ABSTRACT

EFFECTS OF PERSONAL MUSIC PLAYER WITH HEADPHONE USE ON HEARING ACUITY AMONG COLLEGE-AGED STUDENTS

by Sarah Louise Stephenson

This paper reports on an experiment designed to evaluate the effects of personal music player (PMP) usage and listening behavior on the hearing acuity of college-aged adults. Probe-microphone sound pressure levels (SPLs) were measured on 180 college-age participants, converted to free-field equivalents and compared to pure-tone thresholds. Subjects also completed three surveys to assess health history, listening habits and knowledge of risk. Results of the study reveal that seven subjects exceeded the NIOSH guidelines for maximum noise exposure. The students who reported weekly usage times greater than 7.5 hours per week had significantly worse pure-tone hearing across the audiometric frequencies ($p = .03$). Concerns are raised regarding the association between potential volume levels (>85 dB) of modern PMPs and self-reported duration (>7.5 hrs/week) of PMP use with decreased hearing acuity among college student listeners.

EFFECTS OF PERSONAL MUSIC PLAYER WITH HEADPHONE USE ON HEARING ACUITY AMONG COLLEGE-AGED STUDENTS

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Sarah Louise Stephenson

Miami University

Oxford, OH

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Advisor______________________________________
Kathleen Hutchinson, Ph.D.

Reader_______________________________________
Helaine Alessio, Ph.D.

Reader_______________________________________
Laura J. Kelly, Ph.D.

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Hearing loss due to noise exposure is a significant and pervasive public health problem (Daniel, 2007). Recent research has also suggested a relationship between music exposure and noise induced hearing loss (NIHL) (Zhao et al., 2010). Many studies have shown that adolescents and young adults are experiencing hearing loss at earlier ages and higher rates due to their listening habits, particularly when using personal music players (PMPs) such as MP3 players and iPods (Biassoni et al., 2005; Chung et al., 2005; Danhauer et al., 2009; Fallon, 2006; McCormick & Matusitz, 2010; Serra et al., 2005; Vogel et al., 2010). In a study conducted by Niskar and colleagues (2001), 5249 subjects aged 12 to 19 years underwent binaural audiometry and tympanometry testing. The results of Niskar's study showed that 15% of teenagers and young adults had noise induced hearing threshold shifts (NITS) in one or both ears.

Criteria set in place by The National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) recommend an exposure limit of 85 decibels, A-weighted, as an 8-hr time-weighted average (NIOSH, 1998; OSHA 1983). However, with respect to music exposure, an 85 dBA time-weighted average may not be low enough to prevent NIHL. Physical differences exist between industrial noise and music. Spectral, temporal and dynamic variations in music tend to be less predictable than occupational noise, and these differences may affect the actual risk for NIHL (Glorig, 1980). Therefore, it may not be appropriate to apply the occupational risk standards set by the NIOSH or the OSHA to recreational music exposure recommendations. Additionally, several studies have reported that maximum output levels produced by PMPs can surpass the occupational standards for exposure (Fligor & Cox, 2004, Maassen et al., 2001; Rudy, 2007, Ahmed et al., 2007). As a result, there is significant concern regarding the risk of permanent hearing loss due to the listening behavior of young adults who often use PMPs.

In today's society, adolescents and young adults expose themselves to loud music, frequently for hours at a time, with full knowledge that there could be consequences (Chung et al., 2005; Zogby, 2006). The increase in PMP popularity, especially the iPod (more than 300 million sold since 2001), over the past decade has become a source of media attention and concern due to its potential impact of irreversible damage on young listeners' hearing (Costello, 2011). In a study conducted by Torre (2008), over 90% of the 1016 participants who completed his personal music player use survey reported using a PMP. Of that 90% sample, half reported PMP listening durations between 1 and 3 hours, and 90% selected either a medium or loud volume level from an ordinal scale. Torre's findings concur with a study conducted by Williams (2005), which stated that 82.7% of their 150 participants owned a PMP and that typical listening times have more than doubled in the past 20 years. Average listening time was normally 40 minutes a day in the 1980s and has now increased to an average of two hours per day (Williams, 2005).

Personal music player use continues to rise (Ahmed et al., 2007) and the accessories are often packaged with several features that can elevate the level of risk for causing hearing loss. For example, extended memory enables users to listen to large amount of audio stimulation without interruption for lengthy periods of time (Danhauer et al., 2009). PMPs also come outfitted with standard earbuds that enable the source of sound to be closer to the tympanic membrane and potentially produce higher output levels than generated by other sound systems (Keith et al., 2008). In addition, earbuds do not impede ambient noise. With the presence of excess background sound, consumers may find it necessary to raise volume controls for preferred listening levels (Danhauer et al., 2009; Hodgetts et al., 2007).

Thus, it should come as no surprise that Shargorodsky et al. (2010) found the incidence of hearing loss has increased substantially from 14.9% in late 80s and early 90s to 19.5% in 2005 and 2006 for young adults. In fact, many studies have shown an increasing trend of NIHL in adolescents and young adults (Niskar et al., 2001; Lees et al., 1985). The growing prevalence of NIHL in adolescents and young adults is of great concern due to the devastating impact on one's quality of life that can occur with long-term or permanent hearing loss at any age. Even mild hearing loss can lead to depression, poor physical functioning, social isolation and decreased self-sufficiency (Chia et al., 2007; Shaw et al., 2009).

Given the novelty of portable digital audio technology, long term effects of PMP use have not been studied enough to know exactly how much hearing loss may be attributable to PMP use by young adults. Very few studies have attempted to measure sound levels within the ear canal and co-factor PMP use time in order to determine risk of permanent hearing loss. Guidelines to standardize safe music volume and duration settings are difficult to establish for safe listening levels and noise exposure assessment. Given advances in new technology, increasing number of young users and greater potential for hazardous listening behaviors, it is important to identify those individuals who are at risk.

Therefore, the study was designed to investigate PMP usage with headphones within a college-age population and determine its impact on hearing acuity in young adults. This will help determine whether college-age listeners commonly exceed recommended noise exposure dosages as a result of their normal listening patterns.

Design and Method

Participants

One hundred and eighty subjects between 17 and 25 years of age were recruited on Miami University's (Oxford, Ohio) campus. All potential participants reported good general health and hearing ability. Subjects were screened for inclusionary and exclusionary criteria by undergoing an otoscopic exam and tympanometry (Welch Allyn Model GSI 33) to check for middle ear disease. Each participant had pure-tone thresholds $\leq$25 dB HL for octave frequencies from 250 to 8000 Hz and a Type-A tympanograms (Jerger et al., 1974).

Procedures and Measures

Informed consent was obtained prior to data collection. Participants were asked to bring their most-frequently-used PMP and headphones with them to the hearing clinic. Subjects were given a health history questionnaire (see Appendix A) to assess history of, or risk for, hearing loss that could be attributed to factors other than noise exposure. One participant was excluded due to self-reported smoking history.

Thresholds were measured with a diagnostic, clinical audiometer (Madsen, GSI 33) using the standard Hughson-Westlake method. Pulsed tones were presented through earphones (Telephonics, TDH-50P) mounted in supra-aural cushions (MX-51/AR) while participants sat in a double-walled sound booth (Industrial Acoustics Company). Annual calibration of the equipment was performed according to the American National Standards Institute (ANSI) guidelines (ANSI, 2004). A listening check was performed daily on the equipment.

Following the pure-tone test, subjects were given a second survey (see Appendix B) designed to establish self-reported music listening patterns (i.e. hours per day/days per week of PMP with headphone use, years of PMP with headphone use, preferred music genres, etc.) and most-frequently used device types (Danhauer, et al., 2009). Weekly hours of PMP usage obtained from the second survey allowed researchers to categorize subjects into the following groups: rare users (< 2 hours per week), minimum users (≥2 and < 4.75 hours per week), moderate users (≥4.75 and < 7.5 hours per week), and extreme users (≥ 7.5 hours per week). In an effort to try and reduce subject bias, no questions regarding hearing loss from PMP use were asked during the initial surveys.

A Verifit VF-1 Audioscan was used to measure Sound Pressure Levels (SPLs) near the tympanic membrane of each participant in order to determine PMP output. A standard set of iPod earbuds and a PMP was provided to 18 subjects who neglected to bring their own PMP. A reference microphone, situated facing away from the participant's shoulder for optimal performance, hung freely around the pinna and stopped at the base of the ear lobe. A probe microphone connected to the reference microphone was placed inside the participant's ear canal after positioning at 28mm for females and 30mm for males, according to manufacturer specifications (see Figure 1) (Etymonic Design Incorporated, 2009). The Verifit VF-1 system was calibrated weekly.

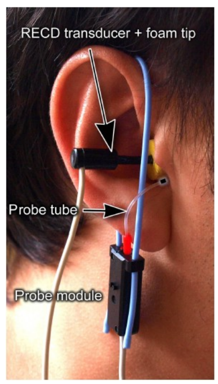


Figure 1. Verifit VF-1 Audioscan probe and reference microphones
*Instead of the RECD transducer + foam tip, the iPod earbud is inserted.

Using the Verifit VF-1 Audioscan, an on-ear control run established baseline data in dBA for each participant, without earbuds, in a quiet environment. Decibel levels and gain received by the probe and reference microphones were documented at a single point in time to ensure equipment function and low ambient noise. The stimulus level of the Verifit VF-1 system was set to 0 dB SPL and the PMP earbud was placed in the ear. All subjects were read identical instructions for setting the volume level of the PMP which directed the subjects to "select the first of three favorite songs and adjust the volume to the most frequently used intensity level." The SPLs near the tympanic membrane were then determined with a 15-second live-voice speech spectrum map collected from three different songs. The Verifit VF-1 displayed the dB SPL values in a long-term average speech spectrum (LTASS) in 1/3 octave intervals from 250 to 6K Hz. In practice, a 10-second average provides a stable spectrum curve (Cox & Moore, 1998). Participants were again prompted to adjust the volume to the intensity level most often used when listening to their device on a routine basis between each song selection. All Verifit VF-1 measurements were taken into account for each of three songs selected by the participant to obtain a range of gain curves for different music stimuli. Data was displayed on graphs and tables, and saved to a secure USB drive to be reviewed at a later time. Recorded values were rounded to the nearest whole decibel by the equipment. Preferred SPLs were then converted from subjects' ear canals to diffuse-field measurements (ISO, 2002).

Testing was concluded with the dispensation of a final survey (see Appendix C) that investigated participant knowledge of the potential risks of hearing loss due to PMP use. Questions discerning participant knowledge of the potential for hearing loss related to PMPs were addressed utilizing a bar graph representational of the iPod volume bar (see Appendix D).

Baseline & Reliability

Baseline volume levels for the iPhone and iPod Nano were taken for 10 subjects (5 males, 5 females) at five points along the volume bar (see Appendix D, Figure A), measured in the ear using the Verifit VF-1 with white noise in 5-second intervals and converted to dBA. White noise provides a consistent waveform to compare devices. With each PMP, three different types of headphones (Skullcandy 2011 INK'D Blue/Black earbuds, Apple Earphones and Sony Earbuds MDR-E9LP Blue) were used for all measurements. The results across the two devices provided descriptive information regarding the differences between devices, earbud types, and individual ear canal response.

Reliability measures were gathered from 21 randomly selected participants (see Appendix E). These participants returned to the Miami University Speech and Hearing Clinic 2-3 weeks following initial testing and repeated the same Verifit VF-1 testing procedure as the original test date. The original probe microphone was utilized again and identical instructions were provided. Each participant was asked to select the same songs they used during the original test and data was collected at the same point in time. Reliability measures helped to substantiate the consistency of the Verifit VF-1 measurement system, as well as participant test-retest reliability.

Statistical Analysis

Statistical analysis was performed using SAS (version 9.2, 2008) for Windows software. The data were first summarized and examined for outliers and consistency. Pure-tone thresholds in dB HL were converted to SPL for analysis purposes (ANSI S3.6 2004 American National Standard Specifications for Audiometers). A multiway-analysis of variance was performed with the pure-tone thresholds as the dependent variables and year in school, usage values of the PMP, and dB SPL measured with the Verifit VF-1 as the independent variables. Several preparatory steps were taken to ready the data for analysis. First, usage time in weeks was calculated by multiplying self-reported hours per day times days per week of PMP usage.

All samples of Verifit SPL values were converted to A-weighted equivalents for comparison to noise exposure standards. The Microphone in Real Ear technique (MIRE) (ISO, 2002) calibration tables were used to determine a coupler to free-field correction factor to report free-field equivalent levels (transfer function of the outer ear [TFOE] of the Verifit VF-1 measurements).

Each of the participants' individual pure-tone threshold levels from both ears were converted to Area Under the Curve (AUC) endpoints. AUC response profiles summarize the inherent capacity of a test for distinguishing a diseased from a non-diseased subject across potential levels of factor points into a single statistic (Liu & Li, 2005). AUC response profiles were also obtained from the 1/3 octave band SPL levels measured from the Verifit VF-1 for the frequencies 250 to 4000 Hz (SAS Institute Inc., 2008). AUC measures better reflect total output volume activity of the music waveform, as traditional amplitude peaks may not adequately describe the frequency peak-to-peak changes (Pynchon et al., 1998). The audiometric and Verifit VF-1 dB SPL data files were restructured to calculate the AUC per person, aggregated, and used as the dependent and independent variables in a standard ANOVA. A value of $p < .05$ was set as the level of statistical significance for all tests reported.

Results

Participant Information

Table 1 illustrates the demographic characteristics of the participants. Audiometric, tympanometric and Verifit VF-1 data for one-hundred and twenty-nine females and fifty-one males (total, 180) is shown. There were a similar number of participants across the class categories and the subject sample was considered to be representative of a typical Midwest college. Table 2 illustrates average threshold levels with standard deviations for each class (freshman, sophomore, junior, senior). One hundred percent of the participants had pure-tone thresholds (i.e. $\leq$ 25 dB HL) within normal limits at all audiometric frequencies. Examination of table 2 shows mean thresholds to be fairly consistent across academic classes within the college-age population.

Table # 1

Demographic Characteristics of Participants

Sex and Age with Standard Deviation (SD) by Academic Class

Class	Males	Females	n	Mean Age (yr)
Freshman	18	26	**44**	18.2
Sophomores	8	39	**47**	19.0
Juniors	8	32	**40**	20.1
Seniors	17	32	**49**	21.2
Total	**51**	**129**	**180**	19.8

Table # 2

Means and SD of Pure-Tone Thresholds (dB HL) by Academic Class

dBHL	Freshman	Sophomore	Junior	Senior
250	9.04 ± 5.31	9.06 ± 5.80	9.12 ± 5.87	9.87 ± 6.83
500	6.22 ± 4.24	4.95 ± 4.59	4.17 ± 4.74	2.86 ± 4.67
1000	4.07 ± 4.47	3.91 ± 4.02	3.57 ± 4.17	1.89 ± 3.94
2000	2.73 ± 5.02	1.67 ± 4.33	2.86 ± 4.74	0.92 ± 4.67
4000	3.66 ± 5.33	4.38 ± 5.91	3.33 ± 5.32	2.91 ± 5.91
8000	10.23 ± 6.75	10.99 ± 7.66	9.76 ± 6.96	10.41 ± 6.91
Mean 2kHz, 4kHz, and 8kHz	5.54 ± 3.80	5.68 ± 3.87	5.32 ± 4.06	4.74 ± 4.38
Mean 250Hz – 8kHz	6.01 ± 2.99	5.83 ± 2.95	5.64 ± 3.51	4.48 ± 3.43

Listening Habits

Table 3 demonstrates the means and ranges of the Verifit VF-1 SPL values for all 180 participants categorized by academic class. Fourteen listeners were found to listen to at least one song at an average level greater than 80 dB SPL. Of those fourteen (5 males and 9 females), eight listened to at least one song at an average level that exceeded 85 dB SPL. Twenty three participants selected listening levels for one or more songs with peak levels within the songs exceeding 85 dB SPL. Furthermore, reliability coefficients for test-retest reliability were high ($r = .78$, $p <.000$) for the 20 subjects who returned for a second measurement series.

Table # 3

Verifit Means in dB SPL

Academic Year:	Freshman	Sophomore	Junior	Senior
dB SPL Means and SD:	61.08 ± 12.57	62.31 ± 12.29	61.50 ± 10.91	61.07 ± 10.91

Examination of the free-field, A-weighted equivalents (Table 4) revealed that the differences between the maximum and minimum levels estimated using the MIRE method averaged 4.6 dB lower than the values reported in Table 3. The average free-field corrected listening level was 72.98 dBA (Range = 46.1 – 103.3; SD = 11.2) with a reported average of 6.93 hours of use per week (*SD* = 9.51*)*. Twenty-six participants sampled selected listening levels which resulted in mean values exceeding 85 dBA. Of those 26, fourteen participants selected listening levels which resulted in mean values exceeding 90 dBA. Table 5 details mean years and hours per week of headphone use organized by academic year. Examination of Table 5 indicates similar values across the four academic years. Participants also reported frequency of noise exposure via headphones as follows: fifty-three subjects (30.1%) reported infrequent noise exposure (<2 hours/week) and forty-three subjects (24.4%) reported frequent exposure to noise (>7.5 hours/week). The results (Table 6) indicate that zero participants in this study exceeded the NIOSH-recommended exposure limit for both the daily and weekly exposures.

Table # 4

Verifit Free-Field, A-Weighted Equivalents (dbA)

Freshman	Sophomore	Junior	Senior
72.42 ± 12.57	73.88 ± 11.93	73.17 ± 10.19	72.44 ± 10.48

Table # 5

Mean Headphone Usage by Academic Year with SD

Variables	Freshman	Sophomore	Junior	Senior
Years of Headphone Use	7.52 ± 3.30	9.00 ± 3.08	8.49 ± 2.90	8.17 ± 3.48
Hours per Week of Headphone Use	8.20 ± 11.52	6.96 ± 5.29	4.77 ± 5.90	7.56 ± 12.90

Table # 6

*Subjective Weekly Usage of 176 Participants**

Hours/Week	Freshman	Sophomore	Junior	Senior
< 2.000	23.26%	21.28%	43.59%	34.04%
≥ 2.000, < 4.75	25.58%	14.89%	17.95%	12.77%
≥ 4.75, < 7.50	23.26%	31.91%	23.08%	31.91%
≥ 7.50	27.91%	31.91%	15.38%	21.28%
Average incidence with SD in hrs/week	8.20 + 11.52	6.96 + 5.29	4.77 + 5.90	7.56 + 12.90

**Four subjects did not respond to survey items*

Listeners reported additional environmental situations in which they were exposed to noise. Table 7 reports the variety of common places participants reported noise exposure. Over half of the listeners reported being subjected to noise exposure at rock concerts. Other common exposure environments included: bars, clubs and parties; listening to music through speakers in the car; athletic events; and when shooting a gun.

Table # 7

Noise Exposure Environments (Other Than Through Headphones)

Noise Exposure	# of Subjects
Concerts	99
Bars/Clubs/Parties	37
Music in Cars	14
Athletic Events	13
Shooting Guns	12
Band Practice	9
Fireworks	9
Heavy Machinery	9
Lawn Mowing	8
Construction	6
Racetracks	6
Airplanes	5
Movies	3
Loud Traffic	3
Fire Alarms	2
Airplane Shows	2
Small Explosion	1
Dance Recitals/Competitions	1
Vacuum	1
Vet (Dogs Barking)	1

Table 8 displays the self-reported headphone types used by participants. The results indicate that earbuds are more often used than over-the-ear types of headphones and that non-noise cancelling headphones are more common than noise-cancelling headphones. Nine subjects reported more than one transducer type as "most often used", accounting for the larger total report than the number of subjects.

Table # 8

Types of Headphones

Headphones	Freshman		Sophomore		Junior		Senior		**Totals**
Regular (R) & Noise-Cancelling (NC)	R	NC	R	NC	R	NC	R	NC	
Earbuds	38	1	47	2	30	3	41	4	166
Over-the-Ear	4	1	4	1	6	1	2	2	21
Totals	42	2	51	3	36	4	43	6	**187**

Verifit VF-1 SPL measures were calculated for two listening devices, at five volume levels on the devices, using three different types of headphones with white noise. Table 9 illustrates the midpoint and maximum output for each configuration. The iPod earbuds yielded consistently lower results than the Sony and Skullcandy earbuds at the minimum and maximum volume levels using the two different PMPs.

Table #9

Verifit VF-1 SPL Baseline Measures (dBA)

Device	Headphones	Means & SD Midpoint Volume (Females)	Means & SD Midpoint Volume (Males)	Means & SD Maximum Volume (Females)	Means & SD Maximum Volume (Males)
iPhone	Sony	82.2 $\pm$ 5.8	82.8 $\pm$ 5.3	112.9 $\pm$ 4.2	113.3 $\pm$ 5.3
	Skullcandy	84.3 $\pm$ 4.1	88.5 $\pm$ 4.1	115.1 $\pm$ 2.2	117.4 $\pm$ 3.0
	iPod	78.6 $\pm$ 4.6	74.7 $\pm$ 7.0	108.2 $\pm$ 3.9	106.2 $\pm$ 3.8
Nano	Sony	79.5 $\pm$ 1.3	78.5 $\pm$ 3.5	111.4 $\pm$ 2.7	112.0 $\pm$ 3.1
	Skullcandy	83.8 $\pm$ 2.7	85.0 $\pm$ 4.1	116.5 $\pm$ 3.3	116.1 $\pm$ 4.1
	iPod	79.3 $\pm$ 6.8	74.2 $\pm$ 1.6	108.3 $\pm$ 3.5	105.1 $\pm$ 2.4

Multivariate Analysis Results

To quantify the significance of music exposure and listening habits on pure-tone threshold levels, a three-way analysis of variance (ANOVA) was performed using threshold as the dependent variable with years of earbud use, reported weekly usage levels and dB SPL output as factors. Tables 2, 3, and 4 demonstrate the similarity of hearing levels and listening levels among academic classes.

The AUC dB SPL response profile for 500 to 8000 Hz converted from the Verifit VF-1 probe-microphone listening levels did not affect the participants' threshold levels, $F(2, 172)= 1.54$, $p = 0.12$ Significant differences were found in the pure-tone thresholds based on report of weekly usage times ($F(2, 172) = 2.22$, $p = 0.03$). These results show that those who reported longer weekly usage times had significantly worse pure-tone hearing across the audiometric frequencies.

Considering academic class as a categorical variable and years of headphone use as a numerical value, an analysis of covariance (ANCOVA) was performed with pure-tone threshold AUC measured at 500 to 8000 Hz as the dependent variable ($F(7, 156) = 0.32$, $p = .81$). Analyses for discrete pure-tone frequencies similarly showed no difference by academic class. Furthermore, the AUC pure-tone thresholds were the same for the participants who reported a long history of earbud use versus those who did not, ($F(7, 156) = -0.44$, $p = 0.51$).

Discussion

The present study examined the relationship between PMP with headphone usage and hearing acuity within a college-age population to assess the risk of hearing damage attributable to the listening habits of young adults. The number of at-risk listeners within younger age groups has increasingly become a topic of discussion over the past several years (Fligor, 2009; Danhauer et al, 2009; Torre, 2008; Daniel, 2007; Epstein et al., 2010; Hoover & Krishnamurti, 2010; McCormick & Matisitz, 2010; McCaffree, 2008). Some studies have found the preferred listening levels of young adult PMP users to be at safe intensities as compared to the risk criteria set by NIOSH and OSHA (Rice, et al., 1987; Wong et al., 1990; Worthington et al., 2009). However, more recent studies have concluded that a typical college student listens to music with their PMP in excess of safe levels and that the students are listening for longer periods of time (Levey et al., 2011; Torre, 2008; Williams, 2005; Zogby, 2006).

The results of this study demonstrate that the vast majority of college students listen to music using PMPs at safe volumes according the existing free-field exposure criteria set in place. Only 26 of the 180 participants listened to their songs at average intensity levels that surpassed 85 dBA. However, the risk for hearing damage resulting from PMP exposure is not solely based on output levels. The duration of exposure over time must be considered in order to accurately assess the risk for NIHL. The current permissible noise exposure limits indicate the maximum number of hours per day a person should be exposed to a sound at a given decibel level is 8 hours at 85 dBA (NIOSH, 1998; OSHA 1983). Whenever higher dBA values are present, the duration of the exposure must be reduced in order to maintain the same level of exposure (Farina, 2007). The NIOSH exposure limit uses an equation that reduces the duration of exposure by half for every 3 dBA increase in SPL to generate consistent risk guidelines (see Table 10). In the current study, individual usage time and diffuse-field equivalency were accounted for to precisely estimate risk for NIHL. At 72.98 dBA, the average free-field equivalent listening level of participants in a typical day fell well below the 85 dBA noise exposure level generally set as the level of acceptable risk for occupational noise exposure. In addition, only seven of the subjects who listened at intensity levels ≥ 85 dBA within their songs reported listening for durations that exceeded the NIOSH guidelines for maximum noise exposure. The results indicate that the majority of listeners sampled are not at a substantially increased risk for hearing loss as a result of their listening habits using PMPs with headphones.

Table # 10

NIOSH Daily Permissible Noise Level Exposure Limits

dB A	Hours	dB A	Hours
85	8 hours	100	15 minutes
88	4 hours	103	7.5 minutes
91	2 hours	106	3.75 minutes
94	1 hour	109	112 seconds
97	30 minutes	112	56 seconds

However, the study did find that weekly usage time was significantly correlated (p = 0.03) with hearing acuity in college-aged students (see Figure 2). While no definitive audiometric signs of early hearing loss were found and much variability is present, a definitive trend exists for the group of the participants who reported longer durations of PMP use (>7.5 hours/week) showing worse pure-tone thresholds than the rest of the population sampled. The results of the current study reveal a differential effect of weekly usage time on pure-tone thresholds from 500Hz to 8000Hz. This concurs with a previous study conducted by Meyer-bisch (1996) which found increased pure-tone thresholds in 54 subjects who reported using PMPs longer than seven hours per week.

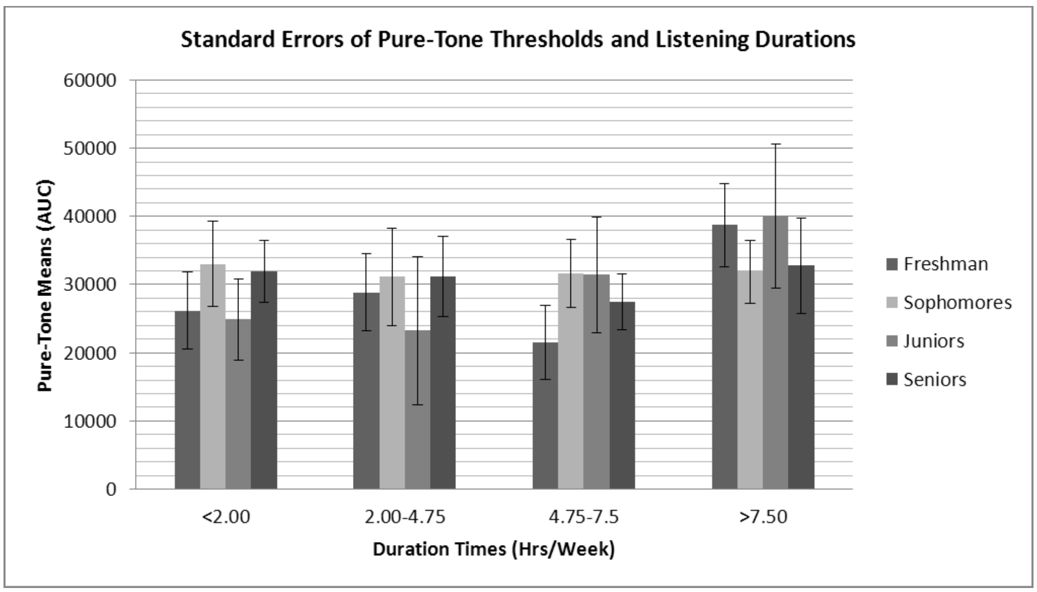


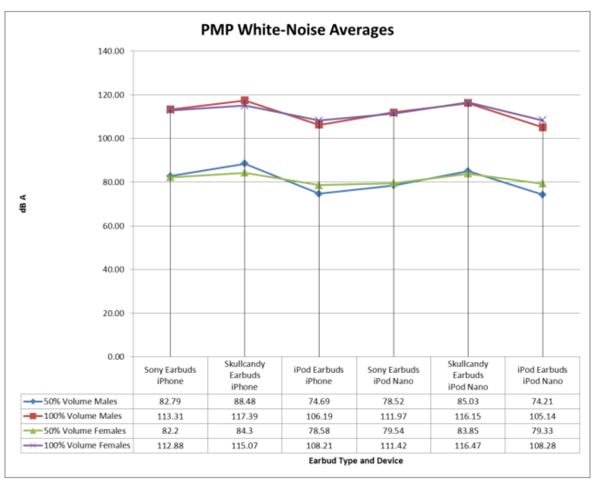
Figure 2. Average PMP usage as compared to pure-tone thresholds.

While the present study did not find conclusive levels of hearing damage when measuring the hearing acuity of 18-25 year old listeners, the absence of meaningfully elevated pure-tone thresholds does not prove that the auditory systems of these students have not been damaged by noise. The effects of long-term noise exposure may not be evident until individuals are older (Levey et al., 2011). Because humans have a considerable amount of cochlear outer hair cells, changes in hearing acuity resulting from outer hair cell damage may not be evident until other systems begin deteriorating. Longitudinal studies are needed that examine how hearing changes over many years of PMP use.

Previous studies have concluded that the objective ear canal measure is needed to help audiologists and consumers understand the actual level of risk associated with PMP use (Hodgetts et al., 2007; Zogby, 2006) While the current study answered this call by measuring the decibel levels in each subjects' ear canal at the level of the tympanic membrane, the testing methods may still not be sensitive enough to determine the actual level of risk. Further investigation is required using more sensitive instrumentation and objective usage times. Studies utilizing otoacoustic emissions testing and the involvement of PMPs that contain usage monitoring applications may provide a more exact measure of hearing health.

Another issue raised in prior research is the increasing rate of PMP use among college students (Torre, 2008; Williams, 2005). In the present study, 100% of the participants reported owning at a PMP, confirming that the majority of undergraduate university students possess and use at least one portable music device. These results indicate that the risk for noise-induced hearing loss in the young adult population could be greater than ever before simply due to the large number of PMP users in this age category.

The capability of PMP devices to play at hazardous levels for longer periods of time was also confirmed with measurements using white noise and three types of earphones. Objective measurements of two modern-day PMPs illustrate the hazardously high sound pressure levels available to listeners (see Figure 3). Results were consistent with earlier work based on similar free-field equivalent measures from the ear canal (Worthington et al, 2009). With the improved sound quality of modern PMPs and the capacity to listen for longer periods of time, it is clear that the potential exists for increased risk.



	Sony Earbuds iPhone	Skullcandy Earbuds iPhone	iPod Earbuds iPhone	Sony Earbuds iPod Nano	Skullcandy Earbuds iPod Nano	iPod Earbuds iPod Nano
50% Volume Males	82.79	88.48	74.69	78.52	85.03	74.21
100% Volume Males	113.31	117.39	106.19	111.97	116.15	105.14
50% Volume Females	82.2	84.3	78.58	79.54	83.85	79.33
100% Volume Females	112.88	115.07	108.21	111.42	116.47	108.28

Figure 3. Objective measurements of two modern-day PMPs at five intensity levels.

Based on previous literature, it could be expected that listener's preferred output levels would be affected by the amount of background noise in the environment in which they are listening (Fligor & Ives, 2006; Portnuff et al., 2009; Worthington et al., 2009). Students in the current study reported habitual use of PMPs in a variety of listening environments that may include significant levels of background noise. Examples of listening environments reported include: when riding a bus, walking to class, studying, exercising, and doing yard work or working. Fifty-two participants reported regularly using volume levels above the 50% mark indicated by the iPod volume bar (see Appendix D, Figure A). Because the current study took place in a quiet environment, the preferred listening levels of the subjects recorded may have been lower than if the subjects were tested in a louder, more natural environment. Future studies should include specific types of background noise that can be generalized to all listening situations.

Lastly, no significant differences between male and female PMP listening habits were found. Previous studies have drawn inconsistent conclusions regarding the relationship between gender and listening behavior. Torre (2008) reported that males choose higher listening levels than females. However, research methodology and settings have varied across investigations. Some studies have taken place in a laboratory setting (Hodgetts et al., 2007; Torre, 2008). Other examinations have measured PMP output levels in a natural, or naturally simulated, environment containing real-world noise conditions (Fligor & Ives, 2006; Williams, 2005). Additionally, the current study contains a larger sample than prior studies that have reported gender differences in the listening habits of young adults (Fligor & Ives, 2006; Torre, 2008; Williams, 2005). The findings of this study agree with previous work by Levey et al. (2011), which also found no significant difference in PMP sound exposure between males and females.

Limitations

Limitations include the reliance on the study participants' to factually report their PMP usage in order accurately assess the risk for NIHL caused by PMP use. In order to yield a representative measure of listening level, the sound levels measured in the ear of the subjects during their three favorite songs were subjected to MIRE conversions (Berger et al., 2009). However, the use of self-reported measures in order to obtain the duration of PMP use denotes an increased risk for inaccuracy. If the participants were inaccurate when reporting duration levels, a greater number of participants who listened at intensity levels that reached $\geq$ 85 dBA within their songs may be in danger of sustaining hearing damage over time. However, similar studies in the past have relied on participant self-report (Worthington et al., 2009; Williams, 2005). In the absence of technical solutions to monitor participants' duration of PMP use, self-report remains the most effective method for estimating usage time in a large number of participants (Griffin et al., 2009).

Conclusion

The aim of this study was to examine the listening habits of college-aged students associated with PMP use in order to critically assess the level of risk for NIHL. While this study found that the PMP users tested typically listened to their music at output levels that resulted in lower exposure levels than the current criteria set in place, some users appear to be at risk. The results of this study suggest that PMPs produce high enough output levels (>85 dB) to pose a risk of hearing loss, especially if the device is used at elevated volume levels for extended amounts of time. The potential for dangerous volume levels, combined with newer technology's capability to prolong duration of use, is cause for concern. It is essential that PMP users become aware of their listening levels and know the maximum amount of time they can safely listen at their preferred level without risking permanent hearing damage. New technology should incorporate software to monitor listening levels and duration of use in order to provide the PMP user with the tools necessary to make better hearing health choices. Educational programs remain vital to raise public awareness that irreversible hearing damage is preventable if the necessary precautions are taken in order to minimize risk for NIHL.

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Appendix A

Health History Questionnaire

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

Subject Demographics:
Age:_________
Sex:_________
Grade Level/Academic Year:_______

Hearing History:

1. Do you have any concerns with your hearing? If yes, please elaborate:

2. Do you listen to music?

3. Have you had a history of ear infections? If yes, please elaborate:

4. Have you ever been exposed to loud noises? If so, in what environment(s)?

5. Do you wear hearing protection when in noise?

6. How often do you wear hearing protection? Please list in what situations:

7. Are you on any medications (Aspirin, etc.) that might influence your hearing? If yes, please list:

8. Have you experienced any ringing in your ears (past or present)? If yes, please explain:

9. Have you had any head or neck injuries or surgeries within the last year? If yes, please explain:

10. Do you have a family history of hearing loss? If yes, please explain:

11. When not using speakers to listen to music, what type of headphones do you use most often?
    a. Earbuds
    b. Over-the-ear
    c. Noise cancelling
    d. Other

Appendix B

Survey of Listening Habits

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

1. What is the name of the listening device you currently use majority of the time?
   - ☐ iPod Classic
   - ☐ iPod Shuffle
   - ☐ iTouch
   - ☐ iPhone
   - ☐ iPod Nano
   - ☐ Zune
   - ☐ Other: _________________

2. How long have you been using this particular listening device?

3. On average, how many days per week do you use your device with headphones?
   _____________ days/week

4. On average, for how many hours per day do you use your device with headphones?
   ___________________hours/day

5. In what situation do you listen to the device under headphones **the majority of the time**?
   - ☐ Home
   - ☐ Bus
   - ☐ Walking to class
   - ☐ While exercising
   - ☐ When studying
   - ☐ Other:___________

6. Do you listen with headphones more often than with speakers?

7. With which devices do you use to listen to music through speakers? Check all that apply:
   - ☐ Computer
   - ☐ Speakers
   - ☐ Stereo system
   - ☐ iHome/Dock
   - ☐ Other: _________________
   - ☐ I do not use speaker

8. Have you previously owned any of the following Portable Music Devices (PMPs)? Check all that apply:
   - ☐ Personal cassette player
   - ☐ Portable compact disk
   - ☐ Personal AM/FM radio
   - ☐ Other: _________________

9. What genres of music do you generally listen to a majority of the time under headphones? Check all that apply.
   - ☐ Pop/Rock
   - ☐ R&B/Hip-Hop
   - ☐ Alternative
   - ☐ Metal
   - ☐ Country
   - ☐ Other:______

Appendix C

Survey of Knowledge of Risk

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

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

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

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

4. 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. 30 minutes
   b. 1 hour
   c. 2 hours
   d. 3 hours

5. Do you feel that you listen to your device at harmful levels? Yes/No/At Times

6. If you learned that you were listening to your device at harmful levels, would you turn it down/limit your daily use?

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

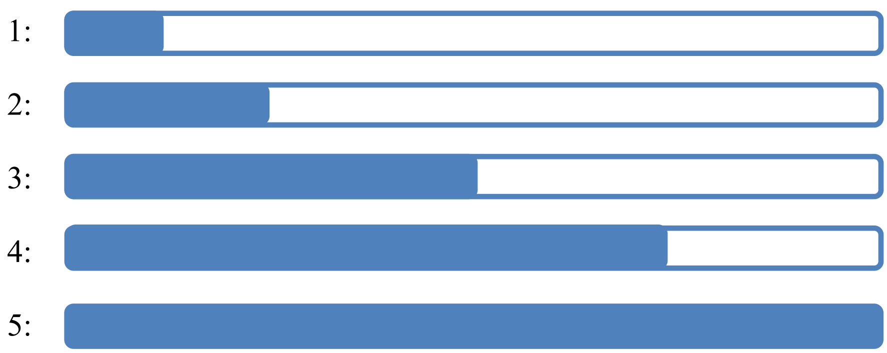
8. Would you like more information regarding iPod/earbud use and potential hearing loss?

Appendix D

Volume Bar

Figure A:

Figure B:



6: None of the above – even the maximum volume on personal listening devices are safe because manufacturers make sure they are.

Appendix E

VerifitVF-1 Measures – Reliability

Subject ID#:_______________ Date (Initial testing):_____________________

Tester Initials:_______ Date (Reliability Measure):_______________

Initial Testing Information

Song Titles:
1. _________________________________
2. _________________________________
3. _________________________________

Volume level (in dB):
1. _________________________________
2. _________________________________
3. _________________________________

Length of play: ____________seconds to__________seconds

Average Volume Level (dB): _____________

Reliability Measure Information

Song Titles:
4. _________________________________
5. _________________________________
6. _________________________________

Volume level (in dB):
4. _________________________________
5. _________________________________
6. _________________________________

Length of play: ____________seconds to__________seconds

Average Volume Level (dB): ___________________