EFFECT OF PERSONAL MUSIC SYSTEMS (PMS) ON HEARING IN YOUNG ADULTS

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A Dissertation Submitted in Part Fulfillment of Final Year

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CERTIFICATE

This is to certify that this dissertation entitled '**Effect of personal music systems (PMS) on hearing in young adults'** is the bonafide work submitted in part fulfillmentfor the Degree of Master of Science (Audiology) of the student with Registration No.:10AUD010. This has been carried out under the guidance of a faculty of thisinstitute and has not been submitted earlier to any other University for the award ofany other Diploma or Degree.

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CERTIFICATE

This is to certify that the dissertation entitled**'Effect of personal music systems(PMS) on hearing in young adults'**has been prepared under my supervision andguidance. It is also certified that this has not been submitted earlier in any otheruniversity for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this Master's dissertation entitled '**Effect of personal music systems (PMS) on hearing in young adults'** is the result of my own study under the guidance ofDr. Ajith Kumar U., Reader in Audiology, Department of Audiology, All India Instituteof Speech and Hearing, Mysore, and has not been submitted in any other Universityfor the award of any Diploma or Degree.

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Acknowledgement

I thank Prof. S R Savithri, Director, All India Institute of Speech and Hearing, Mysore for granting me permission to conduct this study.

I would like to thank Dr. Animesh Barman, HOD of Audiology, for your great support. Thank you Dear Sir & Mam, lecturer and clinical staff (Jijo sir Arunraj sir, Sharath sir, Antony sir, Rajsudagar sir etc. for your extraordinary help. And special thanks to the staffs that had bear & extended their working time for our dissertation purposes in spite of their busy scheduled.

I express my gratefulness to my guide and teacher, Dr. Ajith Kumar U,for your constant support, dedication and concern and accepting me to do this study under your warm guidance. Thank you sir, you have always been patient to me even though I did many mistakes & doing just the opposite of what you told me to do so, never gets angry and always ends up with a smile. Thank you once again sir that made this study possible.

Thank you & love you puru, amma, ammu, anni for your unconditional love, prayer and support. Thank you Lokesh, charan, (younger brother) and chandan (brother like,) potti (sister), Sush, SnehaBkry, Margu Jas, for your love and prayer support.

Special thanks to Nambi Anna, Praveen Anna, senior akka.

Thank you to all my classmates (Saravanan, Spu (Timely Help) junior Harika, Pooja, Priya, and all my subjects for their co-operation and kindness, to turn up in your busy schedule and making it happening.

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CHAPTER 1

INTRODUCTION

Personal music systems (PMSs) such as iPods, MP3 players, portable compact disc (CD) players have been very popular among young people for well over a decade, and their popularity is increasing with advancements in technology. While the use of these devices has become a main source of recreation for the younggeneration, the harmful effect of this habit on hearing ability has become an increasing concern in public health. A recent survey of large sample of adolescents and young adults revealed that many of them are developing hearing impairment at a young age (Chung,Dec Roches,Meunier&Eavey 2005). One of the reason for this may be prolonged use of PMSs, which are typically played at a ‘‘loud’’ volume setting (Zogby, 2006). Prolonged exposure to high levels of noise/music can cause damage to the hair cells in the cochlea and results in permanent/temporary cochlear hearing loss.

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 (1998) guidelines for work place settings 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 (2000) 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 tradeoff 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 behaviors, the general practice is to consider that noise levels exceeding the maximum daily dose as indicative of at-risk listening behavior (Fligor& Cox, 2004).

Recently, research has begun to focus on the risk of hearing loss during leisure-time or recreational activities, such as listening to music through PMSs (Biassoni, Serra &Richtert, 2005; Chung et al., 2005). It has been shown in previous studies that the use of PMSs had damaging effects on hearing (Peng, Yajima, Burns, Zon, Sisodia, Pfaff & Sharma 2007). Additionally, the newer style of headphone that accompanies the PMSs, known as 'earbud', increases the problem by directly channelling the sound into the ear (Fligor& Cox, 2004). With the newer technology PMSs have the potential to be used for longer durations and at higher volumes than older technologies, as digital PMSs have expanded music storage and battery life capabilities and produce very low distortions even at high levels. The prolonged exposure to high levels of music can cause damage to the hair cells in the cochlea and results in permanent noise-induced cochlear hearing loss.

Otoacoustic emission (OAEs)and hearing thresholds are highly susceptible to cochlear trauma, such as exposure to ototoxins or loud noises (Furst, Reshef&Attias, 1992). Kumar, Mathew, Alexander and Karan (2009) showed a significant correlation between increased pure-tone thresholds at 6 kHz and estimated 8-hour equivalent exposure in a group of young adults who were using PMSs. They also reported decreased amplitude of distortion product otoacoustic emission in the high frequencies in individuals who used PMSs when compared to those who did not. Recently, it has been shown that hearing thresholds at frequencies above 8000 Hz are more sensitive to noise exposure than the conventional audiometric frequencies (250 Hz – 8000 Hz). Testing frequencies higher than 8000 Hz may reveal the subclinical damage to the cochlear structures (Peng et al., 2007).

Psychophysical evidence indicates that presence of cochlear hearing loss causes deficits in temporal processing (Moore, 2007). Temporal processing encompasses a wide range of auditory skills including temporal resolution or temporal discrimination (i.e., gap detection and fusion). Normal perception of the temporal aspects of the stimulus is crucial for understanding speech in quiet andin adverse listening conditions. One of the important factors that contribute to the poor performance of hearing-impaired listeners on temporal processing tasks is audibility of high-frequency signals.Apart from audibility, the suprathreshold distortions can also contribute to the poor performance of hearing-impaired listeners on temporal processing tasks. These suprathreshold distortions may be caused by changes in the central auditory system secondary to cochlear damage.The importance of temporal resolution in speech perception has been studied by Drullman, Joost, FestenandPlomp, (1994) in normal hearing individuals and found that temporal modulations <2 kHz were essential for accurate speech perception. Several studies have suggested that word and sentence recognition performances are both positively correlated with temporal resolution in hearing-impaired subjects especially in the presence of background noise (Eg: Glasberg& Moore, 1989).

Need for the study

In developing countries like India, use of PMS, specifically, mobile phone MP3 usage is growing rapidly. About six million new mobile subscriptions are added every month and three quarters of India’s population was covered by a mobile network at the end of 2008 (Murthy, 2008).Kumar, Mathew, Alexander and Kiran(2009) reportedsignificant positive correlation between hearing thresholds and exposed music levels at 6000 Hz suggesting that individuals who listened to music at high levels tend to have higher pure tone hearing thresholds at 6000 Hz. They also reported a significant negative correlation between high frequencies otoacoustic emission amplitudes and output levels of PMS suggesting that individuals who listened to music at higher levels had reduced OAE amplitudes. These relationships were observed even though all the participants in their study had “clinically normal” hearing thresholds and OAE amplitudes. These results suggest that, listening to music through PMS at higher intensities may cause subtle/pre-clinical damage to the outer hair cells (OHCs) and over the years such behavior may be hazardous to hearing. Subtle and subclinical damage to OHCs may lead to higher order perceptual problems. Hence, this study was taken up to with evaluate the effect of PMSs on peripheral and central auditory system.

Statement of the problem

Output levels of the PMS can be as high as 121 dBA (Fligor& Cox, 2004). Prolonged exposure to loud sounds can cause significant/subclinical damage to hair cells of the cochlea. This in turn may lead to dysfunction in the central auditory system. This study aims to assess peripheral auditory system by measuring the otoacoustic Emissions, extended high frequency hearing thresholds and the central auditory processing by evaluating the temporal processing tasks and speech perception in noise in clinically normal hearing individuals who regularly use PMS for more than 2 hours per day for 2 years or more. Specific temporal processing tasks that were evaluated included gap detection in noise, temporal modulation detection, and duration discrimination.Furthermore, this study also measured the output levels of the personal music systems at the level of the ear drum of the participants and compared that to damage risk criteria provided by the Ministry of Forests and environment (2000).

Objectives of the study

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

b) To compare the extended high frequency hearing thresholds (3 kHz-20 kHz) in individuals who use PMS and individuals who don’t.

c) To compare the transient evoked otoacoustic emissions in individuals who use PMS and individuals who don’t.

d) To measure gap detection in noise, duration discrimination and modulation detection thresholds in individuals who use PMS and individuals who don’t.

e) To measure speech perception in noise in individuals who use PMS and individuals who don’t.

CHAPTER 2

REVIEW OF LITERATURE

Recreational noise exposure sources, or music exposure sources, as is the case for this review, include personal music systems (PMS) such as MP3 players and iPods.The widespread use of portable compact disc (CD) players and the recent popularization of portable MP3 players have renewed public and clinical concern about the potential for hearing impairment caused by their use. This is one form of noise induced hearing loss which is on the rise in this generation.

Output of PMSs

Previous studies have shown that output levels of the PMSs at listeners preferred volume control settings depends upon the type of PMS, listening background, style of headphones etc (Catalano & Levin, 1985; Kuras,Janet, Findlay, &Robert,1974; Lee, Senders, Gantz& Otto, 1985; Fligor& Cox, 2004; Williams, 2005; Hodgets,Rieger, &Szarko, 2007;Kumar, Mathew, Alexander &Kiran, 2009). Output levels of personal music systems have been reported to be as low as approximately 80dBA (Williams, 2005) to as high as 121 dBA (Fligor& Cox, 2004). Catalano & Levin (1985) reported that output of cassette players produced a level of 60 dBA at volume control setting “1” and 110–114 dBA at volume control setting “10”. Rice, Breslin and Roper, (1987) showed that output at preferred listening levels (PLL) in quiet was 80.7 dB Leq and when the back ground noise of 70 dBA was introduced, PLL were increased to 85.1 dB Leq, giving a 15 dB signal to noise ratio (SNR). Williams (2005) measured the output levels preferred by 55 listeners in noisy conditions using the Knowles Electronics Manikin for Acoustic

Research(KEMAR), and then converted into diffuse field equivalent levels as well as the average daily A-weighted exposure level. Results indicated a mean listening level of 86.1 dBA and a mean of 79.8 dBA for 8-hour equivalent levels. Peng, Yajima, Burns, Zon, Sisodia, Pfaff and Sharma (2007)indicated that substantial exposure to use of PMSs resulted hearing loss in 14.1% (34 of 240) of ears, and the maximum available SPL from the stereo headphones can exceed 100 dBA, which was much higher than the preferred volume setting of most users.

Torre, (2008) reported that out of 1016 students 930 (91.5%) used PMSs; of these, >50% listened to their PMSs for 1-3 hours, with >90% reported to have used their PMSs at medium and loud volume. The measured output sound pressure level (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 kind of fitness of head phones resulted in different overall SPLs. Output SPLs ranged from 101 dBA for a ‘loose’ fit 101 to 107 dB for a ‘tight’ fit.

Kumaret al., (2009) measured the output SPLs produced by the PMS in three different listening conditions - in quiet, in the presence of background of 65 dB SPL bus noise and at the maximum volume control setting of the PMS using a probe microphone measurement. For mobile phone Leq8houtput ranged from 40 dBA to 93 dBA (mean 73 dBA) and for iPods ranged from 56 dBA to 86 dBA (mean 76 dBA), and for locally made MP3 players range was 70 dBA to 84 dBA (mean 79 dBA), at participants preferred volume control settings in quiet and there was no change in the output SPLs significantly in presence of noise.

Effect of PMSs on Auditory measures

Hearing threshold

Noise-induced hearing loss begins with difficulty in hearing high-frequency tones, slowly extending to lower frequency tones in the spoken communication range (2000-4000 Hz) as it progresses (Biassoni, Serra &Richtert., 2005; Daniel, 2007; Peng et al., 2007). Peng et al., (2007) compared a personal listening device group, comprising 120 young adults aged 19-23 years who used personal listening devices for at least one hour or more per day, with a control group of 30 normal hearing adults aged 19-22 years who had no history of personal listening device use. Hearing thresholds were measured at 250, 500, 1000, 2000, 3000, 4000, 6000, 8000, 10000, 12500, 16000 and 20000 Hz. The study results showed that the hearing thresholds in the 3000 to 8000 Hz frequency range were significantly increased in the personal listening device group. Also, they found that the hearing thresholds of the personal listening device group to be significantly higher than those of the control group in the extended high-frequency region for 10000, 12500 and 16000 Hz. The hearing thresholds of extended high-frequency audiometry in personal listening device users were higher even if their hearing thresholds in conventional frequency audiometric for range were normal. This gives additional support to the claim that PMSs 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 personal listening devices in college students and found to have a 10 dB or greater notch at 3 to 6 kHz.

Otoacoustic emission (OAE)

Lepageand Murray(1998) measured the transient evoked otoacoustic emission (TEOAE) in 700 individuals and found reduced amplitudes of these in individuals with a positive history of noise exposure or PMS use. Recently Montoya,Ibarquen, Vences, Rey and Fernandez (2008) compared the amplitude, incidence and spectral content of (TEOAE) and distortion product otoacoustic emissions (DPOAEs) in normal hearing MP3 player users to those of control group who were non-users of MP3 players. Results showed that subjects who had used MP3 players for greatest number of years and for more hours each week exhibited a reduction in incidence and amplitudes of both types of otoacoustic emissions and an increase in DPOAEs.

Kumar et al., (2009) evaluated DPOAEs in a group of individuals who were using PMSs and compared that to DPOAE amplitudes in group of individuals who never used PMSs. Results revealed a negative correlation between DPOAE amplitudes at 6000 Hz and exposed music levels. This relationship suggests that individuals who listened to music at high levels tend to have lower DPOAE amplitudes. All individuals who used personal music systems in their study had “clinically normal” hearing thresholds, DPOAE amplitudes and SNRs. These results show that listening to music through personal music system at preferred volume control settings may not result in “clinically significant” reduction of DPOAE amplitudes and SNRs but may cause subtle pre-clinical damage to the auditory system and over the years such behavior may be hazardous to hearing. They concluded that the preferred output levels of personal music systems may not cause any serious hearing problem in majority of the users, but, in highly susceptible users it may cause temporary or permanent hearing loss. The output SPLs produced by these personal music systems in children may be significantly more as they have smaller ear canals.

Temporal and speech perception

Temporal processing can be defined as the perception of sound or of the alteration of sound within a restricted or defined time domain (Shinn&Brooke, 2003). Normal temporal processing is necessary for most of our auditory processing capabilities including pitch perception, voice identification (Yost, Patterson &Sheft, 1996), and speech perception (Strouse,Ashmead&Ohde, 1998).

Studies have shown that subjects with high frequency hearing loss may have difficulty in speech perception, especially in challenging listening conditions such as in a noisy environment. The mechanisms underlying speech perception difficulty experienced by adults with high frequency sensory-neural hearing loss have yet to be completely determined. There is no doubt that auditory processing of signals in a given frequency region deteriorates due to both loss of audibility (Moore, 1996) and poorer supra threshold processing in the auditory system. Processing problems may not be limited to the frequency region corresponding to cochlear hearing loss but may spread to surrounding normal hearing regions as well. The off-channel impact of cochlear lesions on signal processing has been indicated in both intensity and frequency coding (Nelson &Freyman, 1986; Simon &Yund, 1993)

There is evidence suggesting that background noise has both transient and sustained detrimental effects on central speech processing. Studies on the effects of noise on neural processes have demonstrated hemispheric reorganization in speech processing in adult individuals during background noise (Kujala&Brattico, 2009). During noise, the well-known left hemisphere dominance in speech discrimination became right hemisphere preponderant (Kujala&Brattico, 2009). Furthermore, long-term exposure to noise has a persistent effect on the brain organization of speech processing and attention control. These results both stress the importance to re-evaluate which noise levels can be considered safe for brain functions and raise concerns on the speech and cognitive abilities of individuals living in noisy environments (Kujawa&Liberman2009).Chang, Imaizumi, Christoph, Schreiner and Merzenich(2005)in animal model showed that when infant rat pups were reared in moderate levels of noise resulted in delay of organizational maturation of the auditory cortex.

The most common way of investigating temporal resolution is by means of gap detection, duration discrimination or modulation detection. In gap-detection experiments, temporal resolution is measured by determining the shortest interruption in a signal that can be detected. The signal, which is usually continuous, can be a broadband noise; a band limited noise, or a pure tone. The advantage of using broadband noise as a signal is that any spectral splatter resulting from the abrupt cessation of sound during the gap will be masked. Another measure widely used for assessing temporal resolution is the detection of amplitude modulation in a broadband noise. The auditory system is highly sensitive to small amplitude fluctuations. Sinusoidal amplitude modulation consists of a carrier tone or noise, which periodically varies in amplitude in the same manner as the modulating sinusoid. The procedure is carried out at different frequencies of amplitude modulation typically from 4 Hz to 200 Hz. The listener is asked to detect which among the two stimuli contained the modulation. The function relating modulation detection thresholds to modulation frequency is called the temporal modulation transfer function (TMTF). The detection of modulation is crucial for speech perception since modulation caused by specific vocal tract characteristics results in amplitude fluctuations in the speech waveform and this temporal envelope carries important information relevant to speech perception (Drullman, Joost, Festen&Plomp, 1995; Shannon, Zeng, WygonskiKamath&Ekelid, 1995). TMTF is affected by factors such as degree, configuration of hearing loss, age etc.

Adults with high-frequency hearing loss showed poorer performance than the age-matched normal-hearing subjects on both the amplitude modulation detection and gap detection tasks, even though the stimuli were restricted to regions of observed normal sensitivity. With increasing time compression, listeners with high frequency sensory neural hearing loss required a larger signal to noise ratio to maintain accuracy in speech perception in adaptive hearingin noise test and exhibited a bigger decrease in score for hearing in noise test at a fixed signal to noise ratio. Multiple regression/correlation analyses showed significant correlation across the scores of amplitude modulation/gap detection tasks and hearingin noise test (Feng, Yin&Wang, 2010).

Kumar, Ameenudin andSangamanatha(In press) evaluated the temporal processing and speech perception skills in individuals who were exposed to occupational noise of more than 80 dBA and not yet incurred clinically significant threshold shifts. They studied a total of 118 train drivers who were divided into three case groups of in the age range of 30–40 (*n* = 13), 41–50 (*n* = 9), and 51–60 (*n* = 6) years. Participants in all age groups had hearing sensitivity within 25 dB HL in the octave frequencies between 250 and 8 kHz. Temporal processing was evaluated using gap detection, modulation detection, and duration pattern tests. Speech recognition was tested in presence multi-talker babble at -5 dB.Results showed a trend of reduced temporal processing skills in individuals with noise exposure. These deficits were observed despite normal peripheral hearing sensitivity. Speech recognition scores in the presence of noise were also significantly poor in noise-exposed group. Furthermore, poor temporal processing skills partially accounted for the speech recognition difficulties exhibited by the noise-exposed individuals. They concluded that noise can cause significant distortions in the processing of suprathreshold temporal cues which may add to difficulties in hearing in adverse listening conditions.

CHAPTER 3

METHOD

Participants

A total of 49 participants participated in the present research. They were divided into two groups based on their music listening habits. Group I consisted of 29 participants aged between 17 and 25 years (10 males, 19 females) who reported regular usage of personal music systems (PMS). Group II consisted of 20 age matched individuals who rarely ever listened to music through PMS. Hereafter, Group I will be called PMS-group and Group II will be called NoPMS-group for easy nomenclature. Participants in both group had their air conduction and bone conduction hearing thresholds within 15 dB HL at octave frequency from 250 Hz to 8 kHz. All participants showed 'A' type tympanogram with acoustics reflex at normal sensation levels. None of them reported any history of middle ear pathology, ototoxic drugs usage or exposure to occupational noise.

The study was conducted in 2 phases.

PHASE 1: Measurement of output sound pressure levels (SPL) of PMS

Only PMS-group participated in this phase of the study. Output SPLs produced by the PMS were measured in the subject's ear canal using a probe microphone. A commercially available real ear probe microphone measurement system (Fonix, 7000) was used for this purpose. Insertion depth of the probe was 28 mm from the tip of the tube to tragal notch. This insertion depth is the standard insertion depth used while doing real ear probe microphone measurements in adults. All the measurements were made with participants own PMS and a standard ear bud type of the earphones. After placing the probe tube in the ear canal, the earphones were placed. Participants were asked to play one of their favorite songs. Output SPLs were measured in two different conditions:

a) by asking the participant's to adjust the volume control to their preferred listening setting in quiet

b) By asking the participant's to adjust the volume control to their preferred listening setting in the presence of 65 dB SPL bus noiseBus noise was considered as background noise as this condition is more naturalistic since most of the participants reported that they 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.

Position of the probe microphone was not changed between any of the measurements. Output SPLs were measured at different frequencies from 200 Hz to 8000 Hz (over all 64 frequencies). These ear canal SPLs were converted to equivalent diffuse field SPLs to which the ear was exposed, by subtracting the transfer function of the open ear. This transformation is required to compare the output of PMS to damage risk criteria. As there is no evidence based definition exists for hazardous sound levels of musicas 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 were converted into to diffuse field levels by subtracting the transfer function of the open ear canal. The transfer function of the open ear was obtained by calculating the difference between the reference location at the opening of the ear canal and the probe microphone SPL near the eardrum for a sweep frequency tone presented at

65 dB SPL. The output SPLs at individual frequencies was converted to dBA values by adding the A-weighting adjustment values. The overall SPL in dBA was then determined by logarithmically adding dBA values at each frequency. From this data 8 hour equivalent continuous A-weighted noise exposure (Leq8h) was calculated using the following equation:

$$Leq8h = L_T + 10 \log_{10} [T/8]$$

Where Leq8h is the 8 hour equivalent continuous noise exposure, T is the exposure time in hours (music listening hours per day); L_T is the Level of noise exposure over the time period T. Example of calculation of Leq8h from the ear canal sound pressure level for one subject is provided in Appendix I and the procedure followed was same as that described in Kumar,Mathew, AlexanderandKiran (2009).

PHASE II: Auditory measures

Extended high frequency audiometry, otoacoustic emissions, temporal processing tests and speech perception in noise were assessed in phase II. Both the PMS-group and NoPMS-group participated in these experiments.

Extended high frequency audiometry

Calibrated two channel diagnostic audiometer GSI 61 with transducer was 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

Otoacoustics emission

Transient evoked otoacoustic emissions (TEOAEs) were recorded using commercially available otoacoustic emission analyzer (ILO-V6). Participants 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 clicks was used for the analysis. The overall TEOAE amplitudes and amplitudes at different frequency bands were noted and used for analysis.

Temporal processing tasks

Stimuli

All temporal processing tests except for the duration pattern test were carried out using mlp (maximum likelihood procedure) toolbox, which implements mlp in Matlab (Grassi&Soranzo, 2008).

General Procedure

The maximum likelihood procedure employs a large number of candidate psychometric functions and after each trial calculates the probability (or likelihood) of obtaining the listener’s response to all of the stimuli that have been presented given each psychometric function. The psychometric function yielding the highest probability is used to determine the stimulus to be presented on the next trial. Within about 12 trials, the maximum likelihood procedure usually converges on a reasonably stable estimate of the most likely psychometric function, which then can be used to estimate thresholds. Stimuli were recorded at 44,100 Hz sampling rate. A two-interval alternate forced-choice method using an mlp was employed to track an 80% correct response criterion. 30 trials were used in the present study. During each trial, stimuli were presented in each of two intervals:

One interval contained a reference stimulus, the other interval the variable stimulus. The participant indicated after each trial which interval contained the variable stimulus. This procedure was used in all temporal processing tests except for the duration discrimination test.

Gap Detection Thresholds

The participant's ability to detect a temporal gap in the center of a 750 ms broadband noise was measured. The noise was 0.5 ms cosine ramps at the beginning and end of the gap. In a two-interval alternate forced-choice task, the standard stimulus was always a 750 ms broadband noise with no gap, whereas the variable stimulus contained the gap.

Duration Discrimination test

In this procedure, the minimum difference in duration that is necessary to perceive the two otherwise identical white noise bursts was measured. Duration of the standard stimulus is 250 ms the duration of the variable stimulus was changed according to the subject's response. In the two-interval alternate forced-choice procedure, the participants were instructed to tell which interval contained the longer duration signal.

Modulation Detection Thresholds for Sinusoidally Amplitude-Modulated Noise

Temporal modulation refers to a recurring change (in frequency or amplitude) in a signal over time. A 500 msec Gaussian noise was sinusoidally amplitude modulated at modulation frequencies, 8 Hz, 20 Hz, and 60 Hz and at 200 Hz. Noises had two 10-msec raised cosine ramps at onset and offset. Participant's had to detect the modulation and tell which interval had the modulated noise. Modulated and un-modulated stimuli were equated for total root mean square power. Depth of the modulated signal was varied according to the subject’s response up to an 80% criterion level. The modulation detection thresholds were expressed in dB by using the following relationship:

Modulation detection thresholds in dB = 20 log10 m

Where m=modulation detection threshold in percentage

Speech perception in noise

Speech perception in noise was evaluated using the speech in noise test developed by Avinash,Methiand Kumar, (2010). 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 different signal to noise ratios (SNRs). First sentence in the each list was at +20 dB SNR, second sentence was at +15 dB SNR, third sentence was at +10 dB SNR, fourth sentence was at +5 dB SNR, fifth sentence was at 0 dB SNR, sixth sentence was at -5 dB SNR and last sentence was at -10 dB SNR. Each sentence had 5 key words. These sentences were presented through a personal computer (Lenovo Z372) at conformable levels using a commercially available headphone (Index Mega supraaural headphone, HS-301B). 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.

Statistical Analysis

Following statistical analysis was carried out on the data obtained to verify the objectives of the study.

1. Paired‘t’ test was done to compare the mean Leq8h in quiet and in presence bus noise.

2. ANOVA was done to compare the hearing threshold, TEOAE amplitudes, modulation detection threshold and speech perception in noise in PMS-group and NoPMS-group.
3. Independent sample‘t’ test was done to compare the gap detection and duration discrimination thresholds.

CHAPTER 4

RESULTS

Measurement of output sound pressure levels (SPL) of personal music systems (PMS)

Figure 1 shows mean output of the PMS at entrance of the ear canal (sound pressure level picked up by the probe microphone – head related transfer function) produced by the PMS at preferred listening levels across different frequencies (200 Hz - 8k Hz) in quiet and in the presence of 65 dB SPL bus noise. As can be seen from the Figure 1 in the presence of 65 dB SPL bus noise, preferred SPLs were higher when compared to quiet condition. Preliminary inspection of the data shows that at low of frequencies output SPLs at preferred listening levels were higher than 80 dB SPL.

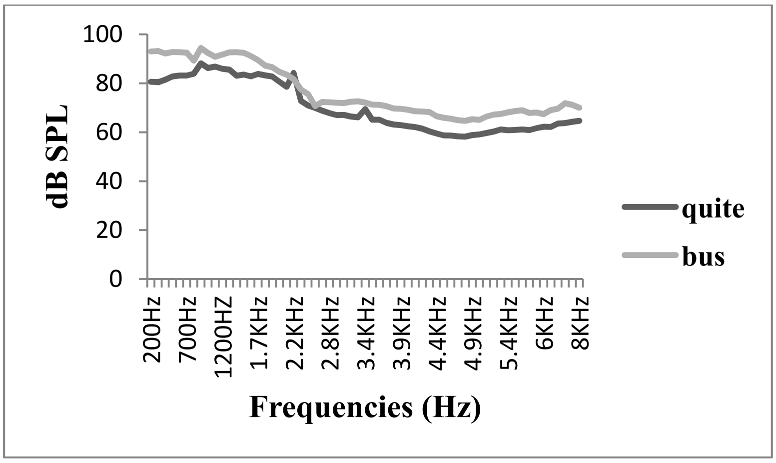

Figure 1: Mean output SPL level used by the participants at preferred listening setting in quite, in the presence of 65dBSPL bus noise. Mean output in dB SPL is depicted at different frequencies. Please note that values in this figure are not converted into dBA and 8 hours equivalent level exposure.

Figure 2 shows the mean Leq8h (8 hours equivalent level exposure) in quiet condition and in the presence of 65 dB SPL bus noise along with one standard deviation of variation. As can be seen from the Figure 2, mean 8 hour equivalent listening levels in quiet was 95.8dBA and in presence of bus noise was 103.43dBA. A paired‘t’-test performed to see the significance of difference between mean Leq8h SPLs between two conditions. Results showed significant difference in mean Leq8h between two conditions (t=3.062, p<0.05). Figure 3, shows the Leq8h for individual participants. Squares indicate the Leq8h in quiet and diamond indicate the Leq8h in the presence of bus noise. From the Figure 3, it can be inferred that most of the individual’s preferred listening levels increased in the presence of bus noise (compare the square and diamond Leq8h for each participant). Preferred listening Leq8h ranged from 63.3 to 114.8dBA in quiet condition and was in the range of 72.8 to 122.1dBA in the presence of 65 dB SPL bus noise. Furthermore, from Figure, 3 it can be observed that 26 of 29 individuals listened to music through their PMS at levels higher than 80 dBA in quiet condition and 27 individuals in the presence of bus noise. These numbers are alarming as more than 90% of the young adults who uses, PMSs listens to music at sufficiently higher levels that can cause temporary/permanent hearing loss.

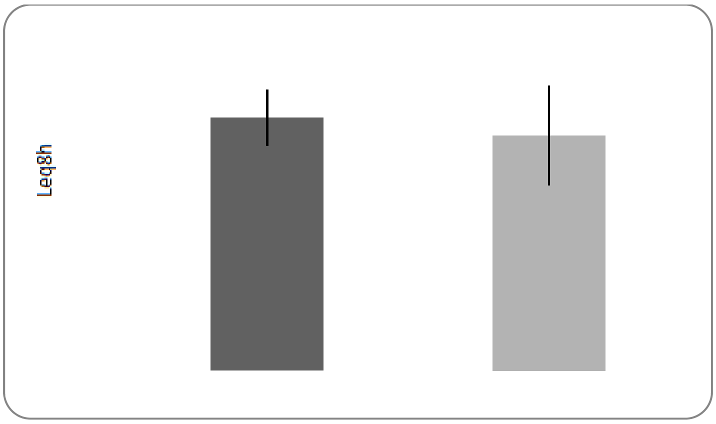

Figure 2: Mean Leq8h in quiet and in the presence of 65dB SPL bus noise. Error bars show 1 standard deviation.

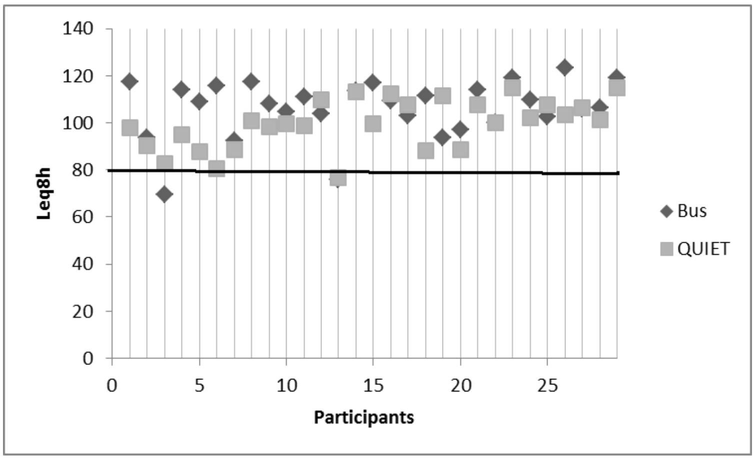

Figure 3: OutputLeq8h values at participants preferred volume control setting in quiet and in the presence of bus noise for individual subjects.A square indicate the Leq8h in quiet and diamond indicate the Leq8h in the presence of bus noise.

Auditory Measures

High frequency audiometry

Figure 4a and 4b shows the mean hearing thresholds in PMS-group and NoPMS-group along with one standard deviation of variation for right and left ear respectively. From the Figure 4, it can be inferred that mean hearing thresholds were higher in the PMS-group compared to NoPMS-group. ANOVA was done to see the significance of difference between the hearing thresholds between the two groups. Results showed a significant main effect of participant's group on hearing thresholds in both right [F (12, 36) = 8.5, p<0.01] and left ear [F(12, 36) =2.89, p< 0.01]. Following pair wise comparison showed that at all the tested frequencies mean hearing thresholds of the PMS-group was significantly poorer than the mean hearing thresholds NoPMS-group.

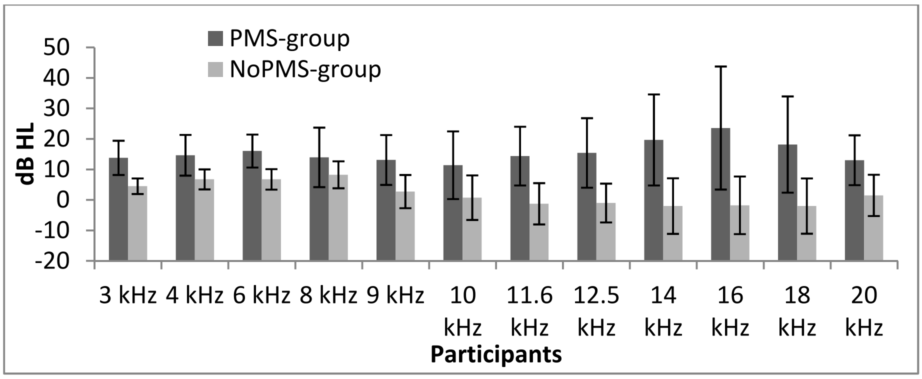

Figure 4a: The mean high frequency hearing threshold across different frequencies in right ear for PMS-group and NoPMS-group. Error bar shows 1 standard deviation error.

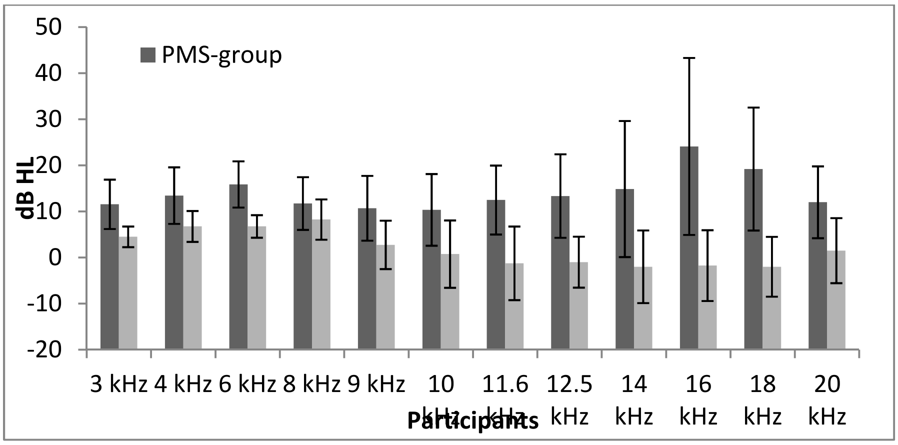

Figure 4b: The mean high frequency hearing threshold across different frequencies in left ear for PMS users and NO-PMSs users. Error bars show 1 standard deviation error.

Transient evoked otoacoustic emissions (TEOAEs)

Figure 5a and 5b shows mean TEOAE amplitudes in two 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 5. From the Figure 5, it can be seen that both overall and band wise TEOAE amplitudes were reduced in PMS-group compared to NoPMS-group. ANOVA was done to find the significance of difference between the mean TEOAE amplitudes between two groups. Results revealed that both the overall and band wise TEOAE amplitudes were significantly reduced in PMS-group compared to NoPMS-group in both the right and left ear (except for 2 kHz in left and 4 kHz in right). F values and significance levels are depicted in Table 1.

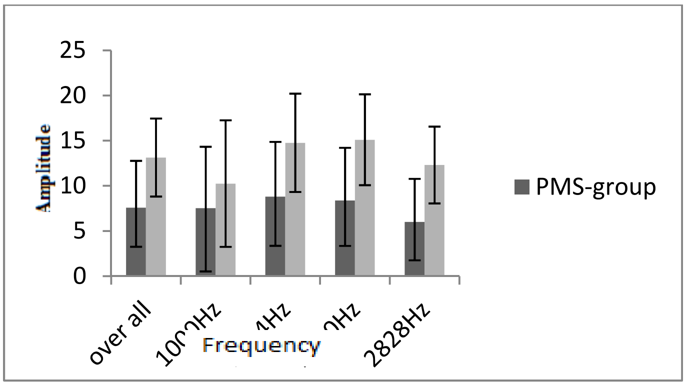

Figure 5a: TEOAE amplitude across different frequencies in the right ear for PMS-group andNoPMS-group.Error bars show 1 standard deviation error.

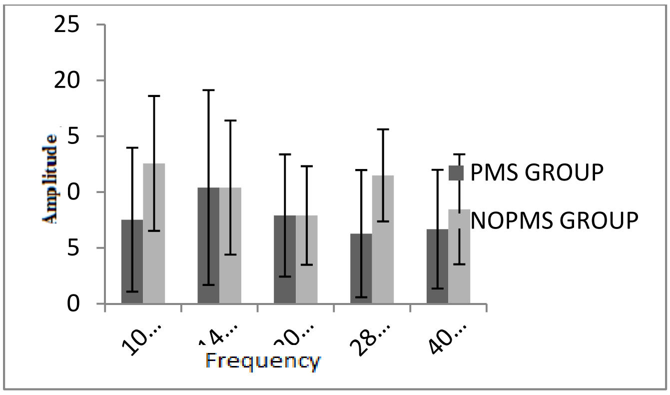

Figure 5b: TEOAE amplitude across different frequencies in the left ear for PMS-group andNoPMS-group.Error bars show 1 standard deviation error.

Table 1: Significant difference between PMS groups and NoPMS-groups in TEOAE results.

Right ear			**Left ear**	
Over all (SPL)	F value	Significance levels	F value	Significance levels
1kHz	4.23	0.045	9.48	0.003
1414 Hz	5.28	0.026	11.48	0.001
2kHz	2.61	0.05	.002	0.107
2828Hz	148	0.001	11.42	0.001

4kHz	.298	0.11	3.70	0.05

Temporal processing

Figure 6 and 7 show the mean gap detection thresholds and duration discrimination thresholds in both the groups along with one standard deviation of variation. Independent samples’t’ test was performed to see the significance of difference between mean gap detection thresholds and duration discrimination thresholds between two groups. Results showed a significant difference in mean gap detection thresholds between both the groups (t=2.09, p<0.05). However, there was no significant difference between the two groups in terms of duration discrimination thresholds (t=0.43, p > 0.05). Figure 8, shows the average modulation detection thresholds along with the one standard deviation of variation in both the groups. ANOVA did not reveal a statistically significant main effect of participants group on modulation detection threshold at 8 Hz [F (1, 33) =1.9, p > 0.05], 20 Hz [F (1, 33) = 0.06, p > 0.05] and 60 Hz. [F (1, 33) =1.1, p > 0.05]. However, at 200 Hz modulation frequency there was a significant main effect of participants group [F (1, 33) = 6.14, p< 0.05] on modulation detection thresholds.

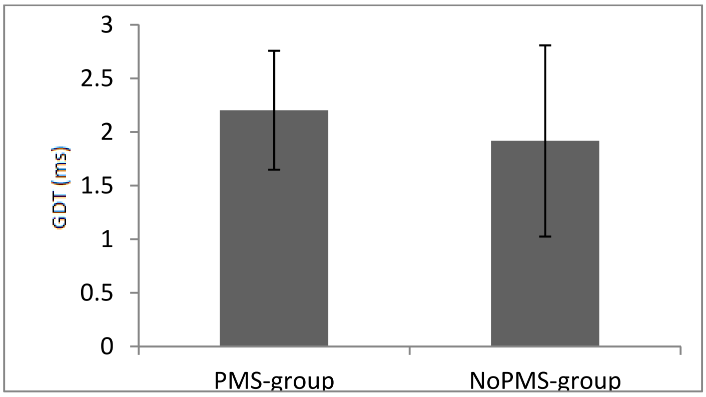

Figure 6: The mean gap detection threshold for PMS and NoPMS-groups.Error bars show 1 standard deviation error.

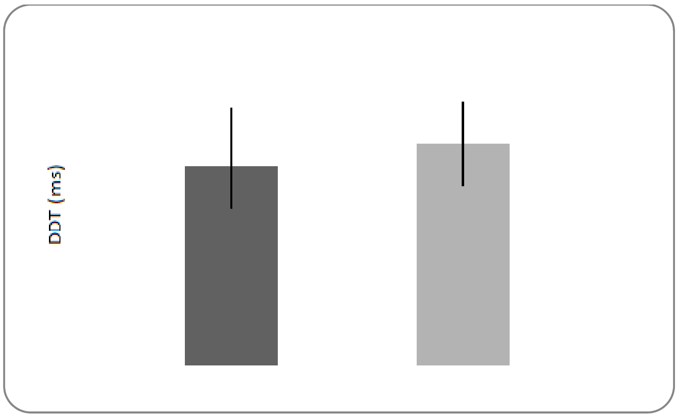

Figure 7: The mean duration discrimination threshold for PMS and NoPMS groups. Error bars show 1 standard deviation error.

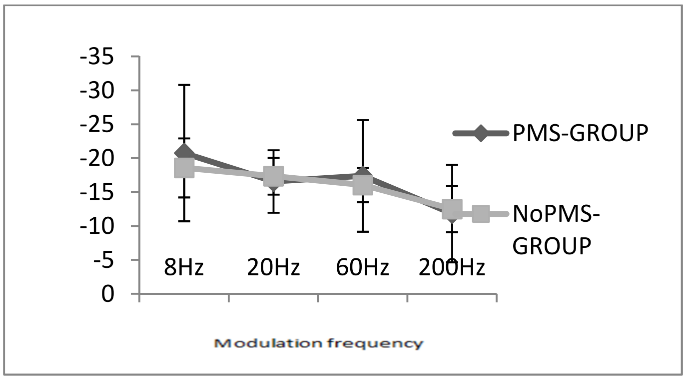

Figure 8: The mean sinusoidally amplitude modulation threshold for across different modulation frequency for PMS and NoPMS groups. Error bars show 1 standard deviation error.

Speech perception in noise

Figure 9 shows the mean scores for speech perception in noise (SIN) along with the one standard deviation variation for the both the groups. The mean scores indicate that the speech perception in noise is better for the NoPMS-group as compared to the PMS group especially at higher signal to noise ratios (SNRs). The raw speech perception scores were converted in rationalized arcsine units (rau). The conversion of raw scores to rau scores was done using the formula by Sherbecoe and Studebaker (2004) which was implemented in MATLAB. All the further statistical analysis was carried out using the rauspeech perception scores. At SNRs +20 dB, +15dB, +10 dB, +5 dB and 0 dB all participants in both the groups obtained 100% correct identification and hence these SNRs were excluded from further statistical analysis. To see the significance of differences in the speech perception scores between two groups ANOVA was performed with speech scores at -5 dB and -10 dB SNR as dependent variable, participants groups as independent variable. Results showed a significant main effect of subject groups on speech identification scores at -5 dB SNR [F(1, 47) = 6.997, $p<0.05$], and -10 dB SNR [F (1, 47) = 6.09, $p<0.05$].

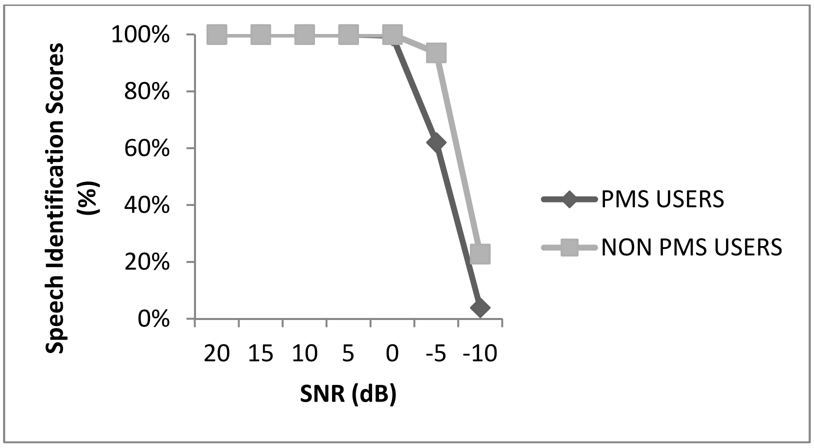

Figure 9: The mean percentage for PMSgroups and NoPMS groups across different SNR levels.

Relationship between Leq8h and hearing measures

To evaluate the relationship between output SPLs and auditory measures Pearson's Product-Moment correlation was carried out between subjects' pure tone thresholds, temporal processing measures and speech perception in noise scores as dependent variable and Leq8h measured in presence of bus noise as the independent variable. Results showed that none of the hearing measures had significant relationship with the leq8h.

CHAPTER 5

DISCUSSION

The purpose of this study was to measure the output levels of the personal music systems (PMS) at the volume control setting that was preferred by the subjects in quiet and in the presence of bus noise. Furthermore, this study also evaluated the extended high frequency hearing thresholds, temporal processing and speech perception skills in group of individuals who uses PMS and compared that to individuals who don't use PMS. The mean dBA Leq8h at preferred volume control settings was 95.8 dBA and ranged between from 63.3 to 114.8dBA in quiet. These preferred listening levels are slightly higher than what participants selected as "sounds best to you" in the Hodgetts, RiegerandSzarko(2007), or "medium/comfortable" in the Torre(2008). In the presence of bus noise of 65 dB SPL the mean preferred listening levels were increased to 103.43 dBA (range 72.8 to 122.1dBA). This increase in the output levels in presence of background noise is comparable to Hodgetts,RiegerandSzarko(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. The bus noise condition used in the current study is more naturalistic as most of the participants reported that they listen to music while commuting. 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 tradeoff between exposure time and sound level. Referencing this criterion about 93.1% individuals in a group of 29 young adults listened to music above the safety limits prescribed by Ministry of Environment and Forests (2000). This is an alarmingly large proportion as majority of the individuals who listen to music through PMS may be putting themselves at risk for permanent noise induced hearing loss if exposed for extended periods of time (years). The output SPLs measured in the current study is slightly higher than what is reported by Kumar, Mathew, Alexander and Kiran(2009). This discrepancy is possibly because of the differences in the type of the earphones used in both the studies. Kumar et al., (2009), used the participants own earphones which ranged from head phones to ear bud type of receivers. In the current study a standard ear bud type of receiver with the deep insertion which is widely used with the current day PMSs was employed.Fligorand Cox (2004) have reported that earbud type of the receiver produces higher sound pressure level (SPLs) than the other types of the receivers.

Effect of PMSs on auditory measures

High Frequency hearing thresholds

Results of the high frequency pure tone audiometry showed that hearing thresholds of individuals who used PMSs significantly poorer compared individuals who did not use PMSs. It should be noted that all the individuals in the PMS group had hearing thresholds within normal limits in the conventional audiometric frequency range. Extended high frequency hearing thresholds are reported to be more sensitive to noise induced damages than the conventional audiometric frequencies. Peng, Yajima, Burns, Zon, Sisodia, Pfaffand Sharma, (2007)reported that extended high frequencies may be affected by the noise earlier when compared to conventional audiometric frequencies. Poorer thresholds in extended high frequency region in combination with the clinically normal hearing thresholds in the conventional audiometric range reveals that listening to music through

PMS at higher intensities may cause subtle pre-clinical damage to the auditory system and over the years such behavior may be hazardous to hearing.

Otoacoustic emissions

Overall transient evoked otoacoustic emission (TEOAE) amplitudes were significantly poorer in individuals who use PMSs compared to those who don't. Miller, Marshall, Heller and Hughes,(2006) reported that amplitudes of distortion product otoacoustic emission (DPOAE) are more sensitive to noise induced hearing loss than pure tone hearing thresholds. Kumar et al., (2009) reported a negative correlation between DPOAE measures and output SPLs of PMSs at preferred volume control settings. They concluded that individuals who listened to music at higher levels had reduced DPOAE amplitudes and signal to noise ratios (SNRs) even though the DPOAE amplitudes were within the clinical norms.

Temporal processing and speech perception in noise

Results revealed that both the temporal processing (gap detection threshold GDT) and speech perception (at higher SNRs) skills were adversely affected in PMS group. Given the present data, the observed deterioration in the temporal and speech processing skills in individuals who uses PMS, in the presence of normal hearing sensitivity probably due to changes in the central auditory system that was caused due to prolonged exposure to loud music through PMS. It has been reported that long-term noise may have persistent effect on brain function and behaviour, even when the peripheral hearing sensitivity is within normal range. Persistent effects of long-term noise exposure on central auditory system were evaluated using auditory evoked potentials. Kujala and Liberman, (2009) assessed the performance in visuo-motor target tracking task and simultaneously recorded the mismatch negativity for /pa/ and /ka/ contrasts on healthy individuals who were exposed to high levels of occupational noise. All their subjects had hearing thresholds that were comparable to the control group. Results showed impaired syllable-discrimination in the left hemisphere of noise-exposed individuals in silence and increased N2b complex for the novel sounds. Furthermore, attention control and ability to focus on visuo-motor tasks were aberrant in noise-exposed group. These results suggest that long-term exposure to occupational noise effects both sound discrimination mechanism and attention control mechanism.

Brattico, Kujala, Tervaniem, Alku and Monitillo,(2005)measured the neural responses in normal hearing, noise-exposed, and non-exposed participants to speech and non-speech deviants. Brain electrical source modelling suggested that speech sound contrast was lateralized to left hemisphere in non-noise-expose group but in right hemisphere in noise-exposed group. This group differences were not found for the non-speech deviants. These studies show that long-term noise can have a detrimental effect on the central auditory system. This detrimental effect has been observed even when the peripheral hearing sensitivity is intact. The observed deficits in the temporal and speech processing abilities in normal hearing, PMS users in this study may be due to compromised central auditory system in these individuals. However, we cannot totally exclude the deleterious effects of distorted cochlear input as a factor. Normal hearing sensitivity does not necessarily mean the normal functioning of the cochlea in PMS-groups.

Evidences from the animal research suggest that cochlear functioning can be affected even in the presence of normal-hearing sensitivity. In the current study, the amplitudes of the TEOAEs were significantly reduced in PMS compared to the group that did not use PMS. Kujawaand Brattico (2009) reported a rapid and irreversible degeneration of spiral ganglion cells by the noise exposure which resulted in the temporary threshold shifts. Even after, hair cells and hearing sensitivity were recovered and neuronal loss persisted. Effects of such neuronal losses on auditory and speech processing are detrimental. In general, a trend of reduced temporal processing skills especially gap detection thresholds and speech perception in noise was observed in individuals who uses PMSs.

Modulation detection thresholds for the high modulation frequency were significantly poorer in PMS group compared with control group. In the auditory system, modulations are represented by phase locked neural discharges of the auditory nerve fibres to individual cycles of modulation frequency. Data from the animal research have shown that acoustic over exposure can cause acute loss of afferent nerve terminals and degeneration of cochlear nerve. This might cause disruption in the phase locking and synchronization in the discharge patterns of auditory nerve fibres causing poor modulation detection thresholds. Poor modulation detection thresholds for higher modulation frequencies suggest that individuals in the PMS-group had difficulty in perceiving rapid fluctuations in the stimulus. Any complex broadband signals such as speech can be decomposed by auditory filters into relatively slow variations in the amplitude over time called envelop and relatively rapid oscillations called temporal fine structure. Importance of slowly varying temporal envelope in speech perception is well documented (Moore, 2008). Recently, it has also been demonstrated that temporal fine structure plays a crucial role in hearing in the presence of background noise (Oxenham& Simonson,2009). It is necessary to perceive the rapid oscillations to derive benefits of temporal fine structure cues. Difficulty in perceiving rapid amplitude fluctuations in PMS group may also pose problems in coding temporal fine structure. This may be one of the reasons for poor performance of PMS group in speech perception measures. It is also been suggest that speech is comodulated at the rate of fundamental frequency (in this study mean fundamental frequency of the target stimulus was 211 Hz). It is important to perceive these comodulations to perceptually separate target speech and background babble as different acoustic streams. Difficulty of noise-exposed individuals in perceiving the rapid amplitude fluctuations may limit their ability perceptually segregate target and background babble.

To summarize, the current study demonstrate that majority of young adults who users PMS, listen to music at hazardously high levels. This behavior did not result in clinically significant auditory changes in the present group of individuals using PMS. However, the individuals demonstrated poor performance in temporal and speech perception skills and reduced OAE and elevated hearing threshold. All the results in combination suggests that listening to music through PMS at high levels results compromised functioning of the cochlea and cerebral auditory systems which may not reversible.

CHAPTER 6

SUMMARY AND CONCLUSION

The proliferation of personal music systems (PMS) in the recent years raises concern because of the tremendous quantity of audio stimulation that user's especially younger generation are exposed to. Hearing loss induced by personal music systems may evolve into a significant social and public health problem in future years. Previous studies have shown that output levels of the PMS can be as high as 121 dBA. Prolonged exposure to loud music can cause 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 the PMS at the volume control setting that was preferred by the participants in quiet and in the presence of 65 dB SPL bus noise
b) To compare the extended high frequency hearing thresholds (3 kHz-20 kHz) in individuals who use PMS and individuals who don't.
c) To compare the transient evoked otoacoustic emissions (TEOAEs) in individuals who use PMS and individuals who don't.
d) To measure gap detection in noise, duration discrimination and modulation detection thresholds in individuals who use PMS and individuals who don't.
e) To measure speech perception in noise in individuals who use PMS and individuals who don't.

A total of 49 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 17 and 25 years, who reported regular usage of personal music systems. Group II consisted of 20 age matched individuals who hardly ever listened to music through PMS. Study was conducted in two phases. In the Phase I output levels of the PMS at preferred volume control settings of the participants were measured in quiet and in the presence of 65 dB SPL bus noise. In Phase II extended high frequency hearing thresholds, transient evoked otoacoustic emissions, temporal processing and speech perception skills were evaluated. Temporal processing included measurement of gap detection thresholds, duration discrimination thresholds and modulation detection threshold for sinusoidally amplitude modulated noise at 8 Hz, 20 Hz, 60 Hz and 200 Hz. Speech perception experiment involved assessing speech perception scores for sentences at presented at +20 dB, +15 dB, +10 dB, +5 dB, 0 dB, -5 dB, -10 dB signal to noise ratios.

Following results were obtained in the present study

a) The mean dBA Leq8h at preferred volume control settings was 95.8 dBA and ranged between from 63.3 to 114.8dBA. In the presence of bus noise of 65 dB SPL the mean preferred listening levels were increased to 103.43 dBA (range 72.8 to 122.1dBA). More than 90% of the participants in the current study used their PMS at levels exceeding the safety limits specified by Ministry of Forests and Environment (2000).

b) Hearing thresholds in the extended high frequency was significantly poorer in individuals who used PMSs compared individuals who did not use PMSs. This difference was observed even though all the individuals in the PMS group had hearing thresholds within normal limits in the conventional audiometric frequency range.

c) Overall TEOAE amplitudes as well as band wise TEOAE amplitudes were significantly poorer in individuals who use PMSs compared to those who don’t.

d) Both the temporal processing (gap detection thresholds and modulation detection thresholds at higher modulation frequency) and speech perception (at higher SNRs) skills were adversely affected in PMS group compared.

From the above results it can be concluded that alarmingly large proportion of the individuals who listen to music through PMS may be putting themselves at risk for permanent noise induced hearing loss if exposed for extended periods of time (years). Results of extended high frequency audiometry and otoacoustic emission showed that listening to music through personal music system at preferred volume control settings may not result in “clinically significant” elevation of hearing thresholds or reduction of otoacoustic emission amplitudes but may cause subtle pre-clinical damage to the auditory system and over the years such behavior may be hazardous to hearing. Poor performance of the PMS-group on temporal and speech perception measures indicate the listening the loud levels of music may compromise central auditory system. It should also be noted that in this study output levels were measured in the ear canals of young adults. The output sound pressure levels produced by these personal music systems in children may be significantly more as they have smaller ear canals. Specific evidence-based and theory-based studies, preferably longitudinal studies, should be conducted in young adults who use personal music systems, to develop effective interventions.

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Appendix I

Shows steps to calculate Leq8h output from the personal music systems for an individual subject.

S NO	Frequency	Octave band SPL(dB	OBL - HRTF= OBL (SPL or L_i)	dBA correction or (K_i)	Corrected OBLs or (L_i+K_i)	10 (L_i+K_i)/10
1	.2kHz	84.1	88.3	-8.6	79.7 77	93325430.08
2	.3kHz	84.3	86.4	-8.6	77.8	60255958.61
3	.4kHz	84.2	84.3	-3.2	81.1	128824955.2
4	.5kHz	83.9	83.2	-3.2	80	100000000
5	.6kHz	83.2	82.2	-3.2	79	79432823.47
6	.7kHz	82.3	80.6	-3.2	77.4	54954087.39
7	.8kHz	83.6	82.2	0	82.2	229086765.3
8	.9kHz	86	85.5	0	85.5	398107170.6
9	1kHz	88.3	88.8	0	88.8	676082975.4
10	1.1kHz	89.4	89.7	0	89.7	870963590
11	1.2kHz	87.8	88.2	0	88.2	602559586.1
12	1.3kHz	89.4	88.4	0	88.4	870963590
13	1.4kHz	87.3	86.5	0	86.5	537031796.4
14	1.5kHz	86.4	84.3	1.2	85.5	354813389.2
15	1.6kHz	82.5	79.6	1.2	80.8	120226443.5
16	1.7kHz	83.8	79.4	1.2	80.6	114815362.1
17	1.8kHz	83.2	77.9	1.2	79.1	81283051.62
18	1.9kHz	83.3	77.1	1.2	78.3	67608297.54

19	2kHz	83.3	75.4	1.2	76.6	45708818.96
20	2.1kHz	83.1	73.6	1.2	74.8	30199517.2
21	2.2kHz	84.2	73.4	1.2	74.6	28840315.03
22	2.3kHz	85.6	73.3	1.2	74.5	28183829.31
23	2.4kHz	87.2	73.8	1.2	75	31622776.6
24	2.5kHz	88.4	74.3	1.2	75.5	35481338.92
25	2.6kHz	88	73.7	1.2	74.9	30902954.33
26	2.7kHz	87.3	72.8	1.2	74	25118864.32
27	2.8kHz	86.2	71.9	1.2	73.1	20417379.45
28	2.9kHz	84.6	71	1.1	72.1	16218100.97
29	3kHz	83.1	70.2	1.1	71.3	13489628.83
30	3.1kHz	82.6	70.5	1.1	71.6	14454397.71
31	3.2kHz	82.4	70.9	1.1	72	15848931.92
32	3.3kHz	81.6	70.8	1.1	71.9	15488166.19
33	3.4kHz	81.2	71.3	1.1	72.4	17378008.29
34	3.5kHz	80	70.6	1.1	71.7	14791083.88
35	3.6kHz	79.2	70	1.1	71.7	12882495.52
36	3.7kHz	78.7	64.9	1.1	66	3981071.706
37	3.8kHz	76.7	67.2	1.1	68.3	6760829.754
38	3.9kHz	75.7	65.8	1.1	66.9	4897788.194
39	4kHz	74.7	63.8	1.1	64.9	3090295.433
40	4.1kHz	74.3	62.7	1.1	63.8	2398832.919
41	4.2kHz	74.3	61.8	1.1	62.9	1949844.6
42	4.3kHz	74.9	61.4	1.1	62.5	1778279.41

43	4.4kHz	75.7	61.1	1.1	62.2	1659586.907
44	4.5kHz	77.3	61.6	1.1	62.7	1862087.137
45	4.6kHz	78	61	1.1	62.1	1621810.097
46	4.7kHz	79.7	61.6	1.1	62.7	1862087.137
47	4.8kHz	79.7	60.9	1.1	62	1584893.192
48	4.9kHz	80.1	60.8	1.1	61.9	1548816.619
49	5kHz	80.4	60.6	1.1	61.7	1479108.388
50	5.1kHz	79.8	60	1.1	61.1	1288249.552
51	5.2kHz	80.4	61	1.1	62.1	1621810.097
52	5.3kHz	79.8	61.1	1.1	62.2	1659586.907
53	5.4kHz	79.1	60.7	1.1	61.8	1513561.248
54	5.5kHz	78.5	60.2	1.1	61.3	1348962.883
55	5.6kHz	77.3	59.3	1.1	60.4	1096478.196
56	5.8kHz	77.4	59.6	1.1	58.5	707945.7844
57	5.9kHz	75.7	57.9	-1.1	56.8	478630.0923
58	6kHz	74.7	56.6	-1.1	55.5	354813.3892
59	6.3kHz	72.7	55.1	-1.1	54	251188.6432
60	6.5kHz	70.2	53.8	-1.1	52.7	186208.7137
61	6.7kHz	70	55.6	-1.1	54.5	281838.2931
62	7.1kHz	69.5	55.6	-1.1	54.5	281838.2931
63	7.5kHz	66.1	53.1	-1.1	52	158489.3192
64	8kHz	65.8	54	-1.1	52.9	194984.46

Total= 588, 526, 179, 7

OBL - Octave band level

HRTF-Head related transfer function

dBA- A weighted sound level

Leq8h-8 hour’s equivalent level exposure.

The OBLs are summed logarithmically according to the formula:

$$\boxed{L_A = 10 \log_{i=1}{}^{n} \Sigma\, 10^{(Li+Ki)/10}}$$

L_A =10 log 5885,261,797

The logarithmic of 588, 526, 179, 7 is 9.769, so that we now have

L_A= 10*9.769.

Hence, the

Overall level of this sound is

L_A= 97.69

Where L_A is the overall (combined) level in dBA,

N is the number of bands,

I is the ith band,

L is the OBL of the I thband, and

Ki is the dBA correction value for each OBL

The correction is accomplished by adding the correction factor to the OBL (Li+Ki). Adding a negative correction value is the same as subtracting.

Calculation of 8 hour equivalent continuous A-weighted noise exposure (Leq8h) was calculated from the equation

$$\boxed{Leq8h = L_T + 10 \log_{10} [T/8]}$$

Where Leq8h is the 8 hour equivalent continuous noise exposure,

T = exposure time in hours,

L_T = Level of noise exposure over the time period T

T=5, L_T = 97.69

Leq8h =97.69+ 10 log10 [5/8]

Leq8h =97.69+ [-2.0412]

Leq8h=95.65.