? (please circle)

- Hip Hop
- Electronic
- Jazz
- Rock
- Pop
- Alternative
- Punk
- Heavy Metal
- Other ______________

28. If you use your portable music player while exercising, do you use the music to: (circle all that apply)

- Drown out environmental background noise
- Drown out the sound of your breathing, heart pounding, etc.
- Distract you from physical discomfort
- Motivate you to work harder
- Alleviate boredom
- Other___________

29. On a scale from 0-100, in which 100 represents maximum volume, to what level would you typically set the volume of your portable music player when you are NOT exercising? (please mark on the line)

____

0 25 50 75 100

30. On a scale from 0-100, in which 100 represents maximum volume, to what level would you typically set the volume of your portable music player when you ARE exercising? (please mark on the line)

____

0 25 50 75 100

31. Do you ever find that, when you're done using your portable music player after exercise, you need to turn down the volume because it sounds too loud? (please circle)

Never Occasionally Frequently

32. After using your portable music player while exercising, do you ever experience the following: (circle all that apply)

- "dull" or "fuzzy" feeling in your ears?
- A feeling like your ears are full?
- A ringing in your ears?
- That it is hard to hear what people are saying?
- Other hearing issues? __________________

33. At what intensity do you most often exercise? (please circle)

Easy	Moderate	Hard	Very Hard
(0-30%)	(30-60%)	(60-80%)	(80-100%)

34. How often do you exercise? (hours/week) _______________

34. What type of exercise do you do most often?

Treadmill Running   Outdoor running   Weight lifting

Exercise Bicycle   Outdoor cycling   Team sports: ______________

Cardio machines (ellipticals, stair climbers, rowers, etc.)

Others:______________

35. **How physically fit would you say you are? (please circle)**

Not fit   Moderately fit   Very fit

Appendix B. Letter of Information

Information for Participants:

Title: **The Effects of Ambient Noise and Physical Exertion on User-Preferred Listening Levels While Using a Personal MP3 Player**

Principal Investigator: **Ryan Szarko, B.A.**

Supervisor: **Bill Hodgetts, M.Sc., Reg. ACSLPA**

Location: **Corbett Hall Audiology Lab (1-108)**

Background:
Sales of MP3 players have grown rapidly in recent years and their use is now widespread, particularly among people who use them while exercising. As many people use MP3 players while exercising in gyms and other exercise facilities, we want to study the ways in which listeners use their MP3 players in such environments.

Purpose:
You are invited to take part in a study to determine how exercise and typical gym noise effect the way you use your MP3 player.

Procedures:
If you agree to participate, you will be asked to listen to a song on an MP3 player in 2 different environments (1. in quiet; 2. with pre-recorded gym noise), and in 2 different exercise scenarios (1. while sitting quietly; 2. while pedalling a stationary exercise bicycle at a moderate-to-high intensity for 5 minutes). In total, there will be 4 separate trials: 1. quiet without exercise, 2. quiet with exercise, 3. gym noise without exercise, 4. gym noise with exercise. A heart rate monitor will be attached around your chest to measure your resting heart rate; during exercise, your heart rate will be continually monitored to ensure that you are exercising at a level that is neither too easy, nor too hard (approximately 70-90% of your maximum heart rate). You can expect to pedal the bike at this intensity for 2, 5-minute segments, plus 1, approximately 5-minute, warm-up segment. A tiny, flexible microphone will be placed in your ear canal to measure the volume you like the best for each of the 4 trials. Your only task is to adjust the volume of the MP3 player up or down until it sounds best to you. You will not be judged based on the volume levels you choose; there are no "right" or "wrong" volume selections. You will not be able to see the volume meter of the device. Following the experiment, you will be asked to complete a short survey that includes questions regarding your typical MP3 player listening habits (ex. "how often do you use your player?; for how long?; in what environments?"). We expect the entire experiment to take only 45 minutes of your time.

Possible Benefits:
You will help us better understand the influence of typical gym environments and exercise on MP3 player use and will learn about your own use habits.

Possible Risks:
You may feel mildly fatigued during the exercise portion of the experiment, as you will be asked to pedal a bike at a moderate-to-high intensity for two, 5 minute sessions.

Confidentiality:
Personal records relating to this study will be kept confidential. Any research data collected about you during this study will not identify you by name, only by your initials and a coded number. Your name will not be disclosed outside the research clinic. Any report published as a result of this study will not identify you by name.

The information collected as part of this study will be kept confidential and will be used only for the purpose of the research study.

Voluntary Participation:
You are free to withdraw from the research study at any time, and your continuing education will not be affected in any way. If the study is not undertaken or if it is discontinued at any time, the quality of your education will not be affected. If any knowledge gained from this or any other study becomes available which could influence your decision to continue in the study, you will be informed promptly.

Study Results:
The information gathered for this study may be looked at again in the future to help us answer other research questions. If so, an ethics board will first review any proposed future use of your data to ensure the information is used ethically.

Study Contacts:

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Additional Contact:
If you have concerns about how this study is being conducted and wish to speak with someone who is not involved with this study, please contact Glenn Griener, Chair of the Health Research Ethics Board (Panel B) at (780) 492-0302.

Appendix C. Recruitment Poster

MP3 Player Experiment:

STUDY PARTICIPANTS NEEDED

- ARE YOU BETWEEN THE AGES OF 18 AND 30?
- DO YOU USE A PORTABLE AUDIO DEVICE WITH EARPHONES (CD PLAYER, MP3 PLAYER, RADIO, WALKMAN, ETC.) FOR 2 OR MORE HOURS PER WEEK ON AVERAGE?
- DO YOU EXERCISE REGULARLY? (3 OR MORE TIMES PER WEEK)
- ARE YOU PHYSICALLY FIT ENOUGH TO PEDAL A STATIONARY BICYCLE FOR APPROXIMATELY 10-15 MINUTES AT MODERATE-TO-HIGH INTENISTY?

If you answered yes to the above questions, you are eligible to participate in a study investigating the effects of gym environments and exercise on MP3 player listening levels.

The study will involve listening to music on an iPod Nano and setting the volume while exercising at 60-80% max heart rate and at rest. A tiny microphone will be placed in your ear to record the levels you choose.

The study will take 45 minutes to 1 hour of your time and will be conducted at Corbett Hall on the south end of campus.

IF INTERESTED, PLEASE CONTACT:

Ryan Szarko

Master's student, Department of Speech Pathology and Audiology