The purpose of this study was to examine the relation between hearing levels and listening habits related to the use of portable listening devices (PLDs) in adults. Duration of PLD use was estimated and volume level in both quiet and noisy environments were directly measured. Biomarkers of cardiovascular health and fitness were also co-factored into the analyses. In total, 67 subjects, ages 30 to 84, participated in this study. Subjects were divided into two sub-groups, PLD users and non-PLD users. Subjects completed audiological and cardiovascular health and fitness tests. Results were analyzed using classification trees to determine trends from contributing variables to hearing sensitivity. Although being a PLD user was not predictive of hearing thresholds, age was a factor. Individuals listened to their PLDs at a higher volume when in a noisy environment versus a quiet setting. Finally, body mass index and waist-to-hip ratio showed trends towards better hearing thresholds.
PERSONAL LISTENING DEVICE USE, HEARING, HEALTH AND FITNESS

A Thesis
Submitted to the
Faculty of Miami University
in partial fulfillment of
The requirements for the degree of
Masters of Arts
Department of Speech Pathology and Audiology
by
Sarah Elizabeth Wagner
Oxford, OH
2013

Advisor: ________________________________
(Kathleen Hutchinson, Ph.D.)
Reader: ________________________________
(Helaine Alessio, Ph.D.)
Reader: ________________________________
(Laura J. Kelly, Ph.D.)
Table of Contents

Introduction ......................................................................................................................... 1
Aims ..................................................................................................................................... 3
Design and Methods ......................................................................................................... 4
Results ............................................................................................................................... 7
Discussion .......................................................................................................................... 12
Conclusion ......................................................................................................................... 14
Appendices ....................................................................................................................... 15
References .......................................................................................................................... 35
List of Tables

Table #1 .................................................................................................................................32
Table #2 .................................................................................................................................32
Table #3 .................................................................................................................................32
Table #4 ..................................................................................................................................33
Table #5 ..................................................................................................................................33
Table #6 ..................................................................................................................................33
Table #7 ..................................................................................................................................33
Table #8 ..................................................................................................................................34
Table #9 ..................................................................................................................................34
Table #10 .................................................................................................................................34
Table #11 .................................................................................................................................34
Table #12 ..................................................................................................................................34
List of Figures

Figure #1 .................................................................................................................................15
Figure #2 .................................................................................................................................17
Figure #3 .................................................................................................................................18
Figure #4 .................................................................................................................................20
Figure #5 .................................................................................................................................21
Figure #6 .................................................................................................................................22
Figure #7 ................................................................................................................................23
Figure #8 ................................................................................................................................24
Figure #9 ................................................................................................................................25
Figure #10 .................................................................................................................................26
Figure #11 ................................................................................................................................27
Figure #12 ................................................................................................................................28
Figure #13 ................................................................................................................................29
Figure #14 ................................................................................................................................30
Introduction

Prevalence/Incidence

Hearing loss is the third most prevalent chronic health condition within the adult population in the United States (Hull & Kerschen, 2010). Seventeen percent of adults between the ages of 20 and 69-years-old have some degree of hearing deficit (Center for Disease Control and Prevention, 2010) typically caused in part by noise exposure. In the past 30 years, the prevalence of hearing loss has almost doubled and is expected to double again by 2050 (Hull & Kerschen, 2010). Increased incidence of noise induced hearing loss (NIHL) can be attributed to an increase in the existence of environmental noise in society and a rise in the amount of leisure noise. Advancements in technology have led to increasingly smaller portable listening devices (PLDs), in turn allowing for a convenient, continuous source of leisure noise (Henry & Foots, 2012). In addition to presbycusis, hearing loss due to aging, noise exposure can contribute to the increased incidence of hearing impairment by negatively influencing hearing thresholds. (Fausti, Wilmington, Helt, Helt, & Konrad-Martin, 2005; Hull & Kerschen, 2010). Social engagements, communication environments, and occupational settings can all include noise levels, which are dangerous enough to negatively influence an individual’s hearing thresholds.

Personal Listening Devices

NIHL is a preventable sensorineural hearing loss which begins with a high frequency deficit and occurs gradually as the result of chronic noise exposure (Petrescu, 2008). Non-occupational noise exposure, also known as leisure noise, has increased in the past 20 years due in part to the increase in popularity of listening to music with PLDs (Henry & Foots, 2012) and listening at loud music levels (McCormick & Matusitz, 2010). While The Occupational Safety and Health Administration (OSHA) guidelines limit noise exposure in the occupational setting, few, if any, such restrictions exist in the non-occupational or leisure setting (Dalton, Cruickshanks, Wiley, Klein, B., Klein, R., & Tweed, 2001). Children are also exposed to many types of noises that exceed the U.S. National Institute of Occupational Safety and Health (NIOSH) Noise Criteria Document standards for harmful listening levels in school situations, such as in band practice, shop class, athletic events, and dances (NIOSH, 1998). Additionally, adults are exposed to harmful listening levels at concerts, fireworks, construction sites, firearms, and the subway (Center for Disease Control and Prevention, 2010). Dalton et al. (2001) examined 4,541 individuals, ages 48 to 92, and found that 98.9% reported participating in at least
one harmful listening activity for at least one year in their lifetime. Music listening has become the primary cause of non-occupational noise induced hearing loss. Average sound levels at dance and music clubs typically range from 95 to 107 dBA (Zhao, Manchaiah, French, & Price, 2010) which if in an environment of 94 dBA for one hour or more, exceeds safe listening levels (NIOSH, 1998).

Excessive use of PLDs with earbuds has the capability of causing both temporary and permanent hearing loss by inflicting damage to the cochlea (Fallon, 2010). In a temporary threshold shift, the stereocillia of the ear lose their stiffness and become flaccid, while a permanent threshold shift occurs when the stereocillia die. With continued exposure to loud noise, more stereocillia die and as a result, the cochlea no longer functions properly (Gelfand, 1998). Personal listening devices have the potential of producing output levels as high as 128 decibels (dB)A, with typical PLD users listening at levels between 75 dBA and 110 dBA (Daniel, 2007; Fligor & Cox, 2004). While the majority of PLD users listen within the safe listening range, 15%-25% of PLD users exceed the safe listening levels (Berger, Megerson, & Stergar, 2009). When determining harmful listening levels, both volume and listening duration must be taken into account (Henry & Foots, 2012; McCormick & Matusitz, 2010). NIOSH stated that determined sounds exceeding 85 dBA for 8 hours or more is considered to be hazardous to an individual’s hearing (Daniel, 2007). Many PLD users listen to music in noisy environments, which also contributes to higher dB output (Berger et al., 2009) because PLD users tend to turn up the volume of the PLDs to block out background noise (Zhao et al., 2010). With earbud output levels reaching 110 dBA, individuals have the capability of turning their PLDs up to harmful listening levels.

*Hearing Preservation*

PLD users tend to be naïve and unaware of hearing loss that can result from excessive PLD use (Epstein, Marozeau, & Cleveland, 2010). There are several uncontrollable factors leading to hearing loss including genetics, age, gender, and race (Daniel, 2007; Fausti et al., 2005). While some amount of hearing loss is common with increased age, men are twice as likely to suffer hearing loss as they age than women (Fausti et al., 2005). Individuals can take preventative measures against hearing loss with the use of hearing protection, avoiding smoking, adequate exercise, balanced diet (Daniel, 2007), and monitoring exposure to dangerous listening levels.
Hearing loss prevention programs exist to attempt to lessen the occurrence of NIHL. These programs have been designed to preserve hearing by focusing on the major causes of NIHL: excessive environmental noise, misuse/nonuse of hearing protection, and a lack of education concerning hearing loss (Fausti et al., 2005). Programs such as Dangerous Decibels® and WISE EARS® exist to educate community members of the value of wearing proper hearing protection (Fausti et al., 2005). Quality hearing conservation programs provide education about ear function, types of hearing loss, dangers of noise exposure, warning signs of and ways to prevent NIHL (Fausti et al., 2005). In Europe, there is a cap at 100 dBA for iPods, however, there is no such limit on iPods in the United States (McCormick & Matusitz, 2010). The biggest challenge seen with existing conservation programs is the lack of generalization and utilization of recommendations (Fausti et al., 2005).

Relationship between Cardiovascular Health and Fitness and Hearing Health

In adult cohorts, high cardiovascular fitness, as measured with maximum oxygen consumption (VO₂ max), has been shown to protect hearing possibly due to increased internal auditory artery and cochlear blood flow (Cristell, Hutchinson, & Alessio, 1998). The inner ear is supplied with nutrients and oxygen for improved regulation of cell, muscles and organ functions associated with hearing. Improved cardiovascular fitness, represented by high VO₂ max, increases the availability of oxygen and nutrients for the inner ear with a greater volume of blood traveling through the arteries during exercise. Increased blood flow leads to increased availability of oxygen and nutrients to the structures of the inner ear, potentially rendering the ear less susceptible to the detrimental effects of noise and loud music (Hull & Kerschen, 2010).

Research Aims

1. **Do adult PLD users have poorer hearing than non-PLD users?**
   - Null: Adult PLD users will not demonstrate different hearing levels than non-PLD users.
   - Alternate: Adult PLD users will have poorer hearing levels than non-PLD users.

2. **Does environmental background noise influence the volume at which individuals listen to PLDs?**
   - Null: Environmental background noise does not influence the volume at which individuals listen to PLDs.
   - Alternate: Environmental background noise will influence the user to listen to PLDs at a higher volume.
3. Does high cardiovascular health and fitness protect hearing health?

• Null: There is no correlation between cardiovascular health and fitness and hearing health.

• Alternate: Individuals with better cardiovascular health and fitness will demonstrate better hearing health.

**Design and Methods**

**Participants**

A total of 67 subjects, ages 30-84, were recruited from the Oxford, Ohio area via e-mails sent to listservs and fliers posted at various locations in Oxford. The participants were categorized into two groups, earbud PLD users and non-PLD users. All participants completed questionnaires, otoscopy, audiometry, tympanometry. Participants who considered themselves PLD users additionally completed a Verifit probe-microphone assessment of listening levels. The three questionnaires used were adapted from Worthington et al. (2009) study of PLDs. These questionnaires included questions regarding health history (Figure 1), listening habits (Figure 2 & 4), and knowledge of potential risks of hearing loss (Figure 3 & 5). The health history survey investigated participant’s hearing health and past and present noise exposure experiences. The listening habits survey asked questions concerning self-reported listening patterns. Lastly, the final survey explored the participant’s opinion and knowledge about noise exposure and education on hearing.

Participants were excluded if they demonstrated visible cerumen occlusions or external ear abnormalities. Prior to beginning testing, participants received an email informing them of the location of the study and their expectations in each portion of the study. Upon arrival to the first part of testing, participants filled out an informed consent form (figure 7).

**Audiological Testing Procedure**

When participants arrived for audiological testing, they reported whether or not they considered themselves earbud PLD users or non-PLD users. Participants then filled out the health history and listening habits surveys. Next, otoscopy was used to look for obstructions or abnormalities in the outer ear and tympanic membrane. Tympanometry measurements were taken to determine the compliance of the tympanic membrane and to check for occlusions or perforations. After confirming the physical health of the ear, the Hughson-Westlake method was used to obtain pure-tone thresholds on a diagnostic audiometer (Carr, 2001). Pulsed pure-tones
were delivered through over-the-ear clinical grade TDH-51 headphones in a soundproof booth. Thresholds were obtained by having the participants raise a hand each when they detected a tone. The frequencies tested were 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. If the participant was a non-listener, they were given the information about potential risks of hearing loss, and testing was completed.

PLD users continued on to the second portion of the testing. Sound pressure levels (SPLs) were obtained via the use of a Verifit VF-1 Audioscan probe-microphone system. Calibration of the instrument occurred Monday of each week. A reference microphone was placed over the participant’s ear with a probe microphone inserted into the ear canal. The microphone was set at 28 mm for females and 30 mm for males (Audioscan, 2006). A baseline measure was taken by recording an on-ear-measure of ambient background levels. Once the earbuds were placed in the participant’s ears, he/she was directed to choose a song and place it at a comfortable listening level in which he/she typically listens to the PLD when in the most common environment. PLD users were encouraged to choose their own song to reduce bias toward artificially high or low listening levels. Previous research has shown that PLD users may possibly turn the volume louder if the music selection is their own versus a selection by researchers (Worthington et al., 2009). An on-ear-measure was taken of this volume level to determine the SPL output at the level of the participant’s tympanic membrane.

The final on-ear measure was taken when the participant listened to a song in a background of noise. A pink noise spectrum with lower amplitude in the high frequencies was similar in frequency response and amplitude to stimuli recorded from a New York subway used by Worthington et al., 2009. Figure 8 illustrates the spectrum of the pink noise stimuli. Pink noise was turned on the HP L2045W Computer and Altec Lansing speaker model number AS90 at 75 dB SPL. Participants were directed to adjust the volume on their PLDs again if necessary. Following these three on-ear-measures, the listener participants were asked to fill out the knowledge of potential risks of hearing loss survey.

White Noise Testing

Changes in amplitudes within music complicates accurate measure of output volume of flat spectrum signal was preferred for comparison purposes. White noise provides the signal for measuring the output levels of each different PLD and brand of headphone by providing equal energy per Hz across frequencies. Baseline probe microphone measurements of white noise
were taken at five different volumes for ten individuals, five males and five females. Two different devices, an iPhone and an iPod Nano, and three brands of earbuds, Sony MDR-E9LP Blue, The Apple Earphones, and Skullcandy 2011 INK’D Blue/Black, were used when taking these measurements. The white noise track was taken from YouTube (Rothstein, 2010). These results provide a representation of the variation between devices, brand of earbuds, and individual ear canal response. The flat frequency spectrum of white noise was verified with the use of probe microphone measurements (Figure 9).

Genre Testing

Testing was done to determine the volume output levels across different genres of music. The songs were chosen from iTunes genre categories (Apple, 2013). Two songs were chosen from each of the five genre groups: alternative, country, metal, pop/rock, and hip-hop/rap/R&B/soul (Table 1). An iPod Nano was used with The Apple Earphones. The iPod was set to 50% volume level for all recordings. Both the right and left ears of four people were tested, two males and two females. The probe microphone was again used for this portion of the study. The Apple Earphones were inserted into the participant’s ears and the songs were played in the order listed in Table 1. Recording started at five seconds into each song. These results provide a representation of the variation between individual ear canal response and genre to determine the differences between genres.

Cardiovascular Health and Fitness Testing Procedure

The following measurements were used to assess cardiovascular health and fitness: resting blood pressure and heart rate, blood lipids, body mass index, waist-to-hip ratio, hand grip strength, daily activity assessment, and sub-maximal VO₂ levels. Instrumentation was calibrated daily. Resting blood pressure and heart rate were assessed by an Omron Intellisense Digital Blood Pressure Monitor, Model HEM-907xL by averaging two separate readings. If more than a 5% difference occurred between readings, a third measurement was taken after 10 minutes. Participants fasted for 12-hours prior to the study for the blood lipid testing. Blood lipid profile, including total cholesterol, high-density lipoproteins, low-density lipoproteins, triglycerides, non-high-density lipoproteins, total cholesterol/high-density lipoproteins, and glucose, was analyzed by a Cholestech LDX analyzer, catalog number 02111239 (Cholestech Corporation, Hayward, CA 94545).
Body composition, including weight, body fat percentage, fat mass, and fat free mass, was measured using a Tanida bioelectrical impedance analyzer, Model TBF-300A. Height was measured using a SECA 210cm stadiometer. Waist-to-hip ratio was determined using a Gulick II Tape, model 67020. The researcher took measures around the umbilicus and widest area around the buttock. Handgrip strength was determined using a Takei physical fitness test grip strength dynamometer, model number 68812 (Japan). Participants held the dynamometer at their side while standing and squeezed as hard as they could for approximately 2 seconds. This measure was taken twice with both the right and left hand; the best score was recorded. Yamax pedometer model SW-200 was used to obtain pedometer data to estimate daily activity of the participants and validate self-reported exercise and daily activity routines. Participants wore the pedometer for 7 days; they were instructed to reset the pedometer at the beginning of each day.

VO$_2$ max was predicted by submaximal exercise tests whereby participants walked for 4 minutes on a flat treadmill and 4 minutes at a five-degree incline. The participants chose a comfortable walking speed. Heart rate was measured with a Polar chest strap (T31) and a wristwatch. Estimated VO$_2$ max was calculated using body weight in kilograms, walking speed (mph), heart rate at termination (bpm), and gender. Finally, in order to estimate the participant’s daily activity, participants were asked to wear a pedometer for seven days following the testing and record the amount of steps taken each day. Upon completion of the study, participants received $20 in compensation for their time.

Results

Participant Information

Sixty-seven subjects participated in this study, 46 females and 21 males. The mean age was 52 ± 12 years with a range of 30-84 years. Subjects were divided into two sub-groups; PLD users (n=28) and non-PLD users (n=39). Over half (n=37) of the participants reported a family history of hearing loss, with the most common cause being due to age; this cause was reported by 89% of the subjects who reported a family history of hearing loss. The other subjects who reported a family history of hearing loss claimed the cause was either job related or due to trauma. Twenty individuals reported a history of ear infections and 29 individuals had experienced tinnitus at some point in their lifetime. On average, those individuals who listen to PLDs were younger than non-PLD users. The average age of PLD users was 48 ±13 years old, while the average age of non-PLD users was 54 ±12 years old.
Audiological Variables

Hearing thresholds varied by age, frequency and gender. In table 2, participants were divided into categories based on their age: young (30-40), middle aged (41-50), older (51-60) and oldest (61 to 84). A pure-tone average was estimated from 500, 1000, and 2000 Hz and a high frequency pure-tone average was assessed from 1000, 2000, 4000, and 6000 Hz. Females had higher pure-tone averages than males in all age groups. In both males and females, pure-tone averages increased with age. As illustrated by table 2, high frequency pure-tone averages were always worse than the traditional measures of pure-tone average. Abnormal hearing was found to be more common in the higher frequencies, 4000-8000 Hz. Analysis of the data showed no measurable differences between the right and left ears.

Figure 10 provides a visual comparison of pure-tone values in the high frequencies by age. The illustration also provides a comparison between PLD users and non-PLD users. The plots of thresholds by age and listener status show little difference between hearing thresholds of PLD users and non-PLD users. Therefore, as analyses below indicate, hearing thresholds are not dependent on PLD listener status. While listening to a PLD did not impact hearing threshold levels, responses became worse as subjects aged. In both table 2 and figure 10, an increase in pure-tone thresholds can be seen as age increases.

Listening duration is important to consider when looking at the impact of PLD use on an individual’s hearing. Based on survey results, 17 of the 28 PLD users in this study have been using earbuds for ten years or more and 9 individuals have been using earbuds for at least 20 years. Over time, exposure to noise can cause permanent threshold shifts. Only six participants listened to music for more than eight hours a week. One of these participants had abnormal hearing across all frequencies and three had normal hearing across all frequencies. The other two participants’ hearing did not become abnormal until 8000 Hz. NIOSH (1998) states that 85 dBA for more than eight hours a day is considered to be dangerous to an individual’s hearing. The participants did not report whether or not these eight hours are in one sitting, or spread out across the week. In a quiet setting, no subjects listen to their music at a potentially harmful volume at any frequency, above 85 dBA. Although subjects turned up their PLD volume with the addition of background noise, only one participant exceeded 85 dBA.

The major difference between the sample of participants used in this study and that of the majority of other studies concerning listening levels is that individuals in this age group have had
more years of PLD use and noise exposure than young, school-aged participants. Before the existence of small portable listening devices, which exist today, there were portable cassette players, radios, and CD players.

Both PLD users and non-PLD users reported placing themselves in environments in which noise levels were high. Examples of reported environments with high noise levels include concerts, sporting events, bars and clubs, transportation, fireworks, fire alarms, construction, and shooting ranges and hunting. Thirty-eight subjects reported being in four or more loud listening environments in their lifetime, which can potentially cause permanent threshold shifts. Only 19 participants said they wore hearing protection when in noisy environments. Participants did not report the frequency of occurrence of noise exposure in these different loud environments. As seen in Table 3, the most common environments of noise exposure are concerts, sporting events, and bars and clubs.

Both listener and non-listener participants were asked about typical genres of music they prefer. As seen in Table 4, the most common genre that both sets of subjects listen to is Pop/Rock. Very few subjects listen to metal, hip-hop, and R&B. Figure 11 compares the volume output levels of the different genres of music to white noise input. Table 5 shows the output levels for three types of earphones and two types of PLDs with white noise stimuli. On average, output levels of Skullcandy earbuds are 5 dB higher than Sony earbuds and 6 dB more than The Apple Earphones at two volume levels. Metal was determined to be quieter than white noise at 500 Hz and higher. Alternative, pop, and rock were louder than white noise till 2000 Hz, at which point they became quieter. Country was louder than white noise through 1000 Hz and then became quieter than white noise starting at 1500 Hz. Hip-hop and R&B became consistently quieter than white noise at 2000 Hz. From 3000 Hz and higher, all genres were quieter than the white noise spectrum.

When listening to a portable listening device, 93% of the individuals turned up the PLD volume when pink noise was played over the computer speakers (figure 12). The average listening level in a quite environment was 60 dBA and with the presence of noise, listening levels increased to a mean level of 77 dBA. High variability of volume level preference exists both in a noisy environment and when the individual is listening to the song in a silent environment. The most common environment for listening to PLDs with earbuds is while exercising, as reported by 20 individuals. Exercise locations also vary in background noise.
levels, from quiet outside runs to spinning at fitness centers with loud music. On average, men
listened approximately 10.93 dBA louder than women in a quiet setting and 4.09 dBA louder in a
noisier setting. Music measurements in the current study may have been affected by the
differences in transducer outputs, although it can be argued that participants would perceive the
difference across headphones and adjust the volumes accordingly.

*Cardiovascular Health and Fitness Variables*

Table 5 shows individual participants’ health risk, ranging from very low risk to very
high risk in terms of waist-to-hip ratio. Risk values vary by gender. Twenty-nine subjects fell in
the low risk group, while only 21 fell into the high-risk category. Table 6 classifies individuals
according to body mass index. The categories range from underweight to obese. There were 32
subjects classified as being either overweight or obese. Finally, Table 7 classifies subjects as
having poor, average, or good estimated VO$_2$ max values according to gender. The majority of
subjects, 43 subjects, were classified as having a good VO$_2$ max.

*Multivariate Analysis*

Decision trees determine trends of different factors by using a combination of variables at
decision nodes. This analysis method was done using the high frequencies, 4000, 6000, and
8000 Hz as dependent variables. This method was used because of the complexity of the
multiple listening, health and cardiovascular factors on results. There were many variables that
played a possible role in the overlying research questions and the trees allow the researcher to
determine the most important variables in which trends were seen.

As seen in figure 13 at 4000 Hz, age, environmental noise exposure, and type of PDL,
played a part in influencing the pure-tone thresholds of subjects. Individuals over the age of 54
are more susceptible to other variables, which result in abnormal hearing. There were 39 of 41
individuals under the age of 54 with normal hearing. Figure 12 shows that six out of the seven
individuals between the ages of 54 and 59 who are exposed to less than 3.5 hours of noisy
environments and use an iPod Classic are more likely to have abnormal hearing. Additionally,
all of the subjects over the age of 54 who use an iPhone, iPod Nano, iPod Shuffle, iTouch,
Blackberry, or other phone device had abnormal hearing.

At 6000 Hz, there were several different factors, which showed trends in the data: age,
duration of listening, number of noisy environments, hearing protection, and brand of earbuds.
As seen in figure 14, nine of the 12 individuals over the age of 53 had abnormal hearing, while
only four under the age of 54 had abnormal hearing. The two individuals who listen to their PLD for two to eight hours a week had abnormal hearing, while 12 individuals who listened for either less than two hours a week or more than eight hours a week had normal hearing. Of the individuals exposed to 3.5 or greater noisy environments, four individuals or 15% of subjects also did not wear hearing protection, had abnormal hearing. However, seven of the individuals or 58% of subjects, who did wear hearing protection, had abnormal hearing. All individuals who wore a generic brand of earbuds or Skull Candy brand earbuds, and were exposed to 3.5 or greater noisy environments, but wear hearing protection, had abnormal hearing. The final variable that showed a trend in the data was waist-to-hip ratio. Abnormal hearing was seen in individuals who were at high or low health risk, who use The Apple Earphones, JVS, or Sony brand earbuds, and who were exposed to 3.5 or greater noisy environments with the presence of hearing protection.

Finally, figure 15 shows trends at 8000 Hz. The variables leading to trends at this frequency were age, brand of earbuds and PLDs, hearing protection and BMI levels. Like at 4000 Hz, age plays an important role in determining which individuals are susceptible to other variables causing abnormal hearing. Subjects who are 50 years or older, are more likely to have abnormal hearing. Individuals who wore The Apple Earphones or JVS with either a Blackberry or other phone (excluding Apple products) and were over the age of 49 had normal hearing. Recall that The Apple Earphones showed the lowest outputs at all volume levels. All individuals who used Apple brand PLDs (iPhone, iPod Classic, iPod Nano, iPod Shuffle, and iTouch) and were over the age of 49 had abnormal hearing. The next determining variable was the presence of hearing protection. There were 82% of the individuals who did not wear hearing protection, who used a generic brand of headphones with a Blackberry or other phone (excluding Apple products) over the age of 49 who displayed abnormal hearing. The final variable that showed trends in the data was BMI level. These variables became important for individuals who wear hearing protection when in noisy environments, and use a generic brand of headphones with a Blackberry or other phone (excluding Apple products) over the age of 49. All individuals in this category who were obese had abnormal hearing, while all but one of the individuals who had normal BMI levels had normal hearing.
Discussion

Although hearing loss is often associated with normal age-related sensory changes, there are several factors that can intervene with worsening of auditory thresholds. As environmental noise in sports and social venues increase, along with use of PLDs, individuals can change the amount and duration of noise exposure in their daily lives. Cardiovascular fitness is another potentially modifiable factor to maintain hearing across the lifespan (Loprenzi, 2012). The main results reported in this study were that the use of PLDs does not influence pure-tone thresholds, the presence of background noise influences PLD users to increase the volume of their device, and cardiovascular fitness and health shows positive trends at various high frequencies. This information may contribute to understanding the role of both leisure noise exposure and cardiovascular health and fitness in protecting and preserving hearing at different ages. Clinicians may benefit from including more detailed queries of cardiovascular health and fitness factors and use of PLDs during audiological assessments.

PLD users vs. Non-PLD users

According to the classification trees, listening to a PLD was predictive of abnormal hearing. However, in both PLD users and non-PLD users, hearing thresholds become worse in the high frequencies, beginning at 4000 Hz. With this sample of participants, hearing loss in the high frequencies as one becomes older was very common. There were 41 participants who had compromised hearing (>25 dB) in at least one frequency from 4000 Hz through 8000 Hz. Individuals with normal hearing levels had higher variability in volume when in a quiet and noisy environment compared to those individuals who had abnormal hearing. Concomitant with these abnormal hearing levels, the presence of recruitment, tinnitus, or hypersensitivity may occur more frequently and can influence the volume level at which individuals listen to music (Fligor & Cox, 2004). Recruitment occurs when an individual has an abnormal perception of sound resulting in a reduction in intensity when compared to individuals with normal hearing. Additionally, hypersensitivity to noise and the intermittent ringing, roaring, or hissing noises present with tinnitus, can also influence the volume at which individuals listen to music (Martin & Clark, 2012). These factors in turn can cause the PLD users to listen to their PLDs at a lower volume level than a population enlisted from a younger cohort of individuals.

Volume Levels of Portable Listening Device in Silence vs. Noise
In the study conducted by Dalton (2001), almost all of the participants reported putting themselves in at least one harmful listening environment. Comparatively, 89% of the participants in the current study put themselves in at least one environment in which harmful noise was present and 58% put themselves in more than three environments in their lifetime. Zhao stated that popular music and leisure environments could reach dangerous decibel levels. Within environments that surpass 100 dB, individuals should not exceed 1.25 hours of exposure (Zhao et al., 2010). In Zhao’s report, most individuals experienced exposure far greater than the amount of time considered safe for one’s hearing. With 71% of participants in the current study listening to their PLDs while exercising, the potential volume output levels are quite dangerous. In an environment with the sound of machines and other individuals also working out, PLDs could reach even higher levels because individuals are trying to drown out the noise from the environment around them (Zhao, 2010). With the addition of pink noise in the testing environment, subjects increased the volume on their portable listening devices on average from 60 dBA to 77 dBA.

The white noise testing determined that Skullcandy headphones had the capability of reaching the highest decibel level while The Apple Earphones had the lowest maximum volume output. These results are consistent with the trends seen in the classification trees. The trees show that individuals who use Skullcandy headphones have abnormal hearing, while the majority of individuals who use The Apple Earphones and Sony brand headphones had normal hearing. Additionally, the results showed that there were no differences between output volumes of an iPod Nano and iPhone. The majority of subjects reported they listened to pop and rock music. After comparing the genre testing results to white noise values, little variation was seen from the white noise output levels, $\pm 2 – 11$ dBA (Table 9).

*Comparison of Cardiovascular Health and Fitness to PLD users vs. Non-PLD users*

While researchers claim that high cardiovascular fitness positively influences the auditory system and in turn protects hearing sensitivity (Loprinzi et al., 2012), the current study does not show significant predictors to support this finding. The current sample, however, was smaller and consisted of 81% of individuals who would be classified with good VO$_2$ max levels. With a larger representation of fitness levels, Hutchinson, Alessio and Baiduc (2010) found that in all cardiovascular fitness levels for older age groups, those with low fitness exhibited significantly worse pure tone thresholds at 2000 and 4000 Hz.
There were some noticeable patterns seen with the current study participants. The group of listener participants had a lower percentage in the average and poor categories of VO$_2$ max levels (Table 12). Almost half (43%) of the participants fell into the low health risk category according to their waist-to-hip ratio. However, non-PLD users appear to be at a higher risk level than PLD users (Table 10). As seen from the classification trees, at 8000 Hz, individuals who were classified with normal BMI levels had normal hearing, while those classified as obese had abnormal hearing. The majority of subjects who had normal BMI levels were non-PLD users. Additionally, more PLD users fell into the extreme categories (underweight and overweight) than non-PLD users (Table 11). According to estimated VO$_2$ max levels, the majority of the participants are in good physical shape.

**Conclusion**

This study examined the relationship between hearing levels, listening habits of PLDs, and cardiovascular health and fitness within individuals between 30 and 84 years of age. Being a PLD user does not serve as a predictor of abnormal hearing, however, age does influence hearing at the higher frequency thresholds. The classification trees illustrate that individuals over the age of 49 are more susceptible to abnormal hearing, consistent with previous research on presbycusis (Martin, Cardinal, & Gilham, 2012). Additionally, abnormal hearing is more common in higher frequencies, beginning at 2000 Hz in the majority of participants. Patterns of abnormal hearing were not different in PLD users and non-PLD users or between the right and left ear. With the presence of background noise, individuals listened to their PLDs at a higher volume level (+17 dBA) than they would if they were in a quiet setting. Finally, within the cardiovascular health and fitness variables, BMI and waist-to-hip ratio both showed trends leading towards better hearing threshold levels, however, there were no trends seen with VO$_2$ max levels due to a the majority of participants in the sample have good levels.
Figure 1: Health History Survey

Name: __________________________

Subject ID#: ____________________ Date: ______________ Tester Initials: ________

Subject Demographics:

Age: _______

Sex: _______

Level of education: _______

Hearing History:

1. Do you have any concerns with your hearing?
   a. Yes (please elaborate________________________________________
      ____________________________________________________________
      ____________________________________________________________
   b. No

2. Do you listen to music?
   a. Yes
   b. No

3. Have you had a history of ear infections?
   a. Yes (please elaborate:________________________________________
      ____________________________________________________________
      ____________________________________________________________
   b. No

4. Please circle all of the following environments in which you may have been exposed to loud noise in the context of employment, home, or recreation. For chosen environments, specify how often and for what duration you are exposed in these specific environments:
   a. Construction Yes / No
   b. Transportation (air planes/trains etc.) Yes / No
   c. Concerts/bands Yes / No
   d. Bars/Clubs Yes / No
   e. Sporting Events (car shows, airplane shows, baseball, basketball, hockey, etc.) Yes / No
   f. Fireworks Yes / No
   g. Shooting Ranges/Hunting Yes / No
   h. Fire Alarms Yes / No
   i. Other _______________________________________________________
5. Do you wear hearing protection when in noise?
   a. Yes
   b. No

6. How often do you wear hearing protection?
   a. Always
   b. Sometimes
   c. Rarely
   d. Never

7. In what situations do you wear hearing protection?
   a. Construction
   b. Transportation (air planes/trains etc.)
   c. Concerts/bands
   d. Bars/Clubs
   e. Sporting Events (car shows, airplane shows, baseball, basketball, hockey, etc.)
   f. Fireworks
   g. Shooting Ranges/Hunting
   h. Fire Alarms
   i. Other________________________

8. Please list any medications (Aspirin, etc.) that might influence your hearing:

9. Have you experienced any ringing in your ears (past or present)?
   a. Yes (please elaborate: ____________________________
   ______________________________________________________________________)
   b. No

10. Have you had any head or neck injuries or surgeries within the last year?
    a. Yes (please elaborate: ____________________________
    ______________________________________________________________________)
    b. No

11. Do you have a family history of hearing loss?
    a. Yes (please elaborate: ____________________________
    ______________________________________________________________________)
    b. No

12. When not using speakers to listen to music, what brand of headphones do you use most often?
    a. Apple
    b. Skull Candy
    c. Sony
    d. JVC
    e. Generic Brand (Wal-Mart, etc.)
    f. Other ____________________
    g. Not applicable (skip Q# 13)

13. Is this brand of headphones a type of:
    a. Earbud
    b. Over-the-ear
    c. Noise-cancelling
    d. Both a & c
    e. Both b & c
Figure 2: Listening Habits (PLD users)

Name: __________________________

Subject ID#: ___________ Date: ___________ Tester Initials: _______

1. What is the name of the listening device you currently use majority of the time?
   a. iPod Classic
   b. iPod Shuffle
   c. iTouch
   d. iPhone
   e. iPod Nano
   f. Zune
   g. Phone/Blackberry
   h. Other: __________________________

2. How many years have you been using this particular device? ____________

3. How many years have you been using headphones to listen to music? ____________

4. On average, how many hours per week do you listen to music with headphones?
   a. 0 – 2 hours/week
   b. 2 – 5 hours/week
   c. 5 – 8 hours/week
   d. 8 – 11 hours/week
   e. Greater than 11 hours/week

5. In what situation do you listen to the device under headphones the majority of the time?
   a. Home
   b. Transportation (bus/cab)
   c. While exercising
   d. Other: __________________________

6. Do you listen with headphones more often than with speakers?
   a. Yes
   b. No

7. With which devices do you use to listen to music through speakers? Circle all that apply:
   a. Computer (built in speakers)
   b. Stereo system
   c. iHome/Dock
   d. Other: __________________________
   e. I do not use speakers

8. Have you previously owned any of the following Portable Listening Devices (PLDs)? Circle all that apply:
   a. Personal cassette player
   b. Portable compact disk
   c. Personal AM/FM radio
   d. Other: __________________________

9. What genres of music do you generally listen to a majority of the time under headphones? Check all that apply:
   a. Pop/Rock
   b. R&B/Hip-Hop
   c. Alternative
   d. Metal
   e. Country
   f. Other: __________________________
Figure 3: Knowledge of Potential Risks of Hearing Loss (PLD users)

Name:________________________

Subject ID#:_______________ Date:_______________ Tester Initials:_____

1. At what sound level do you typically keep your listening device for comfortable listening? Reference Figure 6 on the laminated sheet and select a number rating:
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

2. Have you ever been educated on the risks of hearing from loud sounds? If so, when?
   a. Middle School
   b. High School
   c. College – Required course
   d. College – Elective
   e. Work conference
   f. Other:________________________

3. Can loud sounds cause damage to your hearing?
   a. Yes
   b. No

4. What volume level do you feel is the beginning point for “too loud” that will begin to harm your hearing? Please reference figure 6 on the laminated sheet and select a number rating:
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6

5. What length of listening time with earbud headphones (in one sitting) do you feel is “too long” and will begin to harm your hearing?
   a. 15 – 30 minutes
   b. 1 hour
   c. 2 hours
   d. 3 hours
   e. 4 hours
   f. 5 hours

6. Do you feel that you listen to your device at harmful levels?
   a. Always
   b. Sometimes
   c. Rarely
   d. Never

7. If you learned that you were listening to your device at harmful levels, would you turn it down/limit your weekly use?
   a. Yes
   b. No
8. From which of these persons would you be most likely to follow given advice, regarding iPod/earbud use and hearing loss?
   a. Doctors  
   b. Audiologists  
   c. Manufacturers  
   d. Celebrities  
   e. Family  
   f. Friends  
   g. Other: ______________________  

9. Would you like more information regarding iPod/earbud use and potential hearing loss?
   a. Yes  
   b. No  

10. Would you like an explanation of your hearing test?
    a. Yes (please provide your e-mail: ______________________)
    b. No  

11. What song did you select? ______________________  

12. Who is the artist? ______________________  

13. What genre would you consider it? ______________________
Figure 4: Listening Habits (Non-PLD users)

Name:____________________
Subject ID#:______________ Date:______________ Tester Initials:______

1. Do you use a portable listening device?  
   a. Yes  b. No

2. Do you listen to music with speakers?  
   a. Yes  b. No

3. With which devices do you use to listen to music through speakers? Circle all that apply:  
   a. Computer (built in speakers)  
   b. Stereo system  
   c. iHome/Dock  
   d. Other: __________________________
   e. I do not use speakers

4. Have you previously owned any of the following Portable Listening Devices (PLDs)? Circle all that apply:  
   a. Personal cassette player  
   b. Portable compact disk  
   c. Personal AM/FM radio  
   d. Other: __________________________

5. What genres of music do you generally listen to a majority of the time under headphones? Check all that apply:  
   a. Pop/Rock  
   b. R&B/Hip-Hop  
   c. Alternative  
   d. Metal  
   e. Country  
   f. Other:__________________________
Figure 5: Knowledge of Potential Risks of Hearing Loss (Non-PLD users)

Name: ____________________

Subject ID#: ____________ Date: ____________ Tester Initials: ______

1. Have you ever been educated on the risks of hearing from loud sounds? If so, when?
   a. Middle School       d. College – Elective
   b. High School        e. Work conference
   c. College – Required course   f. Other:____________________

2. Can loud sounds cause damage to your hearing?
   a. Yes                b. No

3. From which of these persons would you be most likely to follow given advice, regarding iPod/earbud use and hearing loss?
   a. Doctors       e. Family
   b. Audiologists   f. Friends
   c. Manufacturers  g. Other: ______________________
   d. Celebrities

4. Would you like more information regarding iPod/earbud use and potential hearing loss?
   a. Yes
   b. No

5. Would you like an explanation of your hearing test?
   a. Yes (please provide your e-mail: ________________________________)
   b. No
Figure 6: Noise Level Reference for PLD Users Surveys

1: [Blue bar] None of the above
2: [Blue bar] None of the above
3: [Blue bar] None of the above
4: [Blue bar] None of the above
5: [Blue bar] None of the above
6: None of the above – even the maximum volume on personal listening devices are safe because manufacturers make sure they are.
INFORMED CONSENT FORM

Title of Investigation: Factors that influence hearing sensitivity in adults who listen to music with ear bud headphones

Investigators: Helaine Alessio, Ph.D1, John Spilman1, Ashley Zaper1, Erika Bills1, Sarah Wagner2, Samantha Lenzini3, Brittany Sproat2, Kari Smith2, and Kathleen Hutchinson Marron, Ph.D2

Department of Kinesiology and Health1 (513-529-2707) and Department of Speech Pathology and Audiology2

Date: __________

This is to certify that I, ___________________________ , hereby agree to participate as a volunteer in a scientific investigation as an authorized part of the education and research program of the Miami University under the supervision of Helaine Alessio, Ph.D.

The investigation and my part in the investigation have been defined and fully explained to me by the investigators and I understand the explanation. A copy of the procedures of this investigation and a description of the study has been provided to me and has been discussed in detail with me.

I have been given the opportunity to ask whatever questions I may have had and all such questions and inquiries have been answered to my satisfaction. A copy of this form will be given to me.

I understand that I am free to deny any answers to specific questions in interviews of questionnaires. I further understand that I am free to withdraw my consent and terminate participation at any time.

I understand that participation does not change the availability of Clinic services at Miami University.

I understand that in the event of physical injury resulting from the research procedures, financial compensation is not available and medical treatment is not provided free of charge.

I have rights as a volunteer subject and if I have any questions about those rights I may contact:

The Office for the Advancement of Scholarship and Teaching (529-3714)

107 Roudebush Hall, Oxford, Ohio 45056

___________________________________________
Date

___________________________________________
Subject’s or Parent Signature

I, the undersigned, have defined and fully explained the investigation to the above subject.

___________________________________________
Date

___________________________________________
Investigator’s Signature
Figure 8: Pink Noise at 50% Volume in Quiet Environment
Figure 9: White Noise at 50% Volume in Quiet Environment
Figure 10: Pure-Tone Thresholds by Frequency for PLD Users/Non-PLD Users vs. Age
Figure 11: Genre Volume Output Difference from White Noise at 50% Volume in a Quiet Environment
Figure 12: Volume Difference by Frequency Between Song in Silence and Song in Noise
Figure 13: Classification Tree Predicting Abnormal Hearing at 4000 Hz
Figure 14: Classification Tree Predicting Abnormal Hearing at 6000 Hz
Figure 15: Classification Tree Predicting Abnormal Hearing at 8000 Hz
Table #1
Songs Used for Genre Testing

<table>
<thead>
<tr>
<th>Genre</th>
<th>Artist – Song (recording start time)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>Fun – Some Nights (0:05)</td>
<td>Vocals, piano, percussion</td>
</tr>
<tr>
<td>Alternative</td>
<td>Josh Kelley – Tidal Wave (0:05)</td>
<td>Vocals, guitar</td>
</tr>
<tr>
<td>Country</td>
<td>Kenny Chesney – I Go Back (0:05)</td>
<td>Vocals, guitar, percussion</td>
</tr>
<tr>
<td>Country</td>
<td>Rascal Flatts – She’d Be California  (0:05)</td>
<td>Vocals, guitar, percussion</td>
</tr>
<tr>
<td>Metal</td>
<td>Metallica – Enter Sandman (0:05)</td>
<td>Vocals, electric guitar, percussion</td>
</tr>
<tr>
<td>Metal</td>
<td>Newsted – Soldierhead (0:05)</td>
<td>Vocals, electric guitar, percussion</td>
</tr>
<tr>
<td>Pop</td>
<td>Andy Grammar – Fine By Me (0:05)</td>
<td>Vocals, piano, percussion</td>
</tr>
<tr>
<td>Rock</td>
<td>The Script – Break Even (0:05)</td>
<td>Vocals, guitar, percussion</td>
</tr>
<tr>
<td>Hip Hop/Rap</td>
<td>Ray J (feat. Yung Berg) – Sexy Can I (0:05)</td>
<td>Vocals, electric guitar, percussion</td>
</tr>
<tr>
<td>R&amp;B/Soul</td>
<td>Usher – Scream (0:05)</td>
<td>Vocals, electric guitar, percussion</td>
</tr>
</tbody>
</table>

Table #2
Pure Tones by Gender and Frequency

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Pure Tone Averages (500, 1000, 2000 Hz)</th>
<th>High Frequency Pure Tone Averages (1000 to 8000 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Young</td>
<td>2.22</td>
<td>4.03</td>
</tr>
<tr>
<td>Middle Aged</td>
<td>3.50</td>
<td>7.17</td>
</tr>
<tr>
<td>Older</td>
<td>5</td>
<td>7.92</td>
</tr>
<tr>
<td>Oldest</td>
<td>12.5</td>
<td>19.25</td>
</tr>
</tbody>
</table>

Table #3
# of Subjects in Environments with Noise

<table>
<thead>
<tr>
<th>Environments</th>
<th># of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concerts/Bands</td>
<td>41</td>
</tr>
<tr>
<td>Sporting Events</td>
<td>36</td>
</tr>
<tr>
<td>Bars/Clubs</td>
<td>33</td>
</tr>
<tr>
<td>Transportation</td>
<td>29</td>
</tr>
<tr>
<td>Fireworks</td>
<td>27</td>
</tr>
<tr>
<td>Fire Alarms</td>
<td>20</td>
</tr>
<tr>
<td>Construction</td>
<td>14</td>
</tr>
<tr>
<td>Shooting Range/Hunting</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
</tr>
</tbody>
</table>
### Table #4
**Genres Listened to by Subjects**

<table>
<thead>
<tr>
<th>Genre</th>
<th>PLD users</th>
<th>Non-PLD users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Country</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Metal</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pop/Rock</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Hip-Hop/R&amp;B</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
<td>17</td>
</tr>
</tbody>
</table>

### Table #5
**Health Risk Level Compared to Waist-to-Hip Ratio by Gender**

<table>
<thead>
<tr>
<th>Health Risk</th>
<th>Male (cm)</th>
<th>Female (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low Risk</td>
<td>&lt;80</td>
<td>&lt;70</td>
</tr>
<tr>
<td>Low Risk</td>
<td>80-99</td>
<td>70-89</td>
</tr>
<tr>
<td>High Risk</td>
<td>100-120</td>
<td>90-109</td>
</tr>
<tr>
<td>Very High Risk</td>
<td>&gt;120</td>
<td>&gt;110</td>
</tr>
</tbody>
</table>

### Table #6
**Disease Risk Relative to Normal Body Mass Index Levels**

<table>
<thead>
<tr>
<th>Classification</th>
<th>BMI</th>
<th>Disease Risk</th>
<th>Men: &lt; 102 cm</th>
<th>Women: &lt; 88 cm</th>
<th>Men: &gt; 102 cm</th>
<th>Women: &gt; 88 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.5</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Normal</td>
<td>18.5 – 24.9</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Overweight</td>
<td>25 – 29.9</td>
<td>Increased</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity Class I</td>
<td>30 – 34.9</td>
<td>High</td>
<td>Very High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity Class II</td>
<td>35 – 39.9</td>
<td>Very High</td>
<td>Very High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obesity Class III</td>
<td>&gt;40</td>
<td>Extremely High</td>
<td>Extremely High</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table #7
**Classifications of Estimated VO\(_2\) Max**

<table>
<thead>
<tr>
<th>Age</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poor</td>
<td>Average</td>
</tr>
<tr>
<td>30-34</td>
<td>&lt;29</td>
<td>30-37</td>
</tr>
<tr>
<td>35-39</td>
<td>&lt;27</td>
<td>28-35</td>
</tr>
<tr>
<td>40-44</td>
<td>&lt;25</td>
<td>26-33</td>
</tr>
<tr>
<td>45-49</td>
<td>&lt;23</td>
<td>24-31</td>
</tr>
<tr>
<td>50-54</td>
<td>&lt;22</td>
<td>23-29</td>
</tr>
<tr>
<td>55-59</td>
<td>&lt;20</td>
<td>21-27</td>
</tr>
<tr>
<td>60-65</td>
<td>&lt;18</td>
<td>19-24</td>
</tr>
</tbody>
</table>
### Table #9
*White Noise Data dBA*

<table>
<thead>
<tr>
<th>Device</th>
<th>Headphones</th>
<th>Means &amp; SD Midpoint Volume (Females)</th>
<th>Means &amp; SD Midpoint Volume (Males)</th>
<th>Means &amp; SD Maximum Volume (Females)</th>
<th>Means &amp; SD Maximum Volume (Males)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPhone</td>
<td>Sony</td>
<td>82.2 ± 5.8</td>
<td>82.8 ± 5.3</td>
<td>112.9 ± 4.2</td>
<td>113.3 ± 5.3</td>
</tr>
<tr>
<td></td>
<td>Skullcandy</td>
<td>84.3 ± 4.1</td>
<td>88.5 ± 4.1</td>
<td>115.1 ± 2.2</td>
<td>117.4 ± 3.0</td>
</tr>
<tr>
<td></td>
<td>iPod</td>
<td>78.6 ± 4.6</td>
<td>74.7 ± 7.0</td>
<td>108.2 ± 3.9</td>
<td>106.2 ± 3.8</td>
</tr>
<tr>
<td>Nano</td>
<td>Sony</td>
<td>79.5 ± 1.3</td>
<td>78.5 ± 3.5</td>
<td>111.4 ± 2.7</td>
<td>112.0 ± 3.1</td>
</tr>
<tr>
<td></td>
<td>Skullcandy</td>
<td>83.8 ± 2.7</td>
<td>85.0 ± 4.1</td>
<td>116.5 ± 3.3</td>
<td>116.1 ± 4.1</td>
</tr>
<tr>
<td></td>
<td>iPod</td>
<td>79.3 ± 6.8</td>
<td>74.2 ± 1.6</td>
<td>108.3 ± 3.5</td>
<td>105.1 ± 2.4</td>
</tr>
</tbody>
</table>

### Table #10
*Waist-to-hip Ratio vs. PLD users/Non-PLD users*

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>PLD users</th>
<th>Non-PLD users</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk Level</td>
<td>10.45%</td>
<td>20.90%</td>
<td>31.34%</td>
</tr>
<tr>
<td>Moderate Risk Level</td>
<td>13.43%</td>
<td>11.94%</td>
<td>25.37%</td>
</tr>
<tr>
<td>Low Risk Level</td>
<td>22.39%</td>
<td>20.90%</td>
<td>43.28%</td>
</tr>
<tr>
<td>Number of Participants</td>
<td>31</td>
<td>36</td>
<td>67</td>
</tr>
</tbody>
</table>

### Table #11
*Body Mass Index vs. PLD users/Non-PLD users*

<table>
<thead>
<tr>
<th>Classification</th>
<th>PLD users</th>
<th>Non-PLD users</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>7.46%</td>
<td>0.00%</td>
<td>7.46%</td>
</tr>
<tr>
<td>Normal</td>
<td>11.94%</td>
<td>32.84%</td>
<td>44.78%</td>
</tr>
<tr>
<td>Overweight</td>
<td>14.93%</td>
<td>11.94%</td>
<td>26.87%</td>
</tr>
<tr>
<td>Obesity</td>
<td>11.94%</td>
<td>8.96%</td>
<td>20.90%</td>
</tr>
<tr>
<td>Number of Participants</td>
<td>31</td>
<td>36</td>
<td>67</td>
</tr>
</tbody>
</table>

### Table #12
*Estimated VO₂ Max vs. PLD users/Non-PLD users*

<table>
<thead>
<tr>
<th>Classification</th>
<th>PLD users</th>
<th>Non-PLD users</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0.00%</td>
<td>1.72%</td>
<td>1.72%</td>
</tr>
<tr>
<td>Average</td>
<td>5.17%</td>
<td>12.07%</td>
<td>17.24%</td>
</tr>
<tr>
<td>Good</td>
<td>34.48%</td>
<td>46.55%</td>
<td>81.03%</td>
</tr>
<tr>
<td>Number of Participants</td>
<td>23</td>
<td>35</td>
<td>58</td>
</tr>
</tbody>
</table>
References


