Premature hearing loss in young adults is becoming more prevalent. Listening behaviors influence hearing levels and research has shown a protective effect of health-related fitness on hearing acuity in adults. The purpose of this study was to examine hearing acuity in college-aged students who use earbud style headphones, and to determine if cardiovascular (CV) health and fitness confer protection against noise-induced hearing. CV fitness, health biomarkers, music listening behavior, including volume and duration, were measured in 183 undergraduate students. Results showed that most students listened at safe intensity levels (<85dB SPL), but listening duration affected hearing acuity ($p = 0.03$). Factor analyses revealed that body composition significantly affected hearing acuity ($p = 0.03$). College-aged students who used earbud style headphones generally listened at safe levels and had normal hearing ranges, but shorter weekly earbud usage time (<7.5 hr/wk) and healthy body composition were significant factors that predicted hearing acuity.
EFFECTS OF HEALTH FACTORS AND PERSONAL LISTENING BEHAVIORS ON HEARING ACUITY IN COLLEGE-AGED STUDENTS WHO USE EARbud STYLE HEADPHONES

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Recent studies have shown that teenagers and young adults are experiencing an unusually high incidence of premature hearing loss, previously associated with advanced age or exposure to very loud noise. Increased popularity of earbud headphones and Personal Listening Devices (PLDs) such as MP3 players and iPods® are believed to contribute to the higher rate of early hearing loss in young adults (Biassoni et al., 2005; Chung et al., 2005; Danhauer et al., 2009; Fallon, 2006; McCormick & Matusitz, 2010; Niskar et al., 2001; Serra et al., 2005; Vogel et al., 2010).

Much of the noise-induced hearing loss data reported among teenagers has been associated with high music listening volume and long duration, although neither of these have been adequately quantified. In a study of adolescents in Dutch secondary schools, Vogel et al. (2010), via self-report data, found that about half of the 1512 students aged 12-19 years old listened to PLDs for longer than 56 hours at over 80 dB per week. These intensity levels and duration times exceed U.S. standards for safe listening levels (NIOSH 1998). Fallon (2006) reported that among American college students, aged 18-27 years old (n = 199), the mean duration of daily usage of PLDs was 4.5 hours; with the highest average daily listening duration of 5.7 hours in 19-year-olds. In the same study, average hearing loss associated with PLD usage was 23.5 decibels with the youngest subjects exhibiting a 19.3 dB deficit and the oldest displaying a loss of 25.6dB.

The risk of hearing loss is known to increase when ears are exposed to loud volumes over long periods of time. The use of earbud headphones adds to the risk of loud exposure because of the trend indicating the smaller the headphone, the higher the output level for a given volume control (Fligor & Cox, 2004). Because of this, earbud headphones and listening behaviors were investigated in the present study. There is also an emerging awareness about factors other than listening behavior that influence hearing acuity. Previous research has established a significant protective effect on hearing acuity in persons with high cardiovascular fitness, as measured by maximum oxygen consumption (V0₂ max.) (Alessio et al. 2002; Cristell, Hutchinson and Alessio, 1998; Hutchinson et al., 2000; Ishmael et al., 1973; Kolkhorst et al., 1998), blood pressure, and body composition (Kolkhorst et al., 1998). A healthy cardiovascular system is theorized to correspond with increased blood flow, oxygen, and nutrient delivery to bones and muscles throughout the body, including those of the inner ear, which are responsible for processing sound waves (Hutchinson and Alessio, 2010). The purpose of this study was to examine hearing acuity
in college-aged students and to determine if earbud style headphone use, listening behaviors, and cardiovascular health and fitness influence hearing acuity.

**Methods:**

**Participant Recruitment**

Undergraduate students from a mid-sized southwest Ohio University (n=183) between the ages of 17 and 22 years were recruited using fliers, word-of-mouth, classroom visits and a campus-wide online participant recruitment software (SONA). Subjects who did not meet the age requirement, who smoked or who had been diagnosed with a cardiovascular disease were excluded. Exclusion criteria for the audiological portion was bilateral hearing loss, middle ear disease or chronic history of noise exposure. A hearing health survey also queried subjects about their earbud usage time and subjective perceptions of loudness levels. If subjects were excluded, they were advised of the reasons and provided with information about appropriate follow up measures. This study was approved by the University’s Institutional Review Board, and all subjects completed informed consent.

**Data Collection: Audiological Testing**

The first audiology test was always otoscopy, where audiology researchers observed the subjects’ external auditory meatus and the tympanic membrane, looking for obstructions, malformations, or occlusions that might exclude participants from the study. Tympanometry was also performed to assess the compliance of the eardrum. The next component of the audiology testing involved randomizing pure-tone and iPod® output testing procedures. Pure tone hearing test and direct measures of sound output from earbud headphones were performed. A Verifit Audioscan VF-1 was used to measure the volume of sound at the level of the ear when wearing earbud headphones. A probe tip microphone was inserted in the ear canal. On the outside was a reference microphone that recorded gain and ambient noises. A baseline with the earphone in place with no music present was taken to measure ambient noise. After the baseline, participants were asked to select a typical favorite song. They were then instructed to set the volume to the level they usually listen to in the environment they most often listen. Three separate songs were recorded using a live-voice speech spectrum map, providing objective data for
intensity in decibels (dB SPL) across 1/12\textsuperscript{th} octave bands; 250, 500, 750, 1000, 1500, 2000, 3000, 4000 and 6000 Hz. An average of the quietest song and loudest song from the live-voice speech spectrum map measures were calculated and recorded. Reliability measures were exercised to ensure accurate data collection (data unpublished). Twenty random subjects were chosen and Verifit testing was repeated using the same song with the same device and headphones and same probe tip for comparison with original data (r=.99).

Pure Tone Thresholds (PTT), using the standard Hughson-Westlake method, were obtained using pulsed tones on a Grason-Standler model GSI-33 diagnostic clinical audiometer. PTT was measured bilaterally in a double walled sound booth at octave intervals; 250, 500, 750, 1000, 2000, 4000, 8000 Hz. Over the ear clinical grade TDH-39 headphones were used. Subjects were instructed to raise their hand when they heard the tone. Threshold was identified at the lowest decibel level heard 50 percent of the time on an ascending run.

Data Collection: Cardiovascular Health and Fitness Testing

Specific markers of cardiovascular and physical health included resting blood pressure and heart rate, blood lipids, BMI, Hip-to-Waist ratio, hand grip strength, daily activity assessments via pedometer, and a sub-maximal VO\textsubscript{2} test. Blood pressure and heart rate were measured on the left arm of all subjects after they had been sitting for 10 minutes using an Omron Intellisense Digital Blood Pressure Monitor, Model HEM-907xL. Blood lipid readings were collected using a Cholestech LDX analyzer, catalog number 02111239 (Cholestec corporation, Hayward, CA 94545). Participants were instructed to fast for at least 12-hours prior to the blood lipid tests. Specific markers measured were total cholesterol (TC), high-density lipoproteins (HDL), low-density lipoproteins (LDL), triglycerides, non-HDL, TC/HDL and glucose.

Body composition was measured using a Tanida body composition analyzer, Model TBF-300A. Participants were instructed to remove their shoes and socks and step on the electrode plates on the scale portion. For all participants, weight of clothes was entered as 1.0lb. and body type entered was “Athletic” for their gender. A SECA 210cm. stadiometer was used to determine height. Specific markers recorded from the Tanida scale were weight, body fat percentage (FAT\%), fat mass (FM) and fat free mass (FFM). Hip and waist measurements were taken using a Gulick II Tape, model 67020. Measures were
taken around the umbilicus and widest area around the buttock. Hand grip strength was measured using a Takei physical fitness test grip strength dynamometer, model number 68812 (Japan). Participants were instructed to stand, hold the dynamometer at their side and to squeeze as hard as they could for approximately 2 seconds. Right hand and left hand were measured twice and the best score was taken.

Daily activity estimates were made using pedometer step data using the Yamax pedometer model SW-200. Participants were instructed to reset the pedometer each morning, wear the pedometer for all activities and record their daily steps at night for 14 days. The collection of pedometer steps was used not only to gain objective data for daily activity but was also used to validate self-reported exercise and daily activity routines.

Sub-maximal VO\(_2\) was measured using a single-stage treadmill jogging test designed for young adults, 18-28 years of age (George, Vehrs, Allsen, Fellingham, and Fisher 1993). This test consisted of running on a motorized treadmill at a constant, participant-chosen speed for 3 minutes to achieve a steady-state heart rate. Minimum speed was no less than 4.3mph and maximum speeds for men and women were 7.5 and 6.5 mph, respectively. According to the protocol, steady state heart rates were not to exceed 180bpm for either gender. The protocol was modified slightly by having the participants ‘warm-up’ by walking at 3 mph for the first minute. Heart rate was measured with a Polar chest strap (T31) and wristwatch. At the completion of the test, the subject’s body weight in kilograms (BW), speed (mph), HR at termination (bpm) and gender (0=Female, 1=Male) were used to calculate the estimated VO\(_2\) max. Reliability measures between VO\(_2\) max values from this submaximal test and a true maximal test in a subsample (n=21) was strong (r = .90).

Equation is shown below:

\[
\text{Est. VO}_2\text{Max}= 54.07-0.1938(\text{BW}) + 4.47(\text{speed in mph}) - 0.1453 (\text{HR on bpm}) + 7.062 (\text{gender: female}=0, \text{male}=1)
\]
Statistics

Fourteen different variables representing CV health, physical activity, and fitness were measured: 1. VO2 max, 2. Daily pedometer steps, 3. Weekly pedometer steps, 4. Days per week in physical activity, 5. Intensity of physical activity, 6. Muscle strength, 7. Body mass index, 8. Waist to hip ratio, 9. Body fat percentage, 10. Total cholesterol (TC), 11. Total triglyceride (TG), 12. TC:TG, 13. HDL, and 14. TC:HDL. A factor analyses was used to reduce the data and search through the fourteen variables for latent constructs among them, and find a combination of these 14 variables that maximized the percentage of overall variability explained. Eigen values were generated, representing a ratio of the variance explained by a particular factor as compared with a variance explained by any one of the 14 input variables. Regression analyses using CV health, physical activity, and fitness as potential predictors of hearing acuity or pure tone threshold, as measured by area under the curve response profile for wide band frequencies, were also performed. Statistical probability level for each statistical analysis was set at 0.05.

Hearing acuity was compared in students across all classes at different frequencies between 500 Hz and 8000Hz using a technique called Area Under the Curve (AUC). The AUC profile was derived by first averaging the hearing loss in both ears at a given frequency. This right ear/left ear mean at a given frequency was then plotted on a graph with the eight frequencies tested on the x-axis and decibels of hearing loss plotted on the y-axis. After mean hearing losses were plotted, a line connecting each adjacent dot was made and the area under the curve was calculated as the area between this line and the X-axis. (Figure 2). This allowed direct comparison between the mean hearing loss in participants at 8 different frequencies using one AUC value.

Results

Table 1 presents descriptive data, including means ± sem for earbud listening volume in different academic classes, earbud headphone use and subjective loudness score. When comparing hearing acuity across academic year, no significant differences occurred and earbud headphones played no significant role in hearing acuity when comparing students in different academic classes. Figure 1 shows how hearing acuity was significantly affected by length of time whereby students listening > 7.5 hours per week had significantly worse hearing than students listening < 7.5 hours per week. Listening volume, on
the other hand, did not differentiate hearing acuity, however, most students’ listening volumes were found to be in the safe range (< 85dB SPL).

Table 4 presents means ± sem for eleven measures of CV health, fitness, and physical activity. These measures, plus three additional measures of physical activity, were analyzed by factor analyses in order to investigate latent variables among all of these biomarkers. Eigen values for each of the fourteen variables were generated, representing the ratio of the variance explained by a given measure compared with a pooled variance from any of the fourteen biomarkers. Five of the measures had Eigen values that exceed 1.0, meaning that each one explained more than any one variable (Table 3). A decision was made to retain only the factors based on an Eigen criterion whereby 70% of the variance of all of the CV and fitness variables was explained. These criteria resulted in five factors being identified. In Table 3, the correlations or loadings are presented, showing five latent variables representing constructs that explain 70% of the variability of all fourteen variables, and these are statistically independent of each other. For example, the construct “body composition” includes two variables: BMI and W:H.

Regression analyses was used to determine if and how all of the factors influenced hearing acuity based on AUC PTT- across a wide band of frequencies. Of all the cardiovascular, fitness, and physical activity factors the only one that significantly affected AUC PTT-wideband, was body composition, which included the BMI and W:H (t-value = -2.15, p = 0.03).

Table 1. Listening Habits Descriptive Data

<table>
<thead>
<tr>
<th></th>
<th>1st Year (n=44)</th>
<th>2nd Year (n=48)</th>
<th>3rd Year (n=42)</th>
<th>4th Year (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listening Volume (AUC verifit units)</td>
<td>6143 ± 411</td>
<td>6529 ± 331</td>
<td>8519 ± 1285</td>
<td>6863 ± 348</td>
</tr>
<tr>
<td>Earbud headphone use (yrs)</td>
<td>7.52 ± .50</td>
<td>9.00 ± .45</td>
<td>8.49 ± .48</td>
<td>8.17 ± .54</td>
</tr>
<tr>
<td>Weekly Earbud use (hours per week)</td>
<td>8.20 ± 1.8</td>
<td>6.96 ± .77</td>
<td>4.47 ± .94</td>
<td>7.56 ± 1.88</td>
</tr>
<tr>
<td>Subjective loudness score</td>
<td>2.83 ± .13</td>
<td>3.22 ± .10</td>
<td>3.0 ± .13</td>
<td>2.93 ± .13</td>
</tr>
</tbody>
</table>
### Table 2. Descriptive data of all participants

<table>
<thead>
<tr>
<th></th>
<th>Non earbud users (n=14)</th>
<th>Earbud users (n=160)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUC of Earbud Volume</strong></td>
<td>7288 ± 1506</td>
<td>6927 ± 357</td>
</tr>
<tr>
<td><strong>AUC Pure Tones 2k-8k Hz</strong></td>
<td>23733 ± 4461</td>
<td>25087 ± 1058</td>
</tr>
<tr>
<td><strong>AUC Pure Tones 500k-8k Hz</strong></td>
<td>27531 ± 4587</td>
<td>29069 ± 1088</td>
</tr>
</tbody>
</table>

### Table 3. Eigen values of the top five factors that explained 70% of the variance of all fourteen cardiovascular, fitness, and physical activity variables.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigen value</th>
<th>Proportion (%)</th>
<th>Cumulative Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fitness</td>
<td>3.089</td>
<td>22.07</td>
<td>22.07</td>
</tr>
<tr>
<td>TG and TC</td>
<td>2.352</td>
<td>16.80</td>
<td>38.87</td>
</tr>
<tr>
<td>Physical Activity</td>
<td>1.620</td>
<td>11.57</td>
<td>50.44</td>
</tr>
<tr>
<td>Body Composition</td>
<td>1.472</td>
<td>10.51</td>
<td>60.96</td>
</tr>
<tr>
<td>HDL and TC</td>
<td>1.336</td>
<td>9.55</td>
<td>70.50</td>
</tr>
</tbody>
</table>
Table 4. Orthogonal transformation matrix presenting strong correlations (< 0.70) of each individual item in the factor analyses investigating latent variables among CV health, fitness, and physical activity.

<table>
<thead>
<tr>
<th>Fitness</th>
<th>TGC and TC</th>
<th>Physical Activity</th>
<th>Body Composition</th>
<th>HDL and TC</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA days•wk^{-1}</td>
<td></td>
<td>.776</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA min•session^{-1}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA intensity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass index</td>
<td></td>
<td>.870</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Fat Percentage</td>
<td>.912</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waist:Hip</td>
<td></td>
<td>.752</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cholesterol</td>
<td>.723</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triglycerides</td>
<td></td>
<td>.916</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TC:TG</td>
<td>.937</td>
<td></td>
<td>.831</td>
<td></td>
</tr>
<tr>
<td>HDL</td>
<td></td>
<td></td>
<td>.917</td>
<td></td>
</tr>
<tr>
<td>TC:HDL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO_{2max}</td>
<td>.906</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steps•day^{-1}</td>
<td></td>
<td>.781</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5. CV & Fitness Variables by Academic Class

<table>
<thead>
<tr>
<th></th>
<th>Freshman (n=44)</th>
<th>Sophomore (n=48)</th>
<th>Junior (n=42)</th>
<th>Senior (n=49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>22.40 ± .38</td>
<td>23.02 ± .51</td>
<td>23.89 ± .54</td>
<td>22.28 ± .41</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>16.91 ± 1.54</td>
<td>21.56 ± 1.05</td>
<td>21.89 ± 1.41</td>
<td>17.71 ± .91</td>
</tr>
<tr>
<td>Waist: hip</td>
<td>.8 ± .007</td>
<td>.80 ± .007</td>
<td>.80 ± .009</td>
<td>.81 ± .008</td>
</tr>
<tr>
<td>Hand Grip strength (kg)</td>
<td>35.15 ± 1.55</td>
<td>31.17 ± 1.13</td>
<td>30.82 ± 1.56</td>
<td>35.05 ± 1.64</td>
</tr>
<tr>
<td>Total cholesterol (mg•dl⁻¹)</td>
<td>162.95 ± 6.56</td>
<td>166.04 ± 4.69</td>
<td>169.44 ± 4.26</td>
<td>165.27 ± 4.0</td>
</tr>
<tr>
<td>Total triglyceride (mg•dl⁻¹)</td>
<td>88.05 ± 5.8</td>
<td>102.06 ± 9.14</td>
<td>102.61 ± 5.49</td>
<td>95.46 ± 6.32</td>
</tr>
<tr>
<td>TC:TG</td>
<td>2.13 ± .12</td>
<td>2.02 ± .11</td>
<td>1.85 ± .10</td>
<td>2.08 ± .135</td>
</tr>
<tr>
<td>HDL (mg•dl⁻¹)</td>
<td>55.78 ± 2.28</td>
<td>55.66 ± 2.32</td>
<td>66.63 ± 5.49</td>
<td>69.25 ± 9.25</td>
</tr>
<tr>
<td>TC:HDL</td>
<td>3.11 ± .11</td>
<td>3.21 ± .16</td>
<td>2.92 ± .96</td>
<td>2.97 ± .15</td>
</tr>
<tr>
<td>VO₂max (ml•kg⁻¹•min⁻¹)</td>
<td>48.94 ± 1.14</td>
<td>45.27 ± .81</td>
<td>45.66 ± .87</td>
<td>46.92 ± .72</td>
</tr>
<tr>
<td>Daily steps (steps•day⁻¹)</td>
<td>12154 ± 707</td>
<td>11081 ± 525</td>
<td>10700 ± 546</td>
<td>11082 ± 492</td>
</tr>
</tbody>
</table>

Discussion

Although often associated as an age-related phenomenon, hearing loss has been identified as a recent problem in young adults and college-age students. Music listening behaviors, particularly when using PLDs, have been identified as the leading cause of premature hearing loss in young adults of traditional college age. Earbud headphones have attracted attention because they are considered more hazardous than over the ear headphones due to the way sound is ‘funneled’ or focused into the ear and the inability to block out ambient noises. Earbud headphones resulted in higher output levels for the same volume setting compared to other styles (Fligor & Cox, 2004) and also the highest preferred listening levels (PLL) (Hodgetts, Rieger & Szarko, 2007).
Hodgetts, Rieger and Szarko (2007) identified two major factors, preferred listening levels and the length of time users choose to listen at those levels that negatively influenced hearing acuity. In his investigation of over 600 college students, Danhauer et al. (2009) concurred that this population typically listen to PLDs at volume levels and durations that could pose a risk for hearing loss. Because less than 8% of participants in the present study used headphones other than earbuds, it was difficult to determine if using earbud use, per se, contributed to hearing loss. The present study found over 92% of participants used earbuds, which was similar to that reported by Torre (2008), with 88% of the 930 subjects using in-the-ear style or earbud headphones and Danhauer et al. (2009), who reported 76% of 609 college-aged students using earbud headphones.

To date, many studies have examined hearing acuity in young adults. Biassoni et al. (2005) in a 4-year longitudinal study of college students, reported significant hearing threshold shifts, exceeding 30dB in some cases, during the third year. Biassoni et al (2005) found that this level of hearing loss continued into the fourth year and even worsened. The level of threshold shift was similar to Fallon’s (2006), research which reported an average 23.5 dB shift in young adults aged 18-27, as main contributors to premature hearing loss. Niskar et al. (2001) evaluated hearing acuity in 5249 children and young adults age 6-19, and found 597 (11.3%) to have significant noise-induced hearing threshold shifts. The cause of these hearing losses have been linked to non-occupational noise exposure, recreational noise exposure and specifically PLDs (Shah, Gopal, Reis and Novak, 2009; Torre 2008; Uppundsa, 2010; Vogel et al., 2010; Zhao, Manchaiah, French and Price, 2010; Biassoni et al. 2005; Danhauer et al., 2009).

In the present study, most college aged students listened to PLDs at levels considered to be safe (< 85 dB) by NIOSH standards (NIOSH, 1998). But, the more important listening variable associated with hearing acuity was listening duration in hours per week, with 7.5 hours being the duration beyond which was associated with poorer hearing acuity (Figure 1).
Figure 1. Hearing Acuity vs. listening duration

* Hearing acuity was significantly compromised in freshman, juniors, and seniors who listened used earbud headphones > 7.5 hours per week, p< 0.05.
Recently, Daniel (2007) cited a variety of non-audiological measures such as regular exercise and eating a healthy diet, as ways to prevent hearing loss. Of the cardiovascular health and fitness factors measured in the current study, the main factor that was significantly related to hearing acuity was body composition, and was comprised of body mass index and waist to hip ratio. Body composition has been previously reported to be associated with hearing acuity (Kalhkorst et al, 1998), and in the current study, there was adequate variability in body composition among all subjects to distinguish hearing acuity by this variable. VO\textsubscript{2}max, on the other hand, which has been shown to be associated with hearing acuity (Alessio et al. 2002; Cristell, Hutchinson and Alessio, 1998; Hutchinson et al. 2000; Ishmael et al., 1973; Kolkhorst et al. 1998), had little variability in this subject pool. Although VO\textsubscript{2}max was determined to be a statistically important variable, it did not show a significant effect on hearing acuity, mainly because virtually all subjects were found to be moderately or high fit and only three subjects were found to have low VO\textsubscript{2}max levels.
In conclusion, results from the current study suggest that young adults who volunteered in this study and listened to music with PLDs followed safe listening habits and were generally moderately or highly fit. Hearing acuity in this sample was within a normal healthy range, with some outliers. The typical protective effects of youth, including healthy cochlea and cardiovascular fitness, appeared to prevent significant threshold shifts often seen in hearing loss, except in individuals who listened to PLDs for long durations, specifically > 7.5 hr/week. These individuals had worse hearing acuity than those who listened for shorter weekly durations. Additionally, most health and fitness variables seemed to contribute to healthier hearing acuity, but body composition, specifically, healthier BMI values and waist:hip ratios significantly predicted hearing loss.

**Limitations**

The current study used a convenience sample of volunteer students from a Mid-West University, which may not have been representative of all college students. As mentioned in the discussion, the homogeny within the subject pool, in regards to predicted V0₂max, lead to inconclusive findings with regards to protective effects of cardiovascular fitness on hearing acuity. It is possible that since the study included health and fitness assessments, students most likely to volunteer would have had a moderate or high level of CV fitness. In addition, inaccuracies in self-reported music listening behaviors could have also affected results. Lastly, despite the significant findings in hearing loss, the intermittent nature of noise exposure, as explained by Torre (2008), may not lead to as much hearing loss as we previously thought; “because of the intermittent nature of this noise exposure, it is possible that an individual could listen to their personal music system in three, 30-minute sessions a day. Even at loud volumes, this would not increase their risk for hearing loss”.

**Future Studies**

Based on our findings, significant disparities in hearing acuity were recorded among young college-age adults. Most subjects in the present study listened to their PLD’s at safe listening levels (<85dB) but listening duration (hrs/week) varied considerably among subjects, which significantly impacted hearing acuity (p < 0.05). Additionally, those with healthier BMI values and waist-to-hip ratios displayed
significantly better hearing acuity. Estimated VO$_2$max. did not reach significance in predicting hearing acuity, but this will allow room for future studies as a greater pool of low-fit young adults is needed.

Risks for smoking began in the early and middle of the 20$^{\text{th}}$ century, as little was known about the hazards associated with this leisure activity. Although cigarettes can still be purchased, risks associated with smoking, now, are well known. With little awareness about the risk of possible premature hearing loss from listening to PMD’s using earbud headphones, more young adults and teenagers than ever are at risk of irreversible NIHL due to popular listening behaviors (McCormick & Matusiz, 2010). It is difficult to predict whether subjects in the present study observe noticeable deficits in their hearing currently, but it can be safely hypothesized that deficits will manifest themselves at a much earlier age for this generation, than generations past if hearing is not protected, preserved and respected. Education may be the most effective solution to the problem of PMDs, ear bud headphone usage and hearing loss. (Daniel, 2007; McCormick, J., Matisitz, J. 2010; Niskar et al. 2001).
Bibliography


Hearing. 28. 290-297.


