COMPARISION OF POST EXPOSURE EFFECT OF MUSIC THROUGH PERSONAL LISTENING DEVICE (PLD) ON HEARING IN YOUNG ADULTS

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MANASAGANGOTHRI

MYSORE-570006,

May, 2013

CERTIFICATE

This is to certify that this dissertation entitled **'Comparison of Post Exposure Effect of Music through Personal Listening Device (PLD) on Hearing in Young Adults'** is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No.: 11AUD010. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree**.**

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CERTIFICATE

This is to certify that the dissertation entitled **"Comparison of Post Exposure Effect of Music through Personal Listening Device (PLD) on Hearing in Young Adults"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other university for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled **"Comparison of Post Exposure Effect of Music through Personal Listening Device (PLD) on Hearing in Young Adults"** is the result of my own study under the guidance of Dr. Ajith Kumar U., Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted in any other University for the award of any Diploma or Degree.

Mysore,

May, 2013 **Registration no: 11AUD010**

DEDICATED TO

GOD ALMIGHTY

&

MY LOVEABLE PARENTS

ACKNOWLDGEMENT

"Tvameva Mata Cha Pita Tvameva Tvameva Bandhuscha Sakha Tvameva Tvameva Vidya Dravinam Tvameva Tvameva Sarvam Mama Deva Deva"

- **Sri guru gita**

O Lord! Thou art my mother and Thou art my father also; Thou art my relative and my friend Thou art; Thou art knowledge and wealth unto me; Thou art my all-in-all, O Lord of Lordsh

So in the happy moments, praise God. Difficult moments seek God. Painful moments trust god. Every moment thanks God. A tearful thank to God for making my life in these years.

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CHAPTER- 1

Introduction

The leading preventable cause of acquired sensorineural hearing loss is exposure to excessive levels of noise, which leads to irreversible loss of cochlear hair cells. Traditionally, noise induced hearing loss was a condition seen in adults who worked in noisy occupations or used firearms. But of late, due to massive growth in the popularity of personal MP3 players, young adults are exposed to high levels of music, and they may be at risk for permanent hearing loss every time they listen to their favourite music (Kasper, 2006). Most often it is seen that the people prefer using personal listening devices (PLDs) during travelling or before sleeping. The rapid development of digital technology has produced new kinds of PLDs whose sound quality at higher volumes is much better, because the sound is no longer distorted. Because the music players are equipped with improved earphones, sound leakage is almost absent, which means that the music players can be played at hazardous high volumes in most environments without disturbing others. Hearing loss induced by PLDs may evolve into a significant social and public health problem in future years. Previous investigations have revealed that output sound pressure levels produced by personal music systems are in 80-120 dBA range. Preferred listening levels were slightly higher for ear bud style of earphones compared to the over-the-ear style (Hodgetts, Rieger & Szarko, 2007). In addition, ear bud type which gives a tailor-made fit in ear canal increases the problem by direct channelling the sound into the ear (Fligor, 2004).

The output levels of the PLDs depend upon the type of PLDs, listening environment and style of headphone (Catalano & Levin, 1985; Kuras & Findlay, 1974; Lee, Senders, Gantz & Otto, 1985; Fligor & Cox, 2004; Williams, 2005;

Hodgets, Rieger & Szarko, 2007; Kumar, Mathew, Alexander & Karan, 2009). The output levels of the PLDs ranges from a minimum of 80 dBA approximately to a maximum as 121 dBA (Filgor & Cox, 2004). Kumar et al. (2009) evaluated the mean output SPLs at preferred listening settings in quiet, in the presence of 65 dB SPL bus noise and at maximum volume control settings for mobile phones, iPods and locally made MP3 players. The mean loudness equivalent exposure for continuous 8-hour of duration (Leq 8hr) were 73 dBA for mobile phones (Range: 40 dBA to 93 dBA), 76 dBA for iPods (Range: 56 dBA to 86 dBA), and 79 dBA for locally made MP3 players (Range: 70 dBA to 84 dBA), at subject preferred volume control settings in quiet. Listening in the presence of bus noise did not increase the output SPLs significantly but at the maximum volume control settings output levels increased compared to the subject preferred volume control setting. Dhanalakshmi (2012) measured the output levels of PLDs at quite and in the presence of 65 dB SPL bus noise condition. Results reaveal that the preferred listening lesser compared to output levels measured in the presence of 65 dB SPL bus noise condition. Mean 8 hour equivalent listening levels in quiet was 96.35 dBA and in the presence of bus noise was 102.97 dBA. These values were alarmingly high and indicate that young listeners listen to music at hazardously high intensities.

It has been shown in the previous studies that the use of PLDs may have hazardous effect on hearing (Tao & Huang, 2007; Kumar et al., 2009; Dhanalakshmi, 2012). Tao and Haung (2007) reported that the hearing thresholds in the 3kHz, 4kHz, 6kHz, and 8kHz frequency range were significantly increased in PLDs listener though hearing thresholds in low frequencies were within normal range. Kumar et al. (2009) also reported that listening to music through PLDs at a preferred volume control setting may not result in “Clinically significant” elevation of hearing threshold and may not be evident during routine pure-tone audiometry. Furthermore, Kumar et al.(2009) reported that amplitude of high frequencies otoacoustic emissions were reduced in individuals who listen to high level of music. Dhanalakshmi (2012) reported elevated high frequency and extended high frequency hearing thresholds and reduced otoacoustic emissions amplitude in the individuals using PLDs compared to those who didn't use.

1.1 Need for the study

The most frequent cause of irreversible acquired sensorinural hearing loss is exposure to high level of noise which can be preventable. Kumar et al. (2009) reported that individuals who listened to music at high levels tend to have higher pure tone hearing thresholds at 6000 Hz. Besides they reported significantly reduced otoacoustic emission amplitude at high frequencies in group of people using PLDs at a higher level. Dhanalakshmi (2012) reported reduced OAEs and elevated extended high frequency threshold in individuals who used PLDs. These results suggest that, listening to music through PLDs at louder intensities may cause pre-clinical damage to the outer hair cells and eventually may result in hearing difficulties over the years. These auditory effects may be temporary or permanent depending on factors such as duration of exposure, intensity, pitch, and other physiological factors. Hence this proposed study is designed to investigate the nature of auditory deficit caused by PLDs.

1.2 Aim of the study

To investigate the effect of listening to PLDs on hearing and to see the nature of these deficits as being permanent or temporary.

1.3 Objective of the study

1. To measure the output levels of the PLDs at the volume control setting that was preferred by the subject in quiet, in the presence of 65 dB SPL bus noise and at maximum volume control of the device.
2. To compare the extended high frequency hearing thresholds (3 kHz-20 kHz) before and after abstaining from listening to music through PLDs
3. To compare the transient evoked otoacoustic emissions before and after abstaining from listening to music through PLDs
4. To compare speech perception in noise before and after abstaining from listening to music through PLDs

CHAPTER- 2

Review of Literature

The habit of using high levels of music is very common in recent population. (Williams, 2009; Keppler, Dhooge Maes, D'haenens, Bockstael, Philips, Swinnen, Vinck, 2010; Shargorodsky, Curhan & Eavey, 2010). There are approximately over 100×10^6 personal listening devices (PLDs) sold annually worldwide (Reuters Press, 2005) and 90% of the college students own PLDs (Torre, 2008). Listener preferred to use digital PLDs more frequently and for a longer duration due to its long battery life, mass storage ability and reduced distortion at high output levels (Reuters, 2005). Those who preferred to listen music as a recreational activity also exposing themselves to high sound levels in different environments (Royster, Royster & Killion, 1991; Gunderson, Moline, & Catalano, 1997; Serra et al., 2005). Recent studies provide evidence of noise induced hearing loss (NIHL) in young people, suggestive of loud rock music along with increasing use of PLDs at a high level may be responsible for this phenomenon.

When calculating the level of risk or amount of exposure, both duration of exposure and intensity of the signal must be considered. The National Institute for Occupational Safety and Health (NIOSH) guidelines for work place settings (1998) specify that any exposure of 85 dBA for more than 8-hours exceeds the maximum daily allowable noise dose. As the intensity of the signal increases, the maximum allowable exposure duration decreases. While this standard is based on industrial noise, it is also currently used as the guideline for recreational noise exposure, including listening to music. In India, the Ministry of Environment and Forests has proposed a maximum allowable noise dose of 85 dBA for an 8-hour period per day. The Ministry of Environment and Forests (2000) recognizes that there is a trade-off between the exposure time and the sound level, which is quantified by a ‘5 dB exchange rule’. Every 5 dB increase in the exposure level will be compensated by halving the exposure time to keep the risk constant. The maximum permissible level is also not fully harmless, as a few percent of people may still incur a permanent hearing loss if exposed to it. Typically, when discussing music listening behaviours, the general practice is to consider that noise levels exceeding the maximum daily dose as indicative of at-risk listening behaviour (Fligor & Cox, 2004).

Several studies have reported that the recent PLDs technologies are sufficient enough to produce the output levels that could enhance the risk of music-induced hearing loss (Airo et al., 1996; Fligor, 2004). The output levels of the PLDs varied from 83.4 to 107.3 dBA depending upon earphone used (Keith et.al, 2008; Filgaro, 2004). Now a day’s digital PLDs are preferred to be used for more durations than the older technologies, with a louder volume setting (Zogby, 2006) resulting in damage to the hair cells in the cochlea which further results in permanent or temporary cochlear hearing loss.

The scenario of using PLDs has been changed in such a way that from 1980 to 1990 it’s gone from 40 min per day to one hour per day. It also noted that in the recent decade its reaches up to two hours per day. (Ahmed et al., 2006; Airo et al., 1996; Bradley et al., 1987; Felchlin et al., 1998; Passchier-Vermeer, 1999; Rice, Rossi & Olina, 1987; Torre, 2008; Williams, 2005). Youngsters frequently preferred to listen their music at a potentially hazardous level without knowing it (Portnuff et al., 2009).The existing evidence by the American Speech-Language- Hearing Association (Zogby, 2006) found that teens more often complain of different symptoms of hearing loss such as increasing the volume on their television or radio, saying “What?” or “Huh?” during normal conversation and experiencing tinnitus or ringing sensation in the ears than adults. Kumar (2010) cited that the individual who used PLDs more than 1hour per day, reports some kind of otologic problem.

2.1 Output levels of PLDs

According to the previous studies output levels of the PLDs at listeners preferred volume control settings depends upon the type of PLDs, listening background, style of headphones etc (Catalano & Levin, 1985; Kuris & Findlay, 1974; Lee, Senders, Gantz & Otto, 1985; Fligor, 2004; Williams, 2005; Hodgets, Rieger & Szarko, 2007; Kumar, Mathew, Alexander & Karan, 2009; Dhanalakshmi, 2012). Output levels of PLDs have been reported to be a minimum of 80 dBA approximately (Williams, 2005) to a maximum as 121 dBA (Fligor, 2004). Catalano & Levin (1985) reported at volume control setting “1” the cassette player produced 60 dBA and 110–114 dBA at volume control setting “10. Rice, Breslin and Roper (1987) showed that output at preferred listening levels in quiet was 80.7 dB loudness equivalent levels and with the background noise of 70 dBA it was raised to 85.1 dB loudness equivalent levels, showing a 15 dB signal to noise ratio (SNR). Williams (2005) measured the output levels preferred by 55 listeners in noisy conditions using KEMAR, and then converted into diffuse field equivalent levels as well as the average daily A-weighted exposure level. The results showed a mean listening level of 86.1 dBA and a mean of 79.8 dBA for 8-hour equivalent levels. Peng, Tao and Huang (2007) indicated that the maximum output SPL from stereo headphones can go beyond 100 dBA which result in hearing loss of 14.1% of PLD user.

Torre (2008) reported that out of 1016 students 930 (91.5%) used PLDs; of these, >50% listened PLDs for 1-3 hours, with >90% reported to have used their PLDs at medium and loud volume. The measured output SPL values were 62.0, 71.6, 87.7, and 97.8 dB SPL for low, medium or comfortable, loud, and very loud respectively. Keith, David, Michaud and Chiu (2008) measured the A-weighted output levels at maximum volume setting from various combinations of portable digital audio players and headphones. Different overall SPLs are also observed in relation to fitness of headphone as 101 dBA for a 'loose' fit 101 to 107 dB for a 'tight' fit.

In a study by Kumar et al. (2009) sound pressure levels produced by the PLDs were measured in different listening environments such as in quiet, in the presence of background of 65 dB SPL bus noise and at the maximum volume control setting of the PLDs using a probe microphone measurement. The dB SPL values were then converted into 8-hour equivalent diffuse field levels. For the mobile phone the loudness equivalent sound pressure level for 8-hour exposure is ranged from 40 dBA to 93 dBA (mean 73 dBA) and the range for iPods was from 56 dBA to 86 dBA (mean 76 dB), and for MP3 players that are locally made range was 70 dBA to 84 dBA (mean 79 dBA), at volume control settings selected by the subject in quiet, and there was no significant change in the output SPLs in presence of noise**.** Dhanalakshmi (2012) also measured the output levels of PLDs at quite and in the presence of 65 dB SPL bus noise condition. Results revels that the preferred listening levels at quite condition was lesser that what it measured in the presence of 65 dB SPL bus noise condition and the mean 8 hour equivalent listening levels in quiet was 96.35 dBA and in presence of bus noise was 102.97 dBA .

So to summarize the preferred output levels of the PLDs may not be potentially hazardous for showing significant hearing problem but the increasing passion of continuously using the PLDs in youngsters can have an alarming signal for future hearing loss. It can be temporary or permanent in nature.

2.2 Measures for Effect of PLDs

2.2.1 Auditory measures for Effect of PLDs

2.2.1.1 Hearing threshold

The daily sound exposure limits measured by Levey and Fligor (2011) showed that the number of PLDs user who go beyond the daily sound exposure limits and the weekly sound exposure limits are 58.2% and 51.9 % respectively. So there is an increased risk of NIHL in the participants of this study. The use of pure tone audiometry hadn't been able to reflect any marked effect of loud music in young population (Carter, Murray, Khan & Waugh, 1984; Carter, Murray & Bulteau, 1985; Kumar et al., 2009). However, this could be due to the poor proficiency of audiometry to find out pre-clinical hearing loss. At the initial stage noise induced hearing loss leads to the problem in hearing high-frequency tones, but at the advance stage it may also slowly extend to the lower frequency tones (Serra et al., 2005; Daniel, 2007; Peng et al., 2007). Peng et al. (2007) compared a PLDs group, comprising 120 young adults (19-23 years) who used PLDs for at least one hour or more per day, with a control group of 30 normal hearing adults who had never used PLDs. Hearing thresholds were taken at 250, 500, 1000, 2000, 3000, 4000, 6000, 8000, 10000, 12500 and 16000 and 20000 Hz. The study results revealed that the hearing thresholds in the 3000 to 8000 Hz frequency range were significantly increased in the PLD group. Also, they found that the hearing thresholds of the PLD group to be significantly higher than those of the control group in the extended high-frequency region for

10000, 12500, and 16000 Hz. The extended high-frequency hearing thresholds of PLD users were higher even if their hearing thresholds in conventional audiometric frequency were normal. Similar finding was also reported by Dhanalakshmi (2012). She reported significantly poor hearing threshold in extended high frequencies in PLD user as compared to controls. This gives additional support to the claim that the use of PLDs may cause sub-clinical damage to auditory systems in the beginning, which may not be evident in the conventional audiometric frequencies. Mostafapour, Lahargoue and Gates (2009) determined the risk of noise induced hearing loss from PLDs in college students and found to have 10 dB or greater notch at 3 to 6 kHz.

2.2.1.2 Otoacoustic emission (OAE)

Research done on large population (1724 participants, 1066 males and 658 females) by LePage and Murray (1998) showed that PLD users had lesser otoacoustic emission strength than non users. The people working in an industrial setup as well as regular user of PLDs exhibited reduced OAE strength than the people who are not exposed to PLDs, but working in the industrial setup. This indicating that due to a clubbed effect of the both kinds of noise exposure, the first group of people are having more reduced OAE strength. Moreover, the amount of decline in OAE strength was reported to be proportional to exposure, as based upon a self report measure by placing the individuals into low, moderate and heavy categories of PLDs use.

Kumar et al., (2009) compared the distortion product otoacoustic emission (DPOAEs) amplitude between the group of individuals who were using PLDs and in a group of individuals who never used PLDs. Results reveales a negative correlation between DPOAE amplitudes at 6000 Hz and the exposed music levels in the group of individuals exposed to PLDs. Hence this correlation reveals that individuals who listen to music at higher output levels tend to have lower DPOAE amplitudes at least at 6000 Hz. However, all individuals who used PLDs in their study had normal hearing thresholds, DPOAE amplitudes and SNRs clinically. These results shows that listening to music through PLDs at preferred volume may not result in “clinically significant” reduction of DPOAE amplitudes and SNRs but can cause slight pre-clinical damage to the auditory system and as the time progresses such behaviour can be dangerous to the hearing system. Dhanalakshmi (2012) also cited significantly poorer transient otoacosutic emissions amplitude in PLDs user than those never had used PLDs

2.2.1.3 Temporal processing and speech perception in noise

Dhanalakshmi (2012) evaluated temporal processing in terms of Gap detection test and speech processing skill in noise in individual who used PLDs compared that to individual who did not use PLDs. Result reveales poorer gap detection threshold in the PLDs user in spite of the normal hearing sensitivity. Also it has been revealed that the speech perception in the presence of noise is better in individual who didn’t use PLDs especially at higher SNR. She provided the explanation as due to the prolonged exposure of loud music through PLDs there might be changes in the central auditory system.

CHAPTER- 3

Method

3.1 Participants

58 Participants in the age range of 16-26 years (mean age of 22 years, 23 males and 35 females) participated in the present research. These participants were divided into two groups. The Group-I consisted of 29 participants who report as the regular user of personal listening devices (PLDs) and Group-II consisted of 29 participants, served as the controls, who were not regular users of PLDs. Participants in Group-I had their air conduction and bone conduction hearing threshold within 15 dB HL at octave frequencies from 250 Hz to 8 kHz. All participants showed 'A' type tympanogram with acoustic reflex at normal sensation levels. None of them reported any history of middle ear pathology, ototoxic drugs usage or exposure to occupational noise.

3.2. Procedure:

The study was conducted in three phases. In the first phase output sound pressure level were measured. In the second phase hearing threshold, speech perception in noise and otoacoustic emissions were measured. In the third phase auditory measurements were repeated after asking PLD users to abstain listening to music for 15 days to evaluate the nature of hearing deficits, if any, being temporary or permanent.

3.2.1 *PHASE I: Measurement of output sound pressure levels (SPL) of PLDs*

Using a probe microphone, the output SPLs produced by PLDs were measured in the participant's ear canal. Fonix -7000 was used for this purpose. The probe microphone insertion depth of 28 mm (tip of the tube to the tragal notch) was maintained for all participants. All measurement were carried out with the subjects own PLDs and earphones. The earphone was placed after placing the probe tube in the ear canal. Before the measurement was done subjects were asked to play one of their favourite songs. Output SPLs were measured in three different conditions:

1) In quite - the subject was asked to set the volume control to their usual preferred listening setting.
2) In the presence of 65 dB SPL bus noise, the subject was asked to set the volume control to their preferred listening setting. Bus noise was given through a personal laptop (Sony Vaio E-series VPCEG17FG). Bus noise was considered as background noise as this condition is more naturalistic since most of the participants listen to music while commuting. Level of the noise produced by the bus engine in normal city ride condition (third gear at a speed of 40 kilometres per hour) at 2 feet from the driver (corresponds to 2-3 row of seat) was 65 dB SPL. Hence this condition was used to measure output SPL of the PMS (Kumar, Mathew, Alexander & Kiran, 2009).
3) At the maximum volume control settings of the instrument.

Position of the probe microphone remained constant in all measurement conditions. Diffuse field SPLs to which ear were exposed was calculated by subtracting the transfer function of the open ear from the obtained ear canal SPL. This transformation is required to compare the output of PLDs to damage risk criteria. As there is no evidence based definition exists for hazardous sound levels of music, as a substitute, standards for exposure to occupational noise have been proposed for use. The occupational noise exposure defines the maximum allowable noise levels in terms of diffuse field values and not as ear canal sound pressure levels. Hence, the ear canal sound pressure levels will be converted into to diffuse field levels by subtracting the transfer function of the open ear canal. The transfer function of the open ear was measured by calculating the difference between the probe microphone SPLs near the eardrum for a sweep frequency tone presented at 65 dB SPL and reference location which is at the opening of the ear canal. The output SPLs at each frequency was converted to dBA values by adding the A-weighting adjustment values. The overall SPL in dBA was calculated by adding the octave band levels logarithmically.

3.2.2 PHASE II: Auditory measures

In this Phase extended high frequency audiometry, otoacoustic emissions, and speech perception in noise were assessed.

3.2.2.1 Extended high frequency audiometry

Calibrated two channel diagnostic audiometer GSI 61 with transducer HDA 200 was used for extended high-frequency audiometry. Using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959) pure tone hearing thresholds were estimated at different frequencies from 3 kHz to 20 kHz.

3.2.2.2 Otoacoustics emission

Transient evoked otoacoustic emissions (TEOAEs) were recorded using commercially available otoacoustic emission analyzer (ILO-V6). Subjects were asked to sit on a reclining chair. TEOAE probe was inserted into their ear canal and TEOAEs were measured for 80 dB peak SPL clicks. Average response from a total of 260 non linear clicks was used for the analysis. The overall TEOAE amplitudes and amplitudes at 1000 Hz, 1414 Hz, 2000Hz, 2828 Hz and 4000 Hz frequency bands were noted and used for analysis.

3.2.2.3 Speech perception in noise

In the present study, speech intelligibility was measured using a signal-to-noise ratio (SNR) required for 50% identification using the sentence list developed by Methi, Avinash & Kumar (2009). Seven equivalent lists from the original test were selected for the present study. Each list contained 7 sentences mixed with the eight talker speech babble noise at a different signal to noise ratios (SNRs). First sentence in each list was at +8dB SNR, second sentence was at +5dB SNR, third sentence was at + 2dB SNR, fourth sentence was at -1dB SNR, fifth sentence was at - 4dB SNR, sixth sentence was at -7dB SNR and last sentence was at - 10 dB SNR. Each sentence had 5 key words. These sentences were presented through a personal computer (Sony Vaio E-series VPCEG17FG) at comfortable levels using a commercially available headphone. The listener's task was to repeat the sentences presented and each correctly repeated key word was awarded one point for a total possible score of 35 points per list.

3.2.3 Phase –III Re-evaluation of the auditory measures

The same test protocol that is extended high frequency eudiometry, otoacoustic emissions, and speech perception in noise were repeated again after a gap of 15 days on PLD user group with the assurance that the participants had abstained from listening to music using PLD.

Hereafter for easy nomenclature the Groups-I is named as PLDs-users, the Group-II who had given a 15 days of rest period will be named as PLDs-rest and the Group-III being named as Non-user.

CHAPTER-4

Results

4.1 Measurement of output sound pressure levels (SPL) of personal listening devices (PLDs)

Figure 1 show the average output levels in quiet condition, in presence of 65 dB SPL bus noise and the maximum output limits of the devices along with one standard deviation of error. The average output levels in quiet condition was 73.34 dBA, at maximum output levels of the devices is at 88.36 dBA and in presence of 65 dB SPL bus noise was 79.44 dBA. Paired t-test was performed to see the significance of difference between mean overall SPL between three conditions. Results showed that mean over all SPLs were significantly higher in bus noise ($t = -3.134$, $p<0.05$) and at maximum volume control settings ($t = -6.297$, $p<0.05$) of the instrument compared to quiet condition.

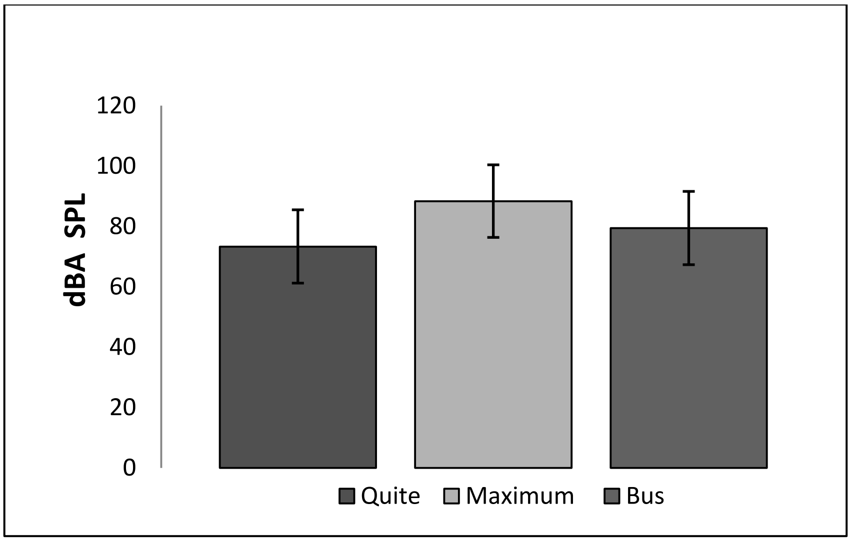

Figure 1: Mean output sound pressure level in quiet and in the presence of 65dB SPL bus noise, and maximum volume control settings of the instrument. Error bars show 1 standard deviation.

4.2 Auditory measures

4.2.1 Extended High Frequency measures

Figure 2a and Figure 2b shows the average high frequency threshold of the PLD-user, PLD users after the rest period of 15 days (called PLD-rest hereafter) and Non-PLD user group for the right ear and Figure 2c and 2d shows similar information for left ear. From Figure 2(a,b,c,d) it can be inferred that hearing thresholds in the high frequency region were poor in PLD user group compared to non user group. Since standard deviations of the high frequency thresholds were high non parametric test was used to evaluate the significance of difference among hearing thresholds in PLD user, PLD rest and PLD non user group. Mann Whitney U test showed that PLD user group had significantly poorer hearing thresholds at 11.2 kHz, 12.5 kHz, 14 kHz, 16 kHz and 18 kHz in both ears. Furthermore, PLD user group had significantly poor hearing thresholds at 4 kHz, 6 kHz in the right ear. Mann Whitney U test revealed that there was no statistically significant difference in hearing thresholds between PLD-user and PLD-rest group for all frequencies tested in both the ears. These results indicate that rest period of 15 days did not change the hearing thresholds of PLD users. Z-values and significance levels are depicted in Table 1.

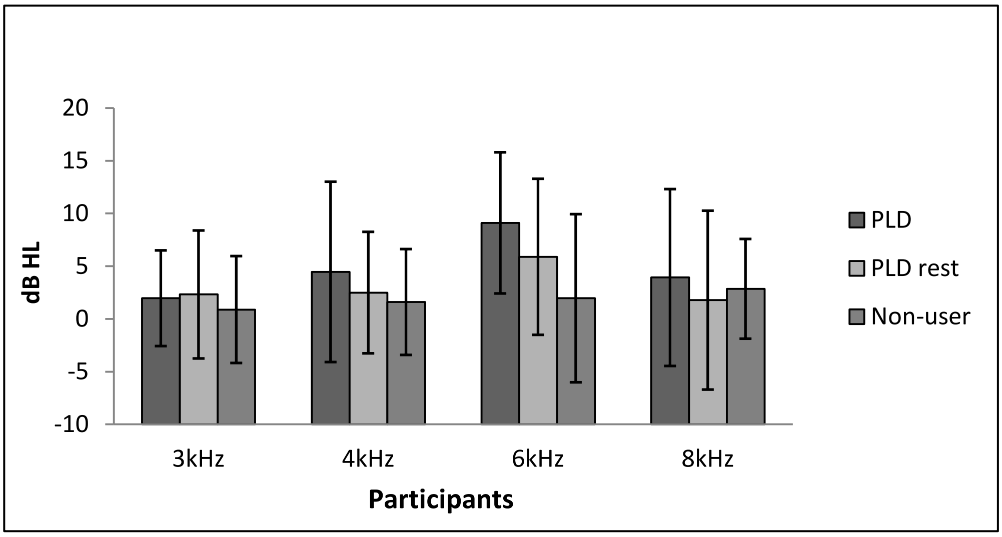

Figure 2a: The mean high frequency hearing threshold across 3kHz to 8kHz frequencies in the right ear for PLD-user, PLD-rest and Non-user.

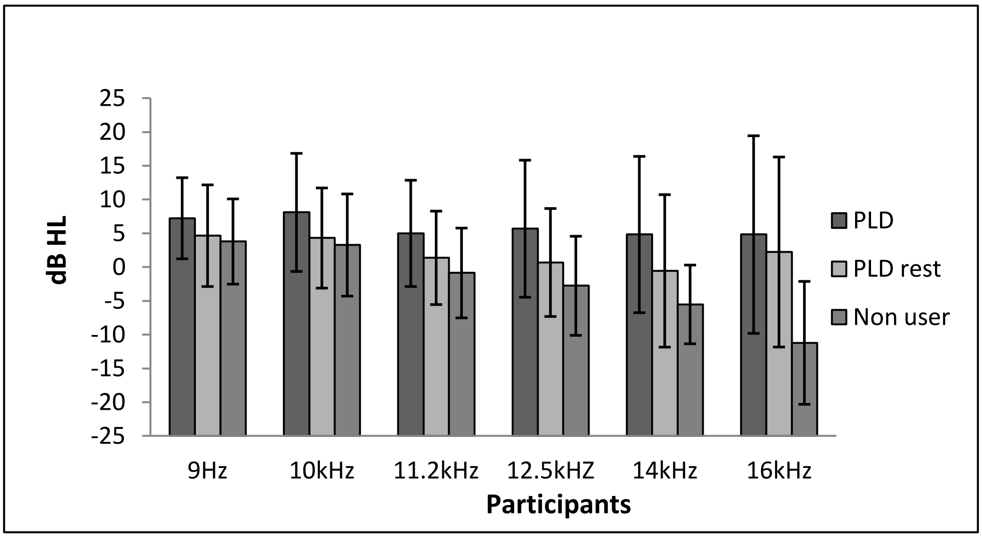

Figure 2b: The mean high frequency hearing threshold across 9kHz to 16kHz frequencies in the right ear for PLD-user, PLD-rest and Non-user.

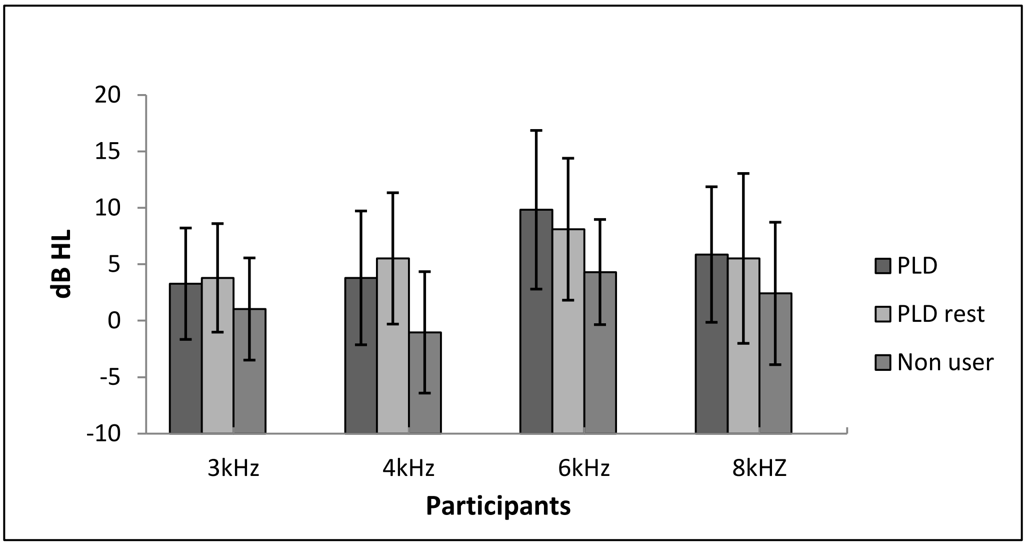

Figure 2c: The mean high frequency hearing threshold across 3kHz to 8kHz frequencies in the left ear for PLD-user, PLD-rest and Non-user.

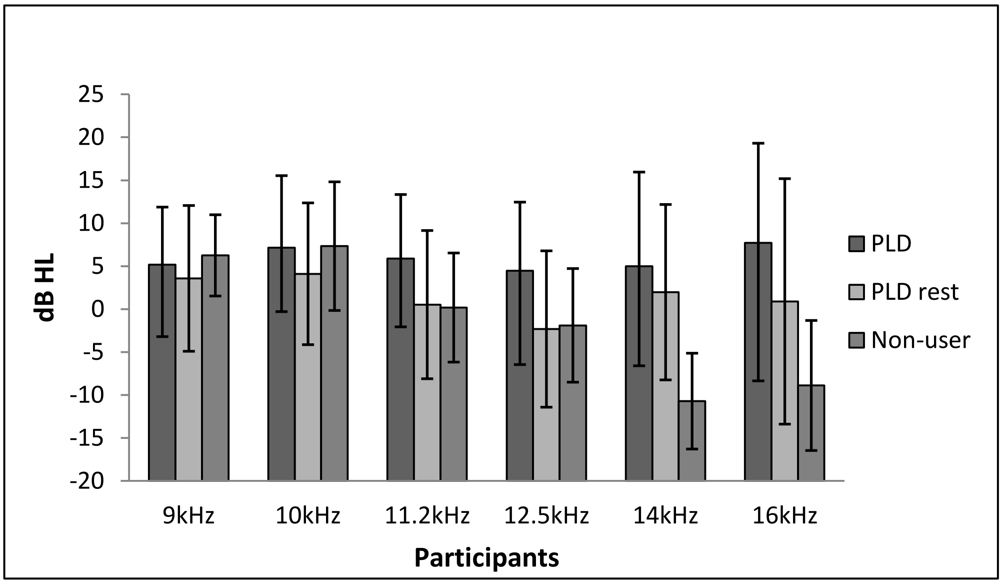

Figure 2d: The mean high frequency hearing threshold across 9kHz to 16kHz frequencies in the left ear for PLD-user, PLD-rest and Non-user.

Table 1: Significant difference between PLD-users and PLD-rest with Non-users in audiometric results.

Groups	***Right ear***			***Left ear***		
	Frequency	Z value	p value	Frequency	Z value	P value
PLD-user and Non-user	4 kHz	-3.16	0.00	6 kHz	-3.37	0.00
	6 kHz	-3.25	0.00	11.2 kHz	-2.29	0.02
	12.5 kHz	-3.63	0.00	12.5 kHz	-2.26	0.02
	14 kHz	-2.80	0.00	14 kHz	-4.18	0.00
	16 kHz	-4.37	0.00	16 kHz	-4.14	0.00
	18 kHz	-3.39	0.00	18 kHz	-3.42	0.00
PLD-user and PLD-rest	3 kHz	-0.42	.967	3kHz	-.169	.866
	4 kHz	-1.242	.214	4kHz	-.571	.568
	6kHz	-.970	.332	6kHz	-1.647	.100
	8kHz	-.256	.798	8kHz	-.917	.359
	9kHz	-.932	.351	9kHz	-.748	.455
	10 kHz	-1.767	.077	10kHz	-1.716	.086
	11.2kHz	-1.268	.205	11.2kHz	-1.839	.066
	12.5kHz	-1.243	.214	12.5kHz	-1.513	.130
	14kHz	-1.321	.186	14kHz	-1.759	.079
	16kHz	-1.047	.295	16kHz	-1.738	.181
	18kHz	-.510	.610	18kHz	-1.538	.124
	20kHz	-1.934	.053	20kHz	-.881	.378

4.2.2 *Transient evoked otoacoustic emissions (TEOAEs)*

Figure 3a and Figure 3b shows mean TEOAE amplitudes in three groups in right and left ear along with one standard deviation of error. Both the overall and band wise TEOAE amplitudes are shown in Figure 3a and Figure 3b. From Figure 3a and Figure 3b it can be seen that both overall and band wise TEOAE amplitudes were reduced in PLD-group and PLD-rest group compared to Non-user group. Since standard deviations of the otoacoustic emission amplitudes were high non parametric test was used to evaluate the significance of difference among hearing thresholds in PLD user, PLD rest and PLD non user group.. Mann-Whitne U-test revealed that TEOAE amplitudes were significantly reduced in PLD user group compared to non PLD user at all the frequencies except for the left ear at global amplitude ($Z = -1.554$, $p>0.05$). However, there was no statistically significant difference between PLD- user and PLD- rest for both the ears at all frequency.

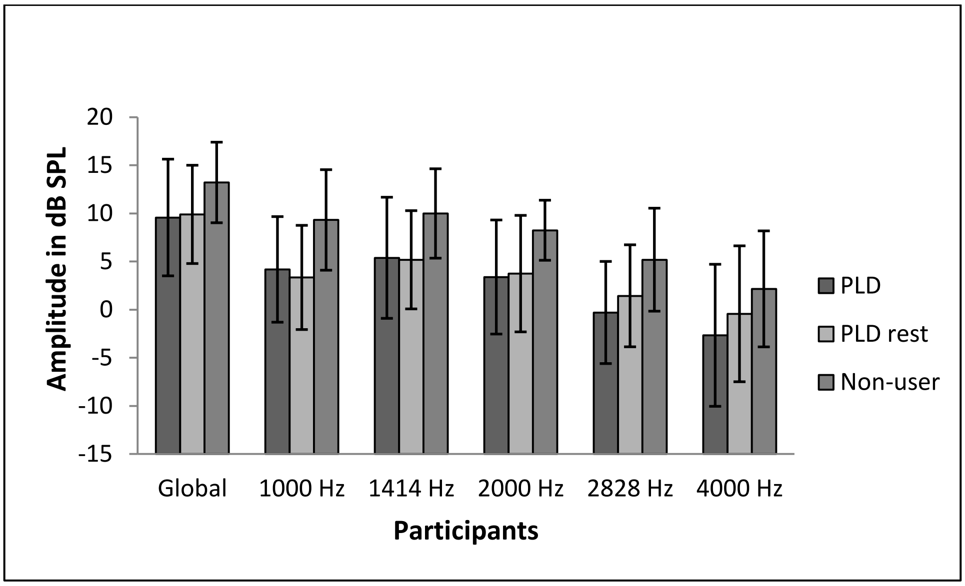

Figure 3a: TEOAE amplitude across different frequencies in the right ear for PLD-user, PLD-rest and Non-user.

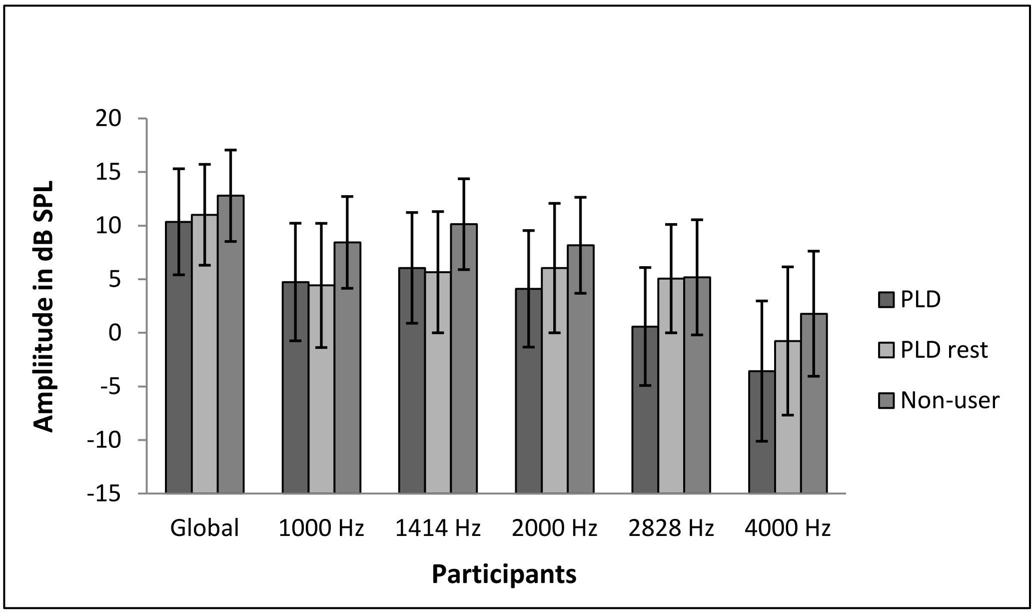

Figure 3b: TEOAE amplitude across different frequencies in the left ear for PLD-user, PLD-rest and Non-user.

4.2.3 Speech Perception in Noise

Figure 4a shows mean word identification scores at different signal to noise rations (SNR) in three groups. From the above data threshold SNR required to obtain the 50% speech identification scores were calculated using Spearman and Karber equation (Finney, 1952)

50% = i + ½(d) – (d)(# correct)/(w)

Where,

i= the initial presentation level (dB S/N)

d= the attenuation step size (decrement)

w= the number of items per decrement

Figure 4b shows mean SNR-50 for the PLDs-group, PLD-rest group and the Non-user group along with one standard deviation of error. Mann-Whitney U test was used to find the significance of difference in SNR-50 obtained among three groups. Results revealed that Non-user group had lower SNR-50 compared to other two groups (Z= -2.891, p<0.05 [PLD-user and non-user] and Z= -2.174, p<0.05[PLD-rest and non-user]). However, there was no significant difference was noticed between PLD-user and PLD-rest group. These results suggest that use of PLDs results in poorer SNR-50 and rest period of 15 will not improve the condition.

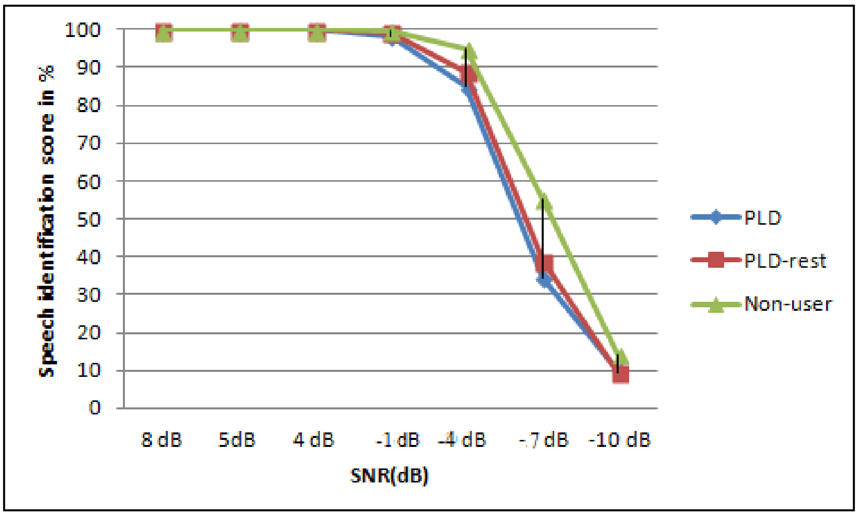

Figure 4a: The mean percentage for PLD-users, PLD-rest and Non-users across different SNR levels

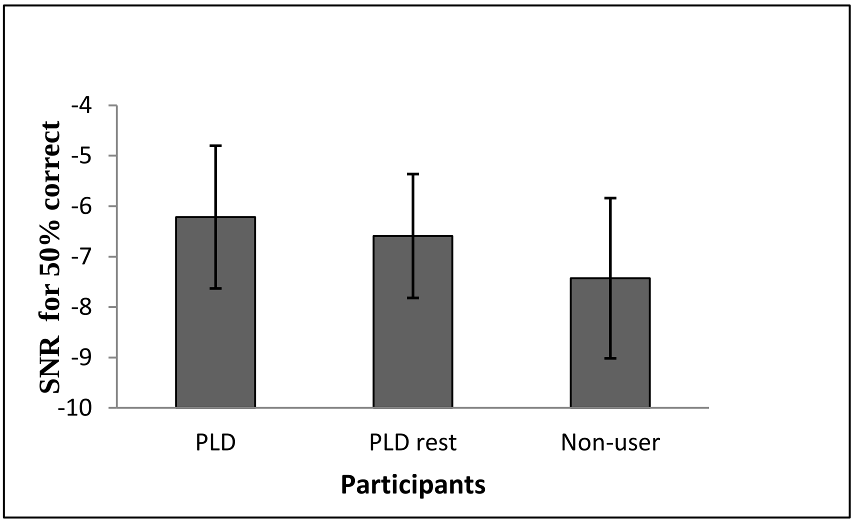

Figure 4b: Average SNR-50 for the PLD-user, PLD-rest and Non-user group

CHAPTER-5

Discussion

The purpose of this study was to measure the output levels of personal listening devices (PLDs) at the volume control setting that was preferred by the subjects in quiet, in the presence of bus noise and at the maximum output level of the devices. Furthermore, this study also evaluated the extended high frequency hearing thresholds, otoacoustic emission and speech perception skills in the group of individuals who uses PLDs and compared that to same individuals after 15 days of period abstaining from music listening and to individuals who did not use PLDs. The average output sound pressure level in quiet condition was noted to be 73.34 dBA (Range 51.98 to 99.54 dBA). These preferred listening levels are quite similar to what participants selected as "sounds best to you" in the Hodgetts, Rieger and Szarko (2007), or "medium/comfortable" in the Torre (2008). In the presence of bus noise the average output level went up to 79.44 dBA (Range 60.02 to 112.80 dBA). This increase in output levels in presence of background noise is comparable to Hodgetts et al. (2007) who reported that participants increased the level of the music approximately 6 to 10 dB when either street noise or multitalker babble was added to the listening environment. Similar findings were also obtained in the study by Heines, Hodgetts, Ostevik and Reiger (2012), who reported that the average output levels of iPods in quiet condition, was 70.3 dBA and in the presence of transportation noise was 83.5 dBA. But the measured output level by Dhanalakshmi (2012) in presence of bus noise is slightly higher than what is obtained in the present study. This might be due to the different types of ear phones used in the study. In the present study along with the ear-bud type ear phones other ear phones like half concha, supraaural earphone are also used. Dhanalakshmi (2012) used only the ear bud type of ear phones. This might have resulted in higher ear canal output sound pressure levels because of reduced leakage of sound. No evidence based definition exists for hazardous sound levels of music. As a substitute, standards for exposure to occupational noise have been proposed for use. In India, the Ministry of Environment and Forests (2000) has proposed a time weighted average level of 80 dBA for an 8-hour period per day as the maximum permissible limit. '5 dB exchange rule' has been proposed by the Ministry of Environment and Forests as a trade off between the exposure time and sound level. Considering this criteria output levels of PLDs at maximum volume control settings or in presence of bus noise is high and may result in permanent noise induced hearing loss if exposed for extended periods of time (years)

5.1 Effect of PLDs on auditory measure

Results of the extended high frequency pure tone audiometry showed that hearing thresholds of individuals who used PLDs are significantly poorer compared to Non-users. Results of the present study is in agreement with Dhanalaksmi (2012). She reported that hearing thresholds in the extended high frequency regions were significantly poor in individuals who used PLDs compared to individuals who did not use. Extended high frequency hearing thresholds are reported to be more sensitive to noise induced damages than the conventional audiometric frequencies. Peng et al. (2007) reported that extended high frequencies may be affected by the noise earlier when compared to conventional audiometric frequencies.

Transient otoacoustics emission (TEOAE) amplitudes were significantly poorer in PLDs-user and PLDs-rest group compared to Non-user. Kumar et al. (2009) reported a negative correlation between DPOAE amplitudes and output SPLs of PLDs at preferred volume control settings. They concluded that individuals who listened to music at higher levels had reduced DPOAE amplitudes even though the DPOAE amplitudes were within the clinical norms. Dhanalakshmi (2012) reported reduced TEOAE amplitude in the individuals using PLDs compared to individuals who don't use. Miller, Marshall, Heller and Hughes (2006) reported that amplitudes of DPOAEs are more sensitive to noise induced hearing loss than pure tone hearing thresholds. Barros, Frota, Atherino and Osterne (2007) suggested that TEOAEs are sensitive tool to identify temporary alteration in cochlea produced by exposure to an elevated sound pressure level. Individuals who used PLDs had significantly poor speech perception abilities in noise compared to Non-user. The observed deterioration in the speech processing skills in the PLD users, probably due to changes in the central auditory system caused due to prolonged exposure to loud music. It has been reported that long-term noise may have a persistent effect on brain function and behavior, even when the peripheral hearing sensitivity is within normal range (Kujala & Liberman, 2009).

None of the auditory measures – extended high frequency audiometry, TEOAE or speech perception in noise – changed significantly following 15 days of abstaining from music. These results suggest that listening to high levels of music through PLDs causes' permanent damage both peripheral and central auditory structures. Kujawa and Brattico (2009) reported a rapid and irreversible degeneration of spiral ganglion cells by the noise exposure which resulted in temporary threshold shifts. Even after, hair cells and hearing sensitivity were recovered, neuronal loss persisted. The effects of such neuronal losses on auditory and speech processing are detrimental.

CHAPTER- 6

Summary and Conclusion

Hearing loss induced by personal listening devices (PLDs) may evolve into a significant social and public health problem in future years. Previous studies have shown that output levels of PLDs can be as high as 113 dBA. Prolonged exposure to loud music leads to a significant/subclinical damage to hair cells of the cochlea. This in turn may lead to dysfunction in the central auditory system. Hence the current study was taken up with the following objectives

a) To measure the output levels of PLDs at the volume control setting that was preferred by the subject in quiet and in the presence of 65 dB SPL bus noise and at the maximum volume setting of devices.

b) To compare the transient evoked otoacoustic emissions (TOAEs) in individuals who use PLDs and individuals after abstaining from listening to music through PLDs.

c) To compare the extended high frequency hearing thresholds (3 kHz-20 kHz) in individuals who use PLDs and individuals abstaining from listening to music through PLDs.

d) To measure speech perception in noise in individuals who use PLDs and individuals abstaining from listening to music through PLDs.

A total of 58 participants participated in the present research. They were divided into two groups based on their music listening habits. Group I consisted of 29 subjects aged between 16 and 26 years, who reported to be a regular user of PLDs.

Group II consisted of 29 age matched individuals who hardly ever listened to music through PLDs. Study was conducted in two phases. In the Phase I output levels of PLDs at the preferred volume control settings of the participants were measured in three different conditions, in quiet and in the presence of 65 dB SPL bus noise and at the maximum volume control setting of devices. In Phase II extended high frequency hearing thresholds, transient evoked otoacoustic emissions, and speech perception in noise (SNR-50) were evaluated.

Following the results were obtained in the present study

a) The mean dBA at preferred volume control settings in quiet was 73 dBA. In the presence of bus noise of 65 dB SPL the mean preferred listening levels were increased to 79 dBA and at the maximum output level of the devices was 88 dBA

b) Extended high frequency hearing thresholds, amplitudes of TEOAEs and SNR-50 values were significantly poor in individuals who used PLDs compared individuals who did not use PLDs.

c) None of the auditory measures – extended high frequency audiometry, TEOAE or speech perception in noise – changed significantly following 15 days of abstaining from music. These results suggest that listening to high levels of music through PLDs causes' permanent damage both peripheral and central auditory structures.

From the above results, it can be concluded individuals who listen to music through PLDs may be putting themselves at risk for permanent noise induced hearing loss if exposed for extended periods of time (years). These results are alarming as more and more children are using PLDs. Some of the recommendations that should be kept in mind while using PLDs are

a) not to keep volume control of the device very high
b) to take periodic breaks of 15-20 minutes when listening to music
c) use loose-fitting ear buds or headphones to minimize intensity of sound
d) device should have an alarming indication when it reached to a hazardous levels

REFERENCES

Ministry of Environment and Forest. (2000) Noise pollution (Regulation control). S. O. 123 (E), [14/2/2000]

Airo, E., Pekkarinen, J., & Olkinuora, P. (1996). Listening to music with earphones: an assessment of noise exposure. *Acustica 82,* 885–894.

Ahmed, S., King, M., Morrish, T.W., Zaszewska, E., & Pichora, F. K. (2006). A survey of the use of portable audio devices by university students, *Canadian Acoustic Journal. 34(3),* 64–65.

American National Standards Institute. (1991). *American National Standard Specification for Sound Level Meters, ANSI S1.4-1983.* New York: American National Standards Institute.

Attias, J., Bresloff, I., Reshef, I., Horowitz, G., & Furman, V. (1998). Evaluating noise induced hearing loss with distortion product otoacoustic emissions . *Brazilian Journal of Audiology, 32(1),* 39-46.

Barros, S., Frota, S., Atherino, C. C. T. & Osterne, F. (2007). The efficiency of otoacustic emissions and pure-tone audiometry in the detection of temporary auditory changes after exposure to high sound pressure levels. *Brazilian Journal Otorhinolaryngology, 73(5),* 592-8.

Bradley, R., Fortnum, H., & Coles, R. (1987). Research note: Patterns of exposure of school children to amplified music, *British Journal of Audiology, 21(2),* 119–125.

Carhart, R. & Jerger, J. F. (1959). Preferred Method for Clinical Determination of Pure-Tone Thresholds. *The Journal of Speech and Hearing Disorders, 24*, 330-345.

Catalano, P., Gunderson, E., & Molini, J. (1997). Risks of developing noise-induced hearing loss in employees of urban music clubs. *Occupational Health and Industrial Medicine, 36 (3),* 122.

Catalano, P. & Levin, S. M. (1985). Noise Induced Hearing Loss and Portable radios with headphones. *International Journal of Pediatric Otorhinolaryngology , 9(1),* 59-67.

Carter N. L., Murray N., Bulteau V.G., (1985). Amplified music, recreational noise and hearing in young people aged 16-21 and 28-33 years. *Australian Journal of Audiology, 7,* 79-83.

Carter, N. L., Murray, N., Khan, A. & Waugh, R. (1984). A longitudinal study of recreational noise and young peoples' hearing. *Australian Journal of Audiology, 6*, 45-53.

Curhan, G., Eavey, R., Shargorodsky, J., & Curhan, C. (2010). Analgesic Use and the Risk of Hearing Loss in Men. *The American Journal of Medicine, 123,* 231-237

Dhanlakshmi, G. (2012). Effect of personal music system (PMS) on hearing in young adults, Unpublished Dissertation.

Drullman, R., Joost M. F., & Plomp, R. (1994). Effect of reducing slow temporal modulations on speech reception. *Journal of Acoustic Society of America, 95(5),* 2670-2680.

Felchlin, I., Hohman, B. W., & Matefi, L. (1998). Personal cassette players: a hazard to hearing ? *Advances in Noise Research, 2,* Protection Against Noise, Ed.

Deepak Prasher, Linda Luxon, and Ilmari Pyykko, Whurr Publishers, Ltd., London.

Finney, D. J. (1952). *Probit Analysis*. Cambridge, England: Cambridge University Press

Fligor, B. J., & Cox, L. C. (2004). Output levels of commercially available portable compact disc players and the potential risk to hearing. *Ear Hearing, 25(6),* 513-27.

Grason-Stadler (1996). *GSI 60 DPOAE*: *Distortion product otoacoustic emission system user manual*". Milford, NH.

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

Jones. S., & Alerkon, R. (2009). Measurement of Decibel Exposure in college students from personal music devices. *International Journal of Academic Research*, *2,* 99-106.

Kasper C. A. (2006). The simple guide to optimum hearing health for the mp3 generation.

Keith, S. E., David, S. Michaud, & Chiu, V. (2008). Evaluating the maximum playback sound levels from portable digital audio players. *Journal of. Acoustic Society of America*, *123 (6)*, 4227-4237.

Kujala, S. G., & Liberman, M. C. (2009). Adding Insult to Injury: Cochlear Nerve Degeneration after temporary Noise-Induced Hearing Loss. *Journal of Neuroscience*, *29(45),* 14077-85.

Kujawa, T. & Brattico, E. (2009). Detrimental noise effects on brain's speech functions. *Biological Psychology, 81,* 135-143.

Kumar, A., Mathew, Alexander, S. N., & Kiran. (2009). Volume Output sound pressure levels of personal music systems and their effect on hearing. *Noise Health*, *11(44)*, 132-140.

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

Lee P. C., Senders, C. W., Gantz B, J., & Otto, S. R. (1985). Transient sensory neural hearing loss after over use of portable headphone cassette radios. *Otolaryngology Head Neck Surgery*, *93(5)*, 633-25.

Le page, E. L., & Murray, N. M. (1998). Latent cochlear damage personal stereo users: A study based on click – evoked otoacoustic emissions. *The Medical Journal of Australia*, *169(11-12)*, 588-92.

Methi, R., Avinash, & Kumar, U. A. (2009). Development of sentence material for Quick Speech in Noise test (Quick SIN) in Kannada. *Journal of Indian speech and Hearing Association*, *23(1)*, 59-65.

Miller, J. A., Marshall, L. Heller, L.M., & Hughes, L.M. (2006). Low-level otoacoustic emissions may predict susceptibility to noise-induced hearing loss. *Journal of Acoustic Society of America*, *120(1)*, 280-296.

Mostafapour, S. P., Lahargoue, K, & Gates, G. A. (1998). Noise-induced hearing loss in young adults: the role of personal listening devices and other sources of leisure noise. *Laryngoscope*, *108(12)*, 1832- 1839.

National Institute of Occupational Safety and Haealth (NIOSH). *NIOSH publication*, 98-126

Oxenham, A. J., & Simonson, A. M. (2009). Masking release for low- and high pass-filtered speech in the presence of noise and single-talker interference. *Journal Acoustic Society of America*, *125(1)*, 457–468.

Passchier & Vermer (1999). Pop music through headphones and hearing loss. *Noise Control Engineering Journal, 47*(5), 182–186.

Portnuff, C., Fligor, B. & Arehart, K. (2009). Teenage use of portable listening devices: a hazard to hearing? presentation at annual conference of the National Hearing Conservation Association, Atlanta, GA.

Peng, C. Y., Yajima, H., Burns, C. E., Zon, L. I., Sisodia, S. S., Pfaff, S. L., & Sharma, K. (2007). Risk of Damage to Hearing from Personal Listening Devices in Young Adults. *The Journal of Otolaryngology, 36 (3),* 181-185.

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

Reuters P. (2005). Limit use of iPod ear buds to protect your ears, MSNBC Online, http://www.msnbc.msn.com/id/10648715/ (Last viewed May 26, 2006).

Torre, P. (2008). Young adults use and output level settings of personal music systems. *Ear Hearing*, *29(5),* 791-799.

Serra, M. R., Biassoni, E. C., UtzRichter, Minoldo, G., Franco, G., Abraham, S., Carignani, J. A., Joekes, S., & Yacci, M. R. (2005). Recreational noise exposure and its effect on hearing of adolescents. Part1: an interdisciplinary long term study. *International Journal of Audilogy*, *44(2*), 65-73.

Williams, W. (2005). Noise exposure levels from personal stereo use. *International Journal of Audiology*, *44(4)*,231-236.

Williams, W. (2009). Trends in listening to personal stereos. *International Journal of Audiology*, *48(11)*, 784-788

Zogby International, (2006). Survey of teens and adults about the use of personal electronic devices and head phones. *American Speech-Language-Hearing Association*, 1-24