Short-term effects of simultaneous cardiovascular workout and personal music device use on the otoacoustic emissions of young adults.

by

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FIGURES

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LIST OF ABBREVIATIONS

PMD	Personal music device
OHC	Outer hair cell
DPOAE	Distortion- Product Otoacoustic Emission
TEOAE	Transient-Evoked Otoacoustic Emission
SFOAE	Stimulus-Frequency Otoacoustic Emission
IHC	Inner hair cell
N.VIII	Vestibulocochlear nerve
OAE	Otoacoustic Emission
NIHL	Noise- induced hearing loss
SNHL	Sensorineural hearing loss
MIHL	Music- induced hearing loss
TTS	Temporary threshold shift
SNR	Signal to noise ratio
NIOSH	National Institute for Occupational Safety and Health
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
CENELEC	European Committee for Electrotechnical Standardisation
ROS	Reactive Oxygen Species
FOR	Free Oxygen Radicals
SANS	South African National Standards
ART	Acoustic reflex threshold
RAS	Reflex activating stimulus
NF	Noise floor

ABSTRACT

Recent advances in the field of audiology have indicated that there has been a growing concern regarding the potential damage to the hearing mechanism induced by recreational noise exposure from personal music devices (PMD). Regular PMD use may have a long-term damaging effect on the outer- and inner hair cells of the cochlea which may result in a progressive hearing loss. As PMDs have advanced to a stage where the memory of the devices are able to contain hours of listening content, the environments where these devices are being used are rapidly expanding. Many young adults tend to use their PMDs whilst exercising. Exercise in itself induces physiological and metabolic changes such as increased blood flow and oxygen levels within the structures of the cochlea.

The purpose of this study was to determine the differential impact and short-term effects of simultaneous cardiovascular workout and personal music device (PMD) use on the otoacoustic emissions of young adults. Seven female and five male subjects completed three testing conditions: (i) one hour exposure to PMD use in isolation, (ii) one hour exposure to cardiovascular workout in isolation, and (iii) one hour simultaneous exposure to PMD use and cardiovascular workout. Distortion product otoacoustic emissions (DPOAEs) were conducted prior to, as well as directly following each testing condition, as primary indicator of cochlear responses emitted through a preset stimulus frequency sequence measuring the $2f_1 - f_2$ (75 – 70 dB SPL) and constructing a plot of DPOAE levels as a function of frequency.

While each of the testing conditions on its own did not result in statistically significant changes of the DPOAE response, a highly significant different profile in the DPOAE response level increase/decrease for the higher frequencies (6-8 kHz) was obtained when comparing the different sessions to each other. Where exposure to cardiovascular workout showed a clear trend of an increased DPOAE response level between the pre-exposure and post-exposure testing from 2 kHz to 8 kHz with a maximum increase at 6 kHz, both the music only condition and the combined condition where the cardiovascular workout was combined with music resulted in a significant different profile. During combined exposure a clear trend of decreased DPOAE response amplitudes between the pre-exposure and post-exposure testing were seen for the higher frequencies.

These findings may support the notion of a clear effect of cardiovascular workout on the otoacoustic emissions at higher test frequencies, measured by DPOAEs when performed with and without music exposure.

Keywords: Personal music device, cardiovascular workout, outer hair cell function, otoacoustic emissions

CHAPTER 1

1. INTRODUCTION

1.1. PROBLEM STATEMENT AND RATIONALE

Recreational noise exposure through personal music device (PMD) use has become a growing concern as the use of PMDs among young adults is rapidly increasing (Haines, Hodgetts, Ostevik & Rieger, 2012; Punch, Elfenbein & James, 2011; Hoover & Krishnamurti, 2010; Fligor, 2009; Hodgetts, Szarko & Rieger, 2009; Shah, Gopal, Reis & Novak, 2009; Singh, Strasser, Saxena & Varshney, 2009; Bhagat & Davis, 2008; Holmes, Widen, Erlandsson, Carver & White, 2007; Santos, Morata, Jacob, Albizu, Marques & Paini, 2007). Over the past decade studies have emphasized the growing risk of cochlear damage due to recreational noise exposure among young adults (Danhauer, Johnson, Byrd, DeGood, Meuel, Pecile & Koch, 2009). More recently noise emitting devices such as PMDs have become readily available in compact packages containing memory to store hours of listening time (Sulaiman, Husain & Seluakumaran, 2014; Haines et al., 2012; Punch et al., 2011; Hoover & Krishnamurti, 2010; Danhauer et al., 2009; Hodgetts et al., 2009; Shah et al., 2009). It has been reported that PMDs are manufactured to produce output levels up to 110 dBA (Keppler, Dhooge, Maes, D'haenens, Bockstael, Philips, Swinnen, & Vinck, 2010; Kumar, Mathew, Alexander & Kiran, 2009; Bhagat & Davis, 2008). Keppler et al. (2010) concluded that temporary changes in OHC function measured by otoacoustic emissions (OAEs) after one hour listening time, indicated potential damaging effects of listening to a PMD. Kumar et al. (2009) reported a negative correlation between distortion product otoacoustic emission (DPOAE) measurements and music levels indicating that DPOAE amplitudes and signal to noise ratios (SNRs) were less significant in subjects who listened to high output music levels. Lastly Bhagat and Davis (2008) found reduced DPOAE levels following high intensity music levels at 1.4 kHz to 6.0 kHz. After a 30 minute exposure time period the results indicated that reduced DPOAE levels may precede the progress of music-induced hearing threshold shifts.

Current legislation regarding noise exposure focuses mainly on occupational noise hazards. According to the National Institute for Occupational Safety and Health (NIOSH) the allowable listening level is 85

dBA for an eight hour exposure time. The NIOSH recommendations state that as the sound level increases with 3 dBA, the listening time should be halved. The increase in the duration of listening time alone poses a great threat to outer hair cell (OHC) damage which can be measured accurately by use of OAEs that directly evaluate the functioning of the OHCs (Hutchinson & Alessio, 2010:26; Singh, Saxena & Varshney, 2009; Attias et al., 2001; Vinck, Cauwenberge, Corthals & De Vel, 1998). However, recent European standards for PMDs and mobile phones stipulate that all PMDs sold after February 2013 should have a default set volume of 85 dB (http://europa.eu/). Reports conducted by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) lead to the implementation of these standards by the European standardisation body, the European Committee for Electrotechnical Standardisation (CENELEC). These standards could possibly have an effect on the use of PMDs worldwide with relation to possible music induced hearing loss (MIHL).

PMD listening environments include both relaxation activities and on-the-go activities. Relaxation activities may include listening to a PMD while at home or on holiday. On-the-go activities may include listening to a PMD while driving in the car or on a train; walking in shopping centres; waiting in a service line; and especially whilst doing cardiovascular workouts (jogging, cycling, strength training etc.). It is generally accepted that cardiovascular fitness is essential to a healthy body and mind. According to Alessio and Hutchinson (2010), cardiovascular workout increases blood flow and blood circulation to the cochlea. Increased oxygen saturation levels are also recorded. Oxygen saturation refers to the amount of oxygen that is transported via the haemoglobin of red blood cells through the bloodstream as a percentage of the maximum it is able to transport. In addition to increased oxygen saturation, increased blood flow to the inner ear is also observed during cardiovascular workout.

The physiological changes that occur within the inner ear during cardiovascular workout are of importance. The latter highlights the notion that other physiological changes also take place in the inner ear after exposure to high intensity sound. Temporary threshold shift (TTS) includes a synaptic fatigue effect that is caused by the changes in metabolic processes of the OHCs and IHCs as well as changes in cochlear blood flow (Keppler, Vinck & Dhooge, 2010; Zhao, Manchaiah, French & Price, 2010). The repeated metabolic changes that occur during music exposure may lead to the generation

of toxic metabolic byproducts such as reactive oxygen species (ROS) and free-oxygen radicals (FOR), which serve as triggers for cell damage and eventual necrosis and apoptosis (Zhao et al., 2010).

Cardiovascular fitness may positively influence hearing sensitivity through the effect of blood circulation to the organs and structures of the inner ear, especially the stria vascularis in the cochlea. Hutchinson, Alessio and Baiduc (2010) mention existing evidence regarding hearing preservation and protection by cardiovascular workout. The latter study indicated that cells under stress from noise generate proteins to protect surviving cells. According to Hutchinson et al. (2010) metabolism and blood flow are directly related to the vascular structure of the cochlea. Variations in cochlear blood flow may consequently affect the availability of oxygen and glucose which is more rapidly metabolized during sound stimulation (Alessio, Hutchinson, Price, Reinart & Sautman, 2002). Vittitow, Windmill, Yates and Cunningham (1994) concluded that a greater TTS is observed during simultaneous cardiovascular workout and noise exposure in comparison to these testing conditions in isolation. Another study conducted by Engdahl (1996) reported increased noise induced TTS during physical exercise. In contrast to these results Krishnamurti, Sridhar, Grandjean and Peter (2003:213) found no evidence of auditory changes after short-term exposure to exercise and loud music. A related study also indicated that although a TTS occurred following simultaneous exposure, a more significant TTS was observed during noise exposure in isolation (Alessio & Hutchinson, 1991). Although conflicting information exists on the effect of simultaneous cardiovascular workout and PMD use, the simultaneous metabolic changes including increased blood flow and oxygen saturation could decrease the risk for permanent music induced hearing loss (MIHL) (Hull & Kerschen, 2010).

Despite the lack of evidence on the simultaneous use of PMDs and cardiovascular workout, feasible metabolic changes that occur during cardiovascular workout and PMD use in isolation may be observed and are magnified when combining the two activities (Hutchinson et al., 2010).

The main aim of this study was to determine the differential impact of and potential short-term effects on DPOAEs in the presence of simultaneous cardiovascular workout and listening to music on a PMD.

1.2. TERMINOLOGY

TERMINOLOGY	DESCRIPTION
Personal music device (PMD)	Compact, portable music player that is used for personal recreational listening purposes through earphones (in-the-ear or over-the-ear earphones).
Otoacoustic Emissions (OAEs)	Soft sounds that are generated by the OHCs within the cochlea in response to external acoustic stimuli and measuring OHC integrity.
Distortion-Product Otoacoustic Emissions (DPOAEs)	Soft sounds that are generated by the OHCs within the cochlea in response to two pure tone signals at frequencies f1 and f2 (f1<f2) presented simultaneously into the ear canal.
Transient-evoked Otoacoustic Emissions (TEOAEs)	Soft click-evoked sounds that are generated by the OHCs within the cochlea.
Sensorineural hearing loss (SNHL)	Permanent hearing loss due to damaged outer and/or inner hair cells of the cochlea of multiple origins.
Noise-induced hearing loss (NIHL)	Permanent hearing loss due to damaged outer and/or inner hair cells of the cochlea and caused by noise over time.
Music-induced hearing loss (MIHL)	New term referring to hearing loss due to damaged outer and/or inner hair cells of the cochlea and caused by recreational music exposure, usually over time.
Temporary threshold shift (TTS)	Reversible auditory fatigue caused by continuous or sudden intense sound exposure.
Temporary Emission Shift (TES)	Reversible shift or change in emissions measured, caused by continuous or sudden intense sound exposure.
Cardiovascular workout	Any form of vigorous aerobic exercise that increases metabolic rate.
Reactive oxygen species (ROS)	Chemically reactive molecules containing oxygen
Free oxygen radicals (FOR)	Unstable oxygen molecules that can cause cell damage.

1.3. CHAPTER LAYOUT

CHAPTER	LAYOUT
1. INTRODUCTION	1.1. Problem statement and rationale; 1.2. Terminology; 1.3. Chapter layout.
2. LITERATURE REVIEW	2.1. Effects of noise exposure on the structures of the cochlea; 2.2. Otoacoustic emissions as a new technique for early detection of outer hair cell damage; 2.3. Effects of personal music device use on otoacoustic emissions: 2.4. Effects of cardiovascular workout on hearing and its function; 2.5. Effects of simultaneous cardiovascular workout and PMD use on hearing and its function; 2.6. Summary.
3. METHODOLOGY	3.1. Research aims; 3.2. Hypotheses; 3.3. Research design; 3.4. Ethical considerations; 3.5. Research participants; 3.6. Procedure for participant selection; 3.7. Data collection; 3.8. Data processing and analysis.
4. RESULTS	4.1. Sub-aim 1: To determine the short term effects of listening to a PMD on the OAEs as measured by DPOAEs. 4.2. Sub-aim 2: To determine the short term effects of cardiovascular workout on the OAEs as measured by DPOAEs. 4.3. Sub-aim 3: To determine the short term effects of simultaneous PMD use and cardiovascular workout on the OAEs as measured by DPOAEs.

5. DISCUSSION	5.1. Sub-aim 1: To determine the short term effects of listening to a PMD on the OAEs as measured by DPOAEs. 5.2. Sub-aim 2: To determine the short term effects of cardiovascular workout on the OAEs as measured by DPOAEs. 5.3. Sub-aim 3: To determine the short term effects of simultaneous PMD use and cardiovascular workout on the OAEs as measured by DPOAEs.
6. CONCLUSION	6.1. Clinical implications and recommendations 6.2. Strengths and limitations of the study 6.3. Future research 6.4. Final statement

CHAPTER 2

2. LITERATURE REVIEW

2.1. Effects of noise on the structures of the cochlea:

Excessive noise exposure may lead to various metabolic and/or mechanical disturbances to the microscopic OHC and IHC structures in the Organ of Corti (Barros et al., 2007; Keppler et al., 2010). Metabolic disturbances refer to resulting cell damage or cell death by means of toxic damage (Keppler et al., 2010). In turn, the mechanical disturbances can be explained as the physical disruption of hair cell integrity (Barros et al., 2007; Keppler et al., 2010). The mechanical alterations may present in several different structures and degrees, determining the permanency of the alterations. Intense exposure to noise may result in the mechanical rupture of the basilar membrane and hair cell structures, which may lead to immediate permanent damage or induce temporary changes depending on the severity of the alteration (Barros et al., 2007). Temporary uncoupling of the stereocilia may be caused by buckling of the pillar bodies, reducing the physical height of the Organ of Corti and consequently uncoupling the OHC stereocilia from the tectorial membrane (Keppler et al., 2010). The result is explanatory of a TTS.

Other morphological changes include biochemical alterations that may lead to the degeneration of the sensory cells in the cochlea and eventual destruction of the spiral ganglion (Keppler et al., 2010). Prolonged exposure to high intensity sounds could in addition lead to accumulation of calcium in the mitochondria, excitotoxic neural swelling and reduction in cochlear blood flow (Keppler et al., 2010). This may result in the activation of ROS enzymes and generation of FOR (Keppler et al., 2010). It is important to acknowledge that ROS formation is not exclusive to the OHCs but also to the surrounding cellular structures. Nonetheless the primary damage is focused on the OHCs (Keppler et al., 2010). Two other co-existing processes involved in eventual cell death are apoptosis and necrosis (Keppler et al., 2010). Apoptosis refers to an active process that is involved with the elimination of damaged cells in order to prevent the possible spread of the lesion to other surrounding cells (Keppler et al., 2010). In contrast to this process, necrosis is a passive process associated with the swelling of

cells leading to rupturing of cells (Keppler et al., 2010). The latter only accounts for a lesser portion of damage and apoptosis can be active for numerous days following high intensity noise exposure (Keppler et al., 2010).

Extended periods of varying intermissions of noise exposure may, over time, result in a permanent NIHL (Barros et al., 2007; Keppler et al., 2010). In literature NIHL is in general used to describe a bilateral, symmetrical moderate to severe SNHL caused by industrial noise exposure (Keppler et al., 2010). Another term that is often used is MIHL, where the hearing loss is generally accepted to be due to long-term high intensity music exposure (Keppler et al., 2010). The difference between the terms can be derived from the explanation whether the exposure to the high intensity sound levels are voluntary or involuntary. Noise is widely accepted as a term used for unwanted sound (Keppler et al., 2010; Santos et al., 2007; Strasser et al., 2008). In contrast to noise, music exposure is often voluntary in nature, hence the term MIHL (Santos et al., 2007; Keppler et al., 2010; Strasser et al., 2008). The effects of noise exposure on the cochlea become permanent over varying time periods and can be determined at an early stage by use of OAEs.

2.2. OAEs as a new technique for early detection of OHC damage:

Literature has demonstrated that the structures of the cochlea, with specific reference to the OHCs, are compromised in integrity when exposed to continuous or long-term high intensity noise exposure. Several consequential effects leading to eventual permanent noise and/or MIHL have also been discussed. Decades of audiological assessment, monitoring, prevention and management of these types of hearing losses have focused on several methods to do so. The OHCs are damaged prior to destruction of the IHCs and nerve terminals (Attias, Horovitz, El-Hatib & Nageris, 2001). In order to accurately diagnose and monitor primary OHC damage due to noise exposure, targeted tests focusing on the direct site and function of the OHCs should be administered. Pure-tone behavioural audiometry is insensitive to subtle noise-induced OHC changes (Attias et al., 2001; Vinck et al., 1999). Previous research has indicated that OAE testing is a more effective tool for evaluating the outer hair cell integrity and determining early OHC deterioration (Attias et al., 2001; Helleman, Jansen & Dreschler, 2010; Singh et al., 2011; Keppler et al., 2010; Vinck et al., 1999; Vinck et al., 1998).

OAEs are non-invasive, sensitive and objective measures that can be applied as a measuring tool for early detection of possible noise and/or music induced audiometric changes, before changes are evident on the audiogram (Attias et al., 2001; Kemp, 2002; Keppler et al., 2010; Seixas, Kujawa, Norton, Sheppard, Neitzel & Slee, 2004; Vinck et al., 1999). OAEs are soft sounds from cochlear origin caused by the movement of the cochlea's sensory hair cells in response to auditory stimulation (Kemp, 2002; Seixas et al., 2004; Vinck et al., 1999).

Several types of OAEs can be distinguished according to the differences in the type eliciting stimulus and the response latency with reference to the stimulus onset (Vinck et al., 1998). These types include: spontaneous otoacoustic emissions (SOEAs), transient evoked otoacoustic emissions (TEOAEs), stimulus-frequency otoacoustic emissions (SFOAEs) and distortion product otoacoustic emissions (DPOAEs) (Vinck et al., 1998). Both TEOAEs and DPOAEs are considered as frequency-specific tests with the ability to monitor and determine cochlear functioning (Kemp, 2002; Keppler et al., 2010; Vinck, De Vel, Xu, & Van Cauwenberge, 1996). In contrast to TEOAEs, DPOAEs use more frequency specific stimuli to elicit the cochlear responses and can be elicited over a wider range of frequencies that extends over the higher frequencies (0.5 – 8 kHz) (Vinck et al., 1996). In addition to this statement, DPOAEs can be recorded with moderate hearing losses in the absence of any TEOAE responses (Kemp, 2002). Thus OAEs are clinically of importance in order to monitor OHC integrity over time to possibly prevent permanent hearing loss at a later stage. The latter can be achieved by early detection of outer hair cell damage.

DPOAEs are soft sounds that are generated by the normal cochlea when two pure tone signals at frequencies f1 and f2 ($f1 < f2$) are simultaneously presented into the ear canal by means of a firmly inserted ear probe (Seixas, 2004; Vinck et al., 1996). DPOAEs have an extensive dynamic range regarding hearing loss that permits to make both liminal and supraliminal measures for hearing losses up to 45 to 55 dBHL (Vinck et al., 1996).

2.3. Effects of PMD use on OAEs:

It is widely accepted that prolonged exposure to high intensity sound levels may pose harmful effects to hearing ability and could lead to permanent hearing difficulties (Barros et al., 2007; Shah, Gopal, Reis & Novak, 2009; Punch, Elfenbein & James, 2011; Keppler et al., 2010). Occupational noise exposure has been proven to cause long-term hearing damage and in the recent literature it has become increasingly evident that recreational noise exposure may also lead to possible long-term hearing difficulties (Torre, 2008; Keppler et al., 2010). Some of the major sources of recreational music exposure include: i) PMDs, ii) attendance of nightclubs, iii) attendance of live concerts, iv) listening to the radio and v) playing a musical instrument (Holmes, Widén, Erlandsson, Carver & White, 2007; Keppler et al., 2010).

A growing concern regarding the use and potential harmful effects of PMDs has become evident (Bhagat & Davis, 2008; Danhauer et al., 2009; Fligor, 2009; Haines et al., 2012; Hodgetts et al., 2009; Holmes et al., 2007; Hoover & Krishnamurti, 2010; Kumar et al., 2009; Punch et al., 2011; Santos et al., 2007; Shah et al., 2009; Strasser et al., 2008; Zhao et al., 2010). It should be taken into account that the damaging effects caused by high intensity sound levels are relative to many factors including duration of listening time, intensity of listening time and frequency of listening time (Keppler et al., 2010). Although the potential exists for developing hearing damage due to PMD use, it cannot be viewed in isolation. Several other and in some instances co-occurring factors including susceptibility, chemical exposure, ototoxic medications, smoking, cardiovascular disease, diabetes, immune function impairment and high cholesterol levels may be potentially harmful to hearing (Phillips et al., 2010; Keppler et al., 2010).

The concerns regarding PMD use is related to various factors involving the duration of listening time and the intensity levels that are produced by these devices. The duration of listening time is directly affected by the availability of the compact PMDs with the capability to store hours of listening time, consequently increasing the duration and frequency of PMD use (Danhauer et al., 2009; Haines et al., 2012; Hoover & Krishnamurti, 2010; Punch et al., 2011; Shah et al., 2009; Sulaiman et al., 2014; Keppler et al., 2010). Another leading concern regarding PMD use is the capability of producing high

intensity sound output levels (Danhauer et al., 2009; Haines et al., 2012; Sulaiman et al., 2014; Torre, 2008; Keppler et al., 2010). Studies have been conducted on whether these devices are capable of output levels high enough to cause damage to the hearing system (Danhauer et al., 2009; Haines et al., 2012; Torre, 2008). Results indicated that these devices are capable of producing damaging output levels between 100 and 120 dBA which easily exceed safe listening limits (Sulaiman et al., 2014). Danhauer et al. (2009) indicated that PMDs used with supra-aural headphones are capable of producing output levels of 130 dBA. Research conducted by Fligor and Cox (2004) reported output levels as high as 121 dBA (Torre, 2008). Keppler et al. (2010) concluded that temporary changes in OHC function measured by OAEs after one hour listening time indicated potential damaging effects of listening to a PMD. Kumar et al. (2009) reported a negative correlation between DPOAE measurements and music levels indicating that DPOAE amplitudes and signal to noise ratio (SNR) changes were less significant in subjects who listened to high output music levels. Lastly Bhagat and Davis (2008) found reduced DPOAE levels following high intensity music levels at 1.4 kHz to 6.0 kHz. After a 30 minute exposure time period the results indicated that reduced DPOAE levels may precede the progress of music-induced hearing threshold shifts (Bhagat & Davis, 2008).

The risks associated with occupational noise exposure are well researched and therefore clear criteria and guidelines have been compiled in order to attempt to reduce the risk of developing NIHL at the workplace (Phillips et al., 2010; Santos et al., 2007). According to the National Institute for Occupational Safety and Health (NIOSH) the allowable listening level is 85 dBA for an eight hour exposure time (Phillips et al., 2010). The NIOSH recommendations state that as the sound level increases with 3 dBA, the listening time should be halved.

However recent European standards for PMDs and mobile phones stipulate that all PMDs sold after February 2013 should have a default set volume of 85 dBA (http://europa.eu/). Reports conducted by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) (2013) lead to the implementation of these standards by the European standardisation body, the European Committee for Electrotechnical Standardisation (CENELEC) (Haines et al., 2012). These standards could possibly have an effect on the use of PMDs worldwide with relation to possible music induced hearing loss

(MIHL) (Haines et al., 2012). Up to date no legislation pertaining specifically to PMD use has been published in South Africa.

2.4. Effects of cardiovascular workout on hearing and its function :

Limited research regarding simultaneous cardiovascular workout and PMD use on DPOAEs has been reported. Engdahl (1996) researched the topic and reported increased noise induced TTS during physical exercise. Up to date other research on this specific topic has not yet been obtained.

It is generally accepted that cardiovascular fitness is essential to a healthy body and mind. According to Alessio and Hutchinson (2004) cardiovascular workout increases the blood flow and circulation to the organs of the cochlea. This leads to increased oxygen saturation levels. Oxygen saturation refers to the amount of oxygen that is transported via haemoglobin through the bloodstream as a percentage of the maximum it is able to transport. In addition to increased oxygen saturation, increased blood flow to the inner ear is also observed during cardiovascular workout.

Additionally, other physiological changes take place in the inner ear after exposure to high intensity sound. Zhao et al. (2010) documented that the TTS includes synaptic fatigue effect that is caused by the changes in metabolic processes of the OHCs and IHCs as well as changes in cochlear blood flow. The repeated metabolic changes that occur during music exposure may lead to the generation of toxic metabolic byproducts such as ROS and FOR, which serve as triggers for cell damage and eventual necrosis and apoptosis (Zhao et al., 2010).

In contrast to the findings of Zhao et al. (2010), Hutchinson et al. (2010) have provided evidence that cardiovascular fitness plays a protective role in hearing preservation with peak oxygen consumption as the basis of comparison. Hutchinson et al. (2010) further mentioned that cells under stress generate proteins to protect surviving cells including positive pharmacological effects of specific proteins against cochlear damage. Cardiovascular fitness may positively influence hearing sensitivity through the effect of blood circulation. The latter refers principally to the organs and structures of the inner ear with specific reference to the stria vascularis in the cochlea. According to Hutchinson et al. (2010)

and Alessio, Hutchinson, Price, Reinhart & Sautman (2002) metabolism and blood flow are directly related to the vascular structure of the cochlea. Variations in cochlear blood flow may consequently affect the availability of oxygen and glucose which is more rapidly metabolized during sound stimulation.

2.5. Effects of simultaneous cardiovascular workout and PMD use on hearing and its function :

Vittitow et al. (1994) concluded that a greater TTS is observed during simultaneous cardiovascular workout and noise exposure in comparison to these testing conditions in isolation. In contrast to these results Krishnamurti et al. (2003) found no evidence of auditory changes after short-term exposure to exercise and loud music. A related study also indicated that although a TTS occurred following simultaneous exposure, a more significant TTS was observed during noise exposure in isolation (Alessio & Hutchinson, 1991). Although conflicting information exists on the effect of simultaneous cardio workout and PMD use, the simultaneous metabolic changes including increased blood flow and oxygen saturation could decrease the risk for permanent MIHL (Hull & Kerschen, 2010).

2.6. Summary:

Numerous previous studies have emphasized the possible negative long term effects of repeated PMD use (Zhao et al., 2010; Kumar et al., 2009; Fligor, 2009; Strasser et al., 2008; Bhagat & Davis, 2008; Santos et al., 2007). These studies based their assumptions on the recorded short-term effects of PMD use. Despite the lack of evidence on the simultaneous use of PMDs and cardiovascular workout, feasible metabolic changes that occur during cardiovascular workout and PMD use in isolation may be observed and are magnified when combining the two activities (Hutchinson et al., 2010).

Thus the research question:

What are the potential short-term effects of simultaneous cardiovascular workout and personal music device use are on the DPOAE response?

CHAPTER 3

3. METHODOLOGY

The following section contains aims of the research including a detailed description of the procedures that will be followed to reach the objectives.

3.1. RESEARCH AIMS

The aims of the study were clearly stated with the intent of answering the research question within a proposed period of time.

RESEARCH AIMS
MAIN AIM:
To determine the short-term effects of simultaneous cardiovascular workout and PMD use on the DPOAE response of young adults.
SUB-AIMS:
Sub-aim 1: To determine the short term effect of isolated exposure to music on a PMD on the DPOAE response.
Sub-aim 2: To determine the short term effect of isolated cardiovascular workout on the DPOAE response.
Sub-aim 3: To determine the short term effect of simultaneous PMD use and cardiovascular workout on the DPOAE response.

3.2. HYPOTHESES

The following statements were tested in order to conclude the outcome of the research procedures in relation to the main aim of the study.

Non-directional null hypothesis (indicated by H_0) is stated as follows:

No short-term significant effects will be observed on the DPOAE response during simultaneous cardiovascular workout and PMD use of young adults.

Alternative hypothesis (indicated by H_1) is stated as follows:

Short-term significant effects will be observed on the DPOAE response during simultaneous cardiovascular workout and PMD use of young adults.

3.3. RESEARCH DESIGN

The research design is logically defined by Welman, Kruger and Mitchell (2005) as an action plan for selecting participants and obtaining information from them. The definition continues by highlighting the procedures that will be used during the research process, ultimately enabling the researcher to have answered the original question and concluded findings that were obtained.

A quantitative research approach was followed. The latter is objective in nature as it seeks accurate measurement and analysis of specific objectives (Leedy & Ormrod, 2013). This approach ensured objectivity towards the participant, as the aim was to classify features and construct statistical models in an attempt to conclude whether or not simultaneous cardiovascular workout and PMD use will exhibit short-term effects on the DPOAE response in a group of young adults. A pre-test/post-test design was used where an experiment was conducted on a group of participants. Before the first phase commenced a complete diagnostic hearing evaluation was conducted including: pure-tone audiometry, immittance testing (ipsilateral acoustic reflexes at 1000 Hz and tympanometry) and DPOAEs. The first testing condition required the group of participants to listen to an identical music sample at a comfortable intensity level for one hour. Due to ethical considerations, the output levels were not measured for each individual participant which could have resulted in differing degrees of

temporary threshold shifts among participants. Prior to exposure DPOAEs were conducted on each participant. The test battery was repeated directly after exposure (no longer than 10 minutes) to the PMD use. The second testing condition required the participants to endure a cardiovascular workout for one hour in isolation. The third and final testing condition required the participants to endure a cardiovascular workout while listening to the identical music sample at the same comfortable intensity level for the one hour duration of the workout. The DPOAEs were repeated prior to and after each testing condition.

Implicit to each research question is the view that certain variables affect other variables and vice versa (Welman et al., 2005). Consequently these variables needed to be identified and taken into account beforehand in order to prevent false-positive results to occur. Two types of variables needed to be considered including independent variables and dependent variables. The independent variables could be manipulated in order to achieve a certain outcome, whilst the dependent variable was the factor that the researcher intended on measuring (Welman et al., 2005). The dependent variable in this study was the DPOAE (2f1-f2) response amplitude that was obtained prior to – and after each condition. The independent variable was the type of activity carried out (music exposure only, cardiovascular workout only, and simultaneous exposure to music and cardiovascular workout). Participants' cardiovascular fitness was not taken into account due to various reasons. The study's main focus was to determine the short-term effects of simultaneous cardiovascular workout and PMD use of an average 18 – 25 year old. People who regularly go to gymnasiums will have fluctuating cardiovascular fitness depending on type and degree of exercise. Thus, the study merely aimed to determine possible short-term effects in spite of varying fitness levels.

The presence of possible confounding variables in the study were identified and excluded prior to the study by means of a questionnaire and a set of predetermined selection criteria. The following factors were set as exclusion aspects in the study.

- Exposure to ototoxic substances;
- Exposure to noise from sources other than leisure noise;

- Middle ear pathology that could have affected the OAE testing (middle ear pathology was determined by immittance testing);
- Family history of hearing loss;
- Post-exposure symptoms experienced by music exposure 72 hours prior to testing procedures.

3.4. ETHICAL CONSIDERATIONS

Research ethics concern the responsibility of the researchers to be honest and show respect towards all the participants who are involved and who might be affected by the study or the results that are obtained. Research is governed by a set of ethical guidelines that assist the researcher in making decisions that will not harm the participants involved in any way. Keeping ethical guidelines in consideration is vital in research. It ensured that the researcher weighed the value of advancing knowledge gains to the value of non-interference on the research participant (Leedy & Ormrod, 2013). According to Welman et al. (2005) ethical research entails that participants are informed in writing of the goals, procedures and importance of a specific study; the risks and benefits involved in the participation, plans for dissemination of the results, as well as measures taken to ensure confidentiality and anonymity. Confidentiality was obtained by using a coding system instead of the names of the participants. For this reason, ethical clearance was obtained from the Ethical Research Committee of the Department of Speech-Language Pathology and Audiology as well as the Research Ethics Committee of Humanities prior to the conduction of the study (*Appendix A*). Subsequently the researcher used the following information as they contribute to the ethical considerations of the study:

3.4.1. Voluntary participation:

Participation in this study was entirely voluntary and the participants had the right to withdraw at any point in time. All the participants were made aware of the voluntary participation in the cover letter sent to all participants (*Appendix B).*

3.4.2. Informed consent:

Informed consent emphasizes that participation in a study should be voluntarily (Leedy & Ormrod, 2013). The principle of informed consent required the investigator to provide all available information about the study so that the participants could make a rational, informed decision about their participation. If this did not happen, deception may have occurred. According to Maxwell and Satake (2006) ethical research entails that participants were informed in writing of the significance, goals, procedures, risks, discomfort as well as plans for the dissemination of the results and interpretations. Thus informed consent was obtained from all participants, by sending them a letter of consent (*See Appendix C*) as well as a cover letter prior to the questionnaire (*See Appendix C & D*).

3.4.3. Beneficence and non-maleficence

During all stages of the study the researcher acted in the best interest of the participants. All data collection procedures were investigated prior to clinical data collection to ensure that no physical harm was done to the participants (Leedy & Ormrod, 2013).

3.4.4. Deception

Deception may have occurred if proper informed consent was not obtained prior to the completion of the questionnaire. Any possible deception of the participants was avoided by sending a carefully constructed cover letter (*See Appendix B*), containing information regarding the nature, goals, aims and procedures of the study. The latter ensured that all participants were completely aware of the nature, goals, aims and procedures of the study. A debriefing was provided to each participant before the clinical testing commenced to avoid deception.

3.4.5. Fraud and plagiarism

Plagiarism, which is unethical, is the representation of someone else's ideas or words as one's own (Welman et al., 2005). This study aimed to utilize creative personal information instead of copying other researchers. Accurate references were used to ensure that all researchers were acknowledged. Fraud is the explicit effort of a researcher to deceive and misinterpret data. The researcher

interpreted the obtained data in an unbiased manner in order to obtain the most accurate and reliable research findings.

3.4.6. Dissemination of findings

All participants were made aware of the fact that the results of the study will be published as a post-graduate dissertation and that the data will be stored for a maximum of 15 years at the Department of Speech-Language Pathology and Audiology.

3.4.7. Validity and reliability

The validity of the test can be defined as the degree to which the measurement process measures the variable it claims to measure. Validity of a test also involves the sensitivity and specificity of a test as it is the extent to which an empirical measurement accurately reflects the concept it is intended to measure (Leedy & Ormrod, 2013). The sensitivity is the probability of a positive test in those who truly have decreased hearing sensitivity while specificity is the probability of a negative test in those who truly do not have decreased hearing sensitivity. Different types of validity were crucial in various situations during the conduction of this research study (Leedy & Ormrod, 2013):

- **Face validity** is the extent to which an instrument appears to measure the intended objective.
- **Content validity** can be defined as the degree to which a test appropriately represents the content domain it is intended to measure.
- **Criterion validity** is the extent to which the results correlate with other results.
- **Construct validity** is the extent to which characteristics which cannot be measured can be observed and inferred from patterns in participants' behaviour.

The validity and sensitivity of this study was ensured as far as possible in the following manner:

- The validity of the study was increased by a pilot study that was conducted prior to the data collection procedures and by means of a questionnaire (*Appendix D*). This ensured that the measurements truly measured the concept (the short-term effect of simultaneous PMD-use and cardiovascular workout on the DPOAEs of the participants) that it intended to measure.

The pilot study also ensured that the questions asked in the questionnaire were clear and concise. This increased the accuracy of the questionnaire.

- Validity of the study was increased by conducting a literature review on similar research studies investigating the effect of noise on the hearing mechanism. This provided the researcher with insight into the limitations of previous research conducted in the field.
- Results were interpreted according to predetermined normative data.

Reliability can be described as the stability or consistency of a measurement (Leedy & Ormrod, 2013). If the same individuals were measured under the same conditions, a reliable measurement procedure would produce identical measurements. Several types and measures of reliability were taken into consideration and successive measurements were conducted. This can be referred to as test-retest reliability. Therefore if the participants' DPOAEs were obtained, the DPOAE amplitude values were repeated in order for the test to be considered reliable. The following forms of reliability were considered during the process of the research study (Leedy & Ormrod, 2013):

- If simultaneous measurements were taken and two tests were conducted simultaneously, the results should correlate in order for the test to be reliable. This can be referred to as **inter-rater reliability**.
- **Split-half reliability** refers to the degree of consistency of scores from separate items on a test or questionnaire consisting of multiple items.
- **Internal consistency reliability** is the extent to which all the items yield similar results.
- **Test-retest reliability** can be defined as the extent to which the same instrument yields the same results on two different occasions of the same group of participants.

Reliability of a study influences the validity, therefore the reliability of a study is crucial. Reliability was ensured as far as possible by considering the following:

- Participants should have comprehended certain characteristics concerning the study including the motivation behind all components of the study. This was guided by the results obtained from the pilot study.

- The cover letter (*Appendix B*) provided sufficient explanations regarding the aims of the study to ensure that all participants understood the nature and aims of the study.
- A letter of consent (*Appendix C*) ensured that the participants comprehended their rights in the participation of the study and provided written consent to participate.
- Reliability of the diagnostic data was ensured by means of sufficient communication with the participants prior to the data collection procedures. The participants were required not to be exposed to high noise levels 72 hours prior to the test date as noise exposure induces pre- and post- stimulatory changes in the DPOAEs that may negatively influence the test results reliability (Vinck et al., 1999).
- A pilot study was conducted to assess the complete experimental procedure in order to ensure the reliability and feasibility of the experiment.
- Calibration of equipment was monitored as it could have had a negative and inconsistent effect on test results obtained. The audiometric equipment was calibrated in January 2012 and complied with the specifications established by SANS 0154-2000 (South African National Standards, 2008). The OAE equipment was also calibrated prior to the OAE data collection procedures on each day.

3.5. RESEARCH PARTICIPANTS

3.5.1. Participant sampling and selection

The participants of this study were selected by means of simple random sampling. This specific type of sampling was convenience sampling depending on the availability of participants (Welman et al., 2005).

The selection of participants depended on various factors in order for them to comply with the prerequisite selection criteria. Each participant completed a questionnaire *(Appendix D)* in order to rule out certain confounding factors that could have influenced the reliability and validity of the study (see page 15).

The study population consisted of young adults between the ages of 18 to 25 years of age. Their ages ranged between 18 and 25 years with a mean age of 23 years [standard deviation (SD) = 0.95]. This specific age group was chosen as Hodgetts, Rieger and Szarko (2007) indicated that a large number of young adults were exposed to the hazards of leisure noise. This population is known to have normal hearing and due to the increasing popularity of PMDs over the past decade, OHC functioning, as evident in OAE measurements, could be compromised.

Participants within this age group completed the questionnaire *(Appendix D)* and were ruled out if any contradicting factors were present. The following inclusion criteria were used:

- The participants had to have normal hearing (pure tone average (PTA) ≤ 20 dB HL) (Vinck, 2011). The study aimed to determine the effect of simultaneous cardiovascular workout and PMD use on the DPOAEs of the participants. Consequently the study aimed to determine whether the simultaneous PMD use and cardiovascular workout had an effect on the DPOAEs of the participant before a hearing loss was evident on the audiogram or experienced. OAEs are present in 98% of people with normal hearing (Avan, Elbez & Bonfils, 1997; Barros et al., 2007; Seixas et al., 2004). The motivation for the above mentioned selection criteria are that persons with present DPOAEs will have normal hearing.
- The participants had to have normal middle ear functioning. According to Martin and Clark (2006) normal middle ear functioning can be indicated by the following immittance values:
    - Pressure: -50 to 50 daPa
    - Compliance: 0.3 to 1.75 ml
    - Ear canal volume: 1 to 1.4 ml
    - Acoustic reflex at 1000 Hz, present at 70 – 90 dB above the accepted normal pure tone threshold.

  According to Vinck et al. (1998) normal OAEs are observed if the cochlea is functioning optimally and if the external and middle ear have a normal status. OAEs will be absent in the presence of middle ear pathology (Kemp, 2002).
- The participants had to have no exposure to other ototoxic substances as certain substances could also negatively affect the normal functioning of the cochlea. Ototoxic substances are known to cause irreversible hearing loss (Fausti, Henry, Schaffer, Olson, Frey & McDonald,

1992; Hutchinson et al., 2010; Phillips et al., 2010). By assuring that the participant was not exposed to other ototoxic substances the deduction could be made that the simultaneous PMD use and cardiovascular workout were the cause of changes to OAE measurements.

- The participants had to have no family history of hereditary hearing loss (Vinck et al., 1998), as various hereditary causes of hearing loss could also have affected the functioning of the cochlea negatively. By assuring that the participants had no family history of hereditary hearing loss the deduction could be made that simultaneous PMD use and cardiovascular workout may have influenced the OAE measurements.
- Participants were briefed on the procedures of the study and informed consent (*Appendix C*) was obtained before testing commenced.

Participants who complied to the above mentioned selection criteria participated in the study. Each participant underwent the two phased selection procedure (questionnaire and diagnostic hearing testing). In order to ensure that a representative sample was used, both males and females were included in the study. Both ears of each participant were tested, but the results were not necessarily interpreted as an entity. The number of participants also contributed to the reliability of the results in terms of representativeness of the population. Therefore the researcher aimed to test at least 12 participants.

3.5.2. Material / apparatus used for participant selection

Various material and apparatus were used during the participant selection procedure as it was important to identify those participants who complied with the specific criteria as set out above. The material and apparatus that were used during participant selection are listed below:

Questionnaire (*Appendix D*). A questionnaire was used to determine whether or not the participants adhered to the selection criteria specified above. A questionnaire was used in the study as some of the advantages of using questionnaires included less financial expenses as well as the ability to offer enhanced confidentiality as there was no face to face interaction between the participants and the researcher (Welman et al., 2005). The questionnaire was used to gather information regarding

previous exposure to recreational or industrial noise. The questionnaire needed to be completed by each participant during the first phase of the study. The following sections were included in the questionnaire *(Appendix D)* (Leedy & Ormrod, 2013):

- Section A - Personal information;
- Section B - Information regarding hearing;
- Section C - Information regarding medical history.

Closed-ended questions dominated the questionnaire. Thus, the possible answers to the questions were provided to the respondent and he/she had to select the option that best described his/her answer. Open-ended questions, "other/please explain" were included to accommodate any response not listed where necessary. The closed-ended questions were relevant in the study as factual information was required. Closed-ended questions assisted the researcher in the classification of the respondents according to the specific selection criteria (Welman et al., 2005).

A **cover letter** *(Appendix C)* accompanied the e-mailed questionnaire. The cover letter was provided to ensure that the instructions were clear and precise in order for the questionnaire to be understandable and accurately completed. The following content was included in the questionnaire:

- An introduction included the rationale for the study and the institution (University of Pretoria, Department of Speech-Language Pathology and Audiology) and information regarding the researcher;
- A description of the main objectives of the study;
- An explanation of the relevance of the study;
- General instructions;
- An indication that participation in the study was voluntary (informed consent);
- The assurance that the information provided would be kept confidential;
- A contact number was provided in case of queries;
- Provision of a deadline date for completion of the questionnaire and;
- Informing participants that collected data will be archived for 15 years at the Department of Speech-Language Pathology and Audiology;
- An expression of gratitude towards the participants for their participation in study.

A Heine Mini 3000 (Germany) otoscope. An otoscopic examination was conducted to determine whether or not the participant had an unobstructed external auditory meatus as well as to ensure that no foreign objects were present within the ear canal.

A GSI 61 audiometer was used to evaluate the hearing sensitivity of the participants. The audiometer was utilized to determine accurate hearing thresholds as well as whether or not those thresholds were within the normal limits for adults (0 to 15 dB) across all test frequencies (125 Hz to 8000 Hz). The GSI 61 Audiometer was calibrated in January 2012 and complied with the specifications established by SANS 0154-2000 (South African National Standards, 2008).

A GSI Tympstar tympanometer was used to determine whether or not the participants had normal middle ear functioning. The GSI Tympstar was calibrated in January 2012 and complied with the specifications established by SANS 0154-2000 (South African National Standards, 2008) before commencement of data collection.

A soundproof booth that complied with the specifications established by SANS 0182-2000 (South African National Standards, 2000) was used during the hearing evaluation of all participants.

Evaluation forms. *(Appendix E)* A standard audiogram from the Department of Speech-Language Pathology and Audiology, University of Pretoria was used to record the audiometric results (pure tone-, and immittance test results).

Immittance probe tips and Milton were used to implement infection control throughout the testing procedures.

3.5.3. Procedure for participant selection

The participants were screened and approved for participation in the study by means of a questionnaire (*Appendix D*) as well as a complete audiometric test battery including immittance testing. The following phases of elimination and selection processes were used:

PHASE 1 OF PARTICIPANT SELECTION:

The questionnaire (*Appendix D*) was distributed to possible participants during phase one. If contraindications for participant selection were found on a returned questionnaire the participant was excluded from the study. Thus, if the participant did not adhere to the predetermined selection criteria according to the questionnaire, the participant was not selected to participate in the study. The absence of contraindications to the selection criteria allowed the participant to progress to the second phase of the participant selection process should the participant have given consent to do so *(Appendix B)*.

PHASE 2 OF PARTICIPANT SELECTION:

A complete audiometric test battery was conducted on each participant to rule out additional structural or functional abnormalities of the auditory mechanism that could have interfered with the results of the study. Participants were informed that they were not allowed to expose themselves to excessive noise levels (> 85 dB) up to 72 hours before the tests were conducted (Vinck, 2011). Excessive noise levels could have induced pre- and post-stimulatory changes in the OHCs of the cochlea and could consequently have affected the test results (Vinck, 2011). The obtained results were analyzed according to the predetermined selection criteria and those participants who adhered to the criteria were selected to participate in the study. The following audiometric tests were included in the diagnostic test battery used for participant selection:

3.5.3.1. Otoscopic examination

The ear canal had to be un-impacted with a clear view of the tympanic membrane and other structural landmarks, as an impacted ear could possibly have altered the results obtained during the recording of DPOAE measurements. If any abnormalities were observed, the researcher had to attend to it if

within the scope of practice of a registered audiologist. Otherwise, appropriate referrals were made, whilst excluding the subject from the study.

3.5.3.2. Immittance testing

Immittance testing including tympanometry and ipsilateral acoustic reflexes at 1000 Hz were conducted in order to assess the middle ear functioning. The middle ear functioning was assessed according to three parameters including middle ear pressure, - compliance and ear canal volume. Normal middle ear functioning was a prerequisite for the conduction of DPOAEs. Middle ear pathology of any kind could have resulted in the absence of DPOAEs without physical damage to the OHCs in the cochlea (Kemp, 2002; Vinck et al., 1998).

Structured and simplified instructions were provided after which the probe was inserted into the participant's ear canal. The start button was pressed after which pressurization of the middle ear occurred. A 226 Hz probe tone frequency was used. Only participants with a Type A tympanogram (pressure: -50 to 50 daPa, compliance: 0.3 to 1.75 ml, ear canal volume: 1 to 1.4 ml) (Martin & Clark, 2006) were included in the study.

The measurement of acoustic reflex thresholds (ARTs) was performed as a cross-check method for determining the presence of middle ear pathology (Campbell, 1998). An ipsilateral acoustic reflex was elicited and measured at 1000 Hz. The reflex-activating signal (RAS) was presented into the ear by an insert probe to the test ear. The participants were instructed not to move, speak or swallow excessively as it could have affected the acoustic reflex measurements. According to Hall (1997) the average normal ART level is measured by setting the RAS at 1000 Hz at 85 dBHL. During the measurement of the ART the RAS was presented to the test ear for one to two seconds. An acoustic reflex was specified by the decrease in compliance of at least 0.02 ml. When the required change in compliance was not observed at 85 dBHL, the intensity of the RAS was increased in increments of 10 dB until a significant decrease in compliance was observed. In the case of adequate change in the compliance, the RAS was decreased in steps of 5 dB. The lowest intensity, at which a compliance change of 0.02 ml or more was observed, was accepted as the ART for the specific frequency of the

test ear (Bezuidenhoudt & van Heerden, 2009). Participants with reflexes obtained at 70 to 90 dB above a normal pure tone threshold were included in the study if informed consent was given (Martin & Clark, 2006).

3.5.3.3. Pure tone Audiometry

Pure tone air conduction

Adults were considered to have clinically normal hearing if their pure tone threshold averages were obtained between 0 and 20 dBHL (Vinck, 2011). Structured and simplified instructions were provided after which the red earphone was placed on the right ear and the blue earphone on the left ear. The better ear, as judged subjectively by the participant, was tested first to prevent cross hearing from the non-test ear. The initial tone was presented at 1000 Hz at 30 dBHL. A pure tone air conduction threshold was determined at each frequency (125 Hz to 8000 Hz, including 3000 Hz and 6000 Hz) using the ascending/descending method. The hearing threshold for each frequency was documented on the audiogram. The PTA should have been recorded between 0 to 20 dBHL for both ears. In the case where a hearing loss was detected appropriate audiological management and referrals were considered and the participant was excluded from the study.

3.5.4. Description of participants

Twelve subjects (7 female, 5 male) were selected through convenience sampling and included in the study. Their ages ranged between 18 and 25 years with a mean age of 23 years [standard deviation (SD) = 0.95]. The mean female age was 22.71 years (SD = 0.95) and the mean male age was calculated at 23.4 years (SD = 0.89). (See next page for TABLE 3.1.)

TABLE 3.1: Description of participants

Subject	Age	Gender	Otoscopic	Tympanogram type	Ipsilateral acoustic reflex (1000Hz)	Pure tone averages (PTA)	DPOAEs
1	24	Female	Normal bilaterally	A	R= 100 dB L= 100 dB	R= 5 dB L= 1,7 dB	Present
2	22	Female	Normal bilaterally	A	R= 100 dB L= 100 dB	R= 5 dB L= 6,7 dB	Present
3	24	Female	Normal bilaterally	A	R= 85 dB L= 85 dB	R= 0 dB L= 3,3 dB	Present
4	22	Female	Normal bilaterally	A	R= 80 dB L= 85 dB	R= 0 dB L= 0 dB	Present
5	22	Female	Normal bilaterally	A	R= 100 dB L= 100 dB	R= 10 dB L= 1,7 dB	Present
6	23	Female	Normal bilaterally	A	R= 90 dB L= 90 dB	R= 0 dB L= 1,7 dB	Present
7	22	Female	Normal bilaterally	A	R= 85 dB L= 80 dB	R= 0 dB L= 3,3 dB	Present
8	24	Male	Normal bilaterally	A	R= 85 dB L= 90 dB	R= 10 dB L= 16,7 dB	Present
9	24	Male	Normal bilaterally	A	R= 80 dB L= 85 dB	R= 3,3 dB L= 6,7 dB	Present
10	24	Male	Normal bilaterally	A	R= 85 dB L= 100 dB	R= 0 dB L= 5 dB	Present
11	22	Male	Normal bilaterally	A	R= 80 dB L= 80 dB	R= 5 dB L= 1,7 dB	Present
12	23	Male	Normal bilaterally	A	R= 75 dB L= 75 dB	R= 3,3 dB L= 1,7 dB	Present
Mean	23	Female 58.3 % Male 41.7 %					
Range	22-24	-					

CRITERIA FOR PRESENT DPOAEs:

- SNR > 6 dB
- SNR < 6 dB = absent

3.6. DATA COLLECTION

3.6.1. Material and apparatus for data collection

In order to obtain the necessary data to provide the researcher with accurate information to deduct appropriate conclusions, specific materials and apparatus were used during the course of the study.

3.6.1.1. Material

The materials that were used during data collection included the material that was used for participant selection as well as additional materials. The following materials were used during the process of data collection:

- Probe tips and Milton disinfectant were used for infection control.

3.6.1.2. Apparatus

The apparatus that was used during data collection included the apparatus used for participant selection as well as additional apparatus. The following apparatus was used during the process of data collection:

- 5 Apple iPod Shuffles.
- A music sample consisting of pop – and rock songs.
- Cateye Ergociser EC-3200 cycling/spinning equipment.
- Otodynamics DP Echoport ILO 288-II.
- A HP PSC 1410 printer was used to obtain hard copies of the collected data.

3.6.2. Procedure for data collection

Complete, organized procedures consisting of several steps of data collection was conducted throughout the research process.

3.6.2.1. Pilot study

A pilot study can be defined as an exploratory study that is conducted prior to the onset of data collection. It entailed administering the data collection procedure to a limited number of participants from the same population as for which the eventual testing was intended (Welman et al., 2005). The purpose of a pilot study could be summarized as the following:

- To detect possible errors in the measurement procedures including ambiguous instructions and time constraints;
- To identify unclear or ambiguously formulated information within the questionnaire, cover letter for the questionnaire as well as the informed consent letter;
- To observe the participants' reactions and behaviours during the data collection process in order to identify whether negative reactions were present.
- To determine the duration of the testing procedures and consequently for planning purposes.

The pilot study required three participants to complete the questionnaire *(Appendix D)* and read the letter of informed consent *(Appendix C)*. Consequently it was expected of the participants to provide feedback on the positive and negative aspects of each of the above mentioned procedures. The latter assisted and guided the researcher to correct or refine questions that was utilized during this process. Secondly an audiometric test battery consisting of an otoscopic examination, immittance testing, pure tone testing as well as DPOAEs was conducted after which it was expected of the participant to listen to a comfortable maximum intensity of music through the PMD for one hour. The OAEs were repeated directly after the listening period. The process was repeated on two separate allocated days. On the second day the participants only exercised for one hour after which the OAEs were repeated prior- and after the exercise period. On the third day the participants listened to the PMD at a comfortable intensity level whilst simultaneously engaging in cardiovascular workout for one hour. The pre – and post test procedures remained unchanged. Important feedback regarding the test procedures was provided by each participant in order to rule out later complications that may have interfered with the obtained test results. The exact duration of the entire test procedure was calculated as one hour and ten minutes on each day of testing. The results from the pilot study

indicated satisfactory outcomes from all of the participants. These participants were also included as subjects in the final study and data collection procedures.

3.6.2.2. Data collection procedure

The 12 participants who complied with the predetermined selection criteria and gave informed consent were included in the process of data collection. Several phases were included in the process of data collection. In order to control the outcomes of the study, the research needed to be conducted on each participant in the exact same fashion. The participants had to undertake a pledge ensuring that they would not expose themselves to any noise 72 hours before the tests commenced. According to Vinck et al. (1999) the participants should not have been exposed to any loud sounds 72 hours before diagnostic tests as noise exposure induces pre- and post- stimulatory changes in the OHC functioning that may have negatively influenced the test results. The following parameters were used and supported by research (Bhagat & Davis, 2008):

Identical music sample:

A pop-rock music sample was selected and songs recorded directly after the other in order to eliminate the silent periods between the songs. This was done in order to ensure that the music was presented at a uniform intensity level to all participants (Bhagat & Davis, 2008).

Identical PMD:

The same PMD (iPod Shuffle with standard iPod insert earphones) was used on all participants in order to rule out the possible effects of device differences.

Listening intensity:

The listening intensity level of the PMD was adjusted individually by each participant to an intensity which was comfortable to each individual listener.

Listening time:

Each participant was exposed to the music for one hour (Bhagat & Davis, 2010).

Cardiovascular workout:

Each participant completed a one hour cardiovascular workout on a Cateye ergociser EC-3200. Participants exercised according to their individual subjective fitness levels.

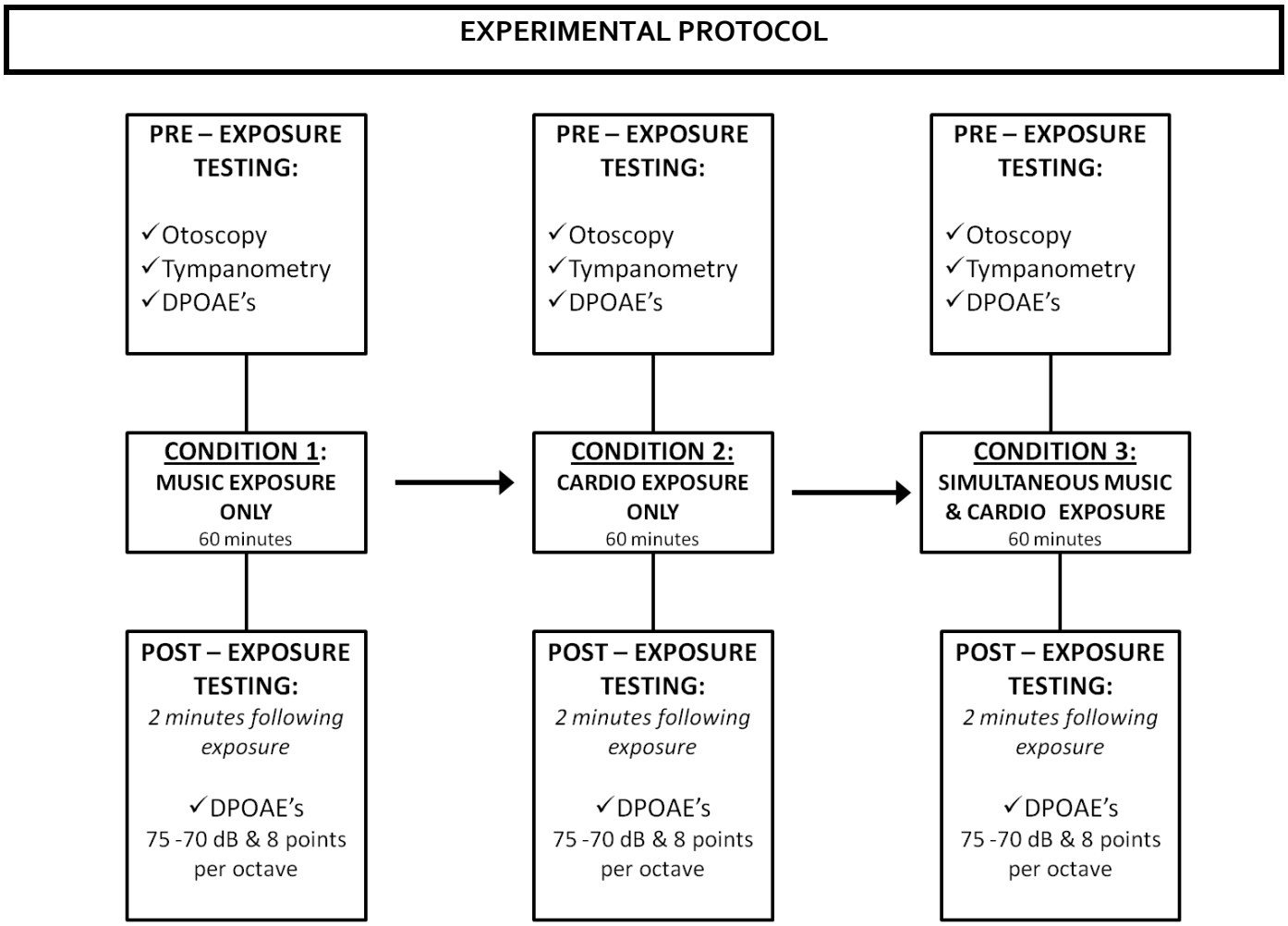

Figure 3.1. Experimental Protocol

In this study a pre-test post-test approach was used and participants participated in three testing conditions with altered variables including (i) one hour PMD use in a resting state, (ii) one hour cardiovascular workout on a Cateye ergociser EC-3200 with inserted ear plugs to rule out potential external noise and, (iii) one hour simultaneous PMD use and cardiovascular workout on a Cateye ergociser EC-3200. The testing conditions were completed on three separate days, each following a 72 hour non-exposure time period. Each subject listened to identical pop-rock music samples on identical iPod Shuffle PMDs during the first and final testing conditions. Due to ethical considerations subjects were instructed to adjust the volume to the loudest comfortable volume for the full hour of the first and final testing conditions (Table 3.2. Description of duration of music sample).

TABLE 3.2. Description of duration of music sample

	Track	Duration
1	Track 1	3:20 min
2	Track 2	3:01 min
3	Track 3	3:40 min
4	Track 4	6:17 min
5	Track 5	3:52 min
6	Track 6	3:58 min
7	Track 7	3:24 min
8	Track 8	3:21 min
9	Track 9	3:42 min
10	Track 10	3:22 min
11	Track 11	4:26 min
12	Track 12	3:55 min
13	Track 13	3:38 min
14	Track 14	3:01min
15	Track 15	4:07 min
16	Track 16	3:16 min
17	Track 17	3:30 min
TOTAL DURATION		**63:50 min**

Audiological testing was conducted in a quiet office. The pre-exposure session included an otoscopic examination, tympanometry and DPOAE testing (see Figure 3.1). The exposure phase then commenced directly followed by DPOAE testing.

Procedures pre-exposure testing

Outer – and middle ear examination

The external ear canal was carefully examined for cerumen or foreign objects and the tympanic membrane was inspected for scars, perforations and tympanosclerosis. The participants' middle ear functioning was evaluated through immittance measurements by means of the GSI tympstar tympanometer. A baseline tympanogram with a probe tone of 220 Hz and ipsilateral reflexes at 1000 Hz was performed prior to each of three testing conditions. Tympanometry testing and response parameters were calculated and interpreted as follows: tympanometric peak pressure (TPP) expressed in daPa, compliance and the estimated ear canal volume.

Procedures pre- and post-exposure testing measured by DPOAEs

DPOAEs were performed prior to and following each exposure (exposure = i) PMD use only, ii) cardiovascular workout only, iii) simultaneous PMD use and cardiovascular workout). The noise levels in the environment were minimized by closing the windows and doors and isolating the surrounding hallway and rooms. The testing equipment monitored the noise levels internally throughout the testing procedures.

Two simultaneous pure tones at the primary frequencies of f_1 and f_2 were generated by the ILO92 Otodynamics Analyser. The two stimuli were varied acoustically and delivered to a probe that was sealed with a foam tip into the external ear canal. The adequate positioning of the measurement probe in the external ear canal was monitored by using the 250 Hz tone 'checkfit' procedure prior to each session. Following confirmation that the probe was fitted in a suitable volume (2 cc), the test ear was presented with a click stimulus and the real time in-the-ear sound spectrum was shown on the screen (Vinck *et al.*, 1996).

In order to rule out artefacts, the probe was manipulated to obtain a spectrum as uniform as possible with a realistic ear canal volume for each participant. The stimulus variables that were selected to elicit the DPOAEs can be compared to earlier studies of DPAOEs in normal hearing subjects. The DP-grams were recorded using eight points/octave delivered from 75 to 70 dB SPL. The test frequencies

that were used were automatically selected by the Otodynamics DP Echoport ILO 288-II, based upon the resolution (point/octave) that was pre-selected by the researcher. The DP-gram collection process consisted of a cycling procedure through the preset stimulus frequency sequence, measuring the $2f_1$-f_2 (75-70 dBSPL) DPOAE and constructing a plot of DPOAE levels as a function of frequency. Each point of the DP-gram was recorded using a summation-averaging algorithm. Data was collected in short sections, in each of which the noise level was assessed. The clean data was sub-averaged before being added to the main pool average. Each particular frequency pair was examined, the new data was added to the pooled data for that frequency pair, thus continuously increasing the SNR. Target sound levels and noise contamination areas were calculated and displayed on the screen (Vinck et al., 1996).

3.6.3. Data processing and analysis

The observed differences in the mean DPOAE amplitude response levels (dB SPL) of the $2f_1$ - f_2 levels between the pre – and post measurements of each session were statistically analysed by means of a repeated measures ANOVA using a commercially available statistical software package (IBM SPSS version 21). Tukey HSD post-hoc analysis was carried out to reveal significant differences among the different experimental sessions. Normal distributivity of the data, a requirement for ANOVA, was evaluated by means of the Kolgomorov-Smirnov test. A level of $p< 0.05$ was used as the level of significance for this study. Data analysis was done by comparing the post-exposure results to the pre-exposure results of the three testing conditions through calculating the difference between post - exposure and pre-exposure results. The difference between post-exposure and pre-exposure response levels of PMD use and cardiovascular workout in isolation was calculated. Secondly, the difference between post-exposure and pre-exposure response levels of PMD use in isolation and PMD use in combination with cardiovascular workout was calculated and finally the difference between post-exposure and pre-exposure response levels of combined cardiovascular workout and PMD use and cardiovascular workout in isolation was calculated.

CHAPTER 4

4. RESULTS

Twelve subjects (7 female, 5 male) were included in the study to determine the differential impact and potential short-term effects on OHC function in the presence of simultaneous cardiovascular workout and listening to music on a PMD as measured by DPOAEs. The subjects had to participate in three testing conditions: (i) one hour exposure to PMD use in isolation, (ii) one hour cardiovascular workout in isolation, and (iii) one hour simultaneous exposure to PMD use and cardiovascular workout. DPOAEs were measured before and after each testing condition, according to the experimental protocol (Figure 1).

4.1. Sub-aim 1:

To determine the short term effect of isolated exposure to music on a PMD on the DPOAE response.

Table 4.1. Condition 1: Pre-exposure, post-exposure, and averaged differences in DPOAE response amplitude (dB SPL) across the different frequencies.

f2 frequency	[PRE] mean level (dB SPL)[SD]	[POST] mean level (dB SPL) [SD]	Post-Pre (dB SPL)
A. CONDITION 1 - MUSIC EXPOSURE ONLY CONDITION			
1 kHz	10.42 [5.7]	10.23 [6.2]	-0.19
2 kHz	8.64 [9.0]	8.26 [6.8]	-0.38
3 kHz	9.56 [4.9]	8.02 [7.2]	-1.54
4 kHz	15.46 [4.8]	13.3 [7.5]	-2.16
6 kHz	13.47 [1.3]	10.57 [9.0]	-2.72
8 kHz	3.11 [1.5]	0.72 [9.1]	-2.39

During the recording of the DPOAE response amplitudes of condition 1, each frequency was recorded separately ranging from 1 kHz up to 8 kHz. During the recording of condition 1 where the participants

were exposed to music by PMD use in isolation the pre-exposure DPOAE response amplitudes' mean levels ranged from a minimum of 3.11 dB SPL [SD = 1.5] at 8 kHz up to a maximum DPOAE response amplitude of 15.46 dB SPL [SD = 4.8] at 4 kHz. Following exposure to PMD use for one hour the DPOAE response amplitudes' mean levels ranged from a minimum of 0.72 dB SPL [SD = 9.1] at 8 kHz up to a maximum of 13.3 dB SPL [SD = 7.5] at 4 kHz. The difference between the post-exposure DPOAE response amplitudes and pre-exposure response amplitudes ranged from a minimum difference of -0.19 dB SPL at 1 kHz up to a maximum difference of -2.39 dB SPL at 8 kHz.

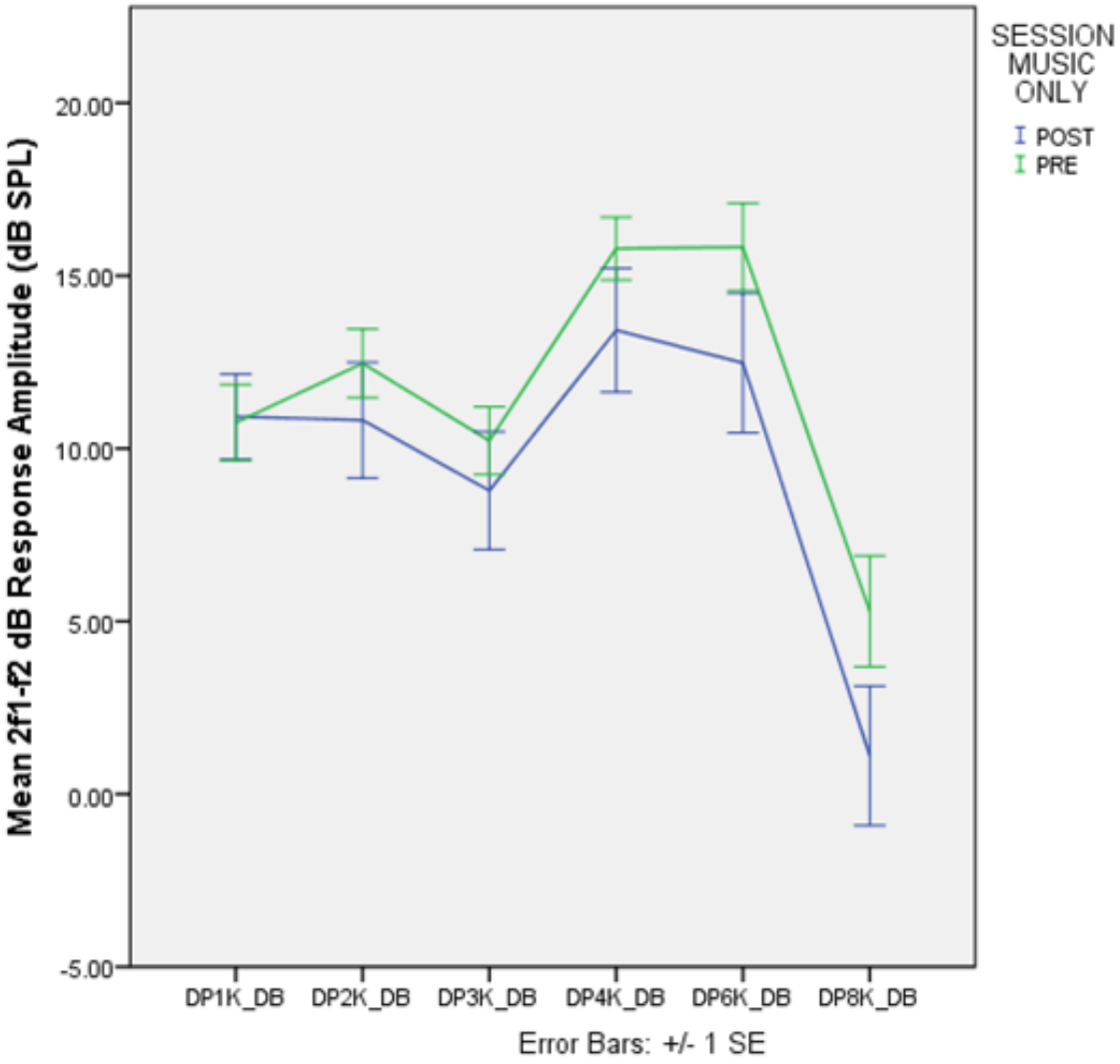

Figure 4.1. Mean $2f_1 - f_2$ DPOAE response levels (dB SPL) comparing the pre-music exposure and post-music exposure condition across test frequencies. Error bars indicate +/- 1 standard error around the mean (SE).

A decrease of the DPOAE response level was observed for all half octave frequency bands between 1 kHz and 8 kHz (Table 4.1). Repeated measures one-way ANOVA was carried out to compare the pre-exposure and post-exposure $2f_1 - f_2$ DPOAE response measurements. Although there was a clear trend in decrease of the DPOAE response amplitude over the frequency range 2 to 8 kHz in the study population, no statistically significant effect ($p > .05$) was obtained. Thus, no significant effect of listening to the one hour music sample could be demonstrated.

4.2. Sub-aim 2:

To determine the short term effect of isolated cardiovascular workout on the DPOAE response.

Table 4.2. Condition 2: Pre-exposure, post-exposure, and averaged differences in DPOAE response amplitude (dB SPL) across the different frequencies.

f2 frequency	[PRE] mean level (dB SPL)[SD]	[POST] mean level (dB SPL) [SD]	Post-Pre (dB SPL)
B. CONDITION 2 – CARDIOVASCULAR WORKOUT ONLY CONDITION			
1 kHz	11.75 [6.0]	10.99 [7.0]	-0.76
2 kHz	10.79 [9.4]	11.44 [7.9]	0.65
3 kHz	8.8 [8.5]	8.83 [7.2]	0.03
4 kHz	13.47 [8.7]	14.52 [7.2]	1.05
6 kHz	12.33 [11.2]	14.54 [6.7]	2.21
8 kHz	2.42 [9.4]	3.14 [7.6]	0.72

During the recording of the DPOAE response amplitudes of condition 2, each frequency was recorded separately ranging from 1 kHz up to 8 kHz. During the recording of condition 2 where the participants performed cardiovascular workout in isolation the pre-exposure DPOAE response amplitudes' mean levels ranged from a minimum of 2.42 dB SPL [SD = 9.4] at 8 kHz up to a maximum DPOAE response amplitude of 13.47 dB SPL [SD = 8.7] at 4 kHz. Following cardiovascular workout for one hour the DPOAE response amplitudes' mean levels ranged from a minimum of 3.14 dB SPL [SD = 7.6] at 8 kHz up to a maximum of 14.52 dB SPL [SD = 7.2] at 4 kHz. The difference between the post-exposure DPOAE response amplitudes and pre-exposure response amplitudes ranged from a minimum difference of -0.76 dB SPL at 1 kHz up to a maximum difference of 2.21 dB SPL at 6 kHz.

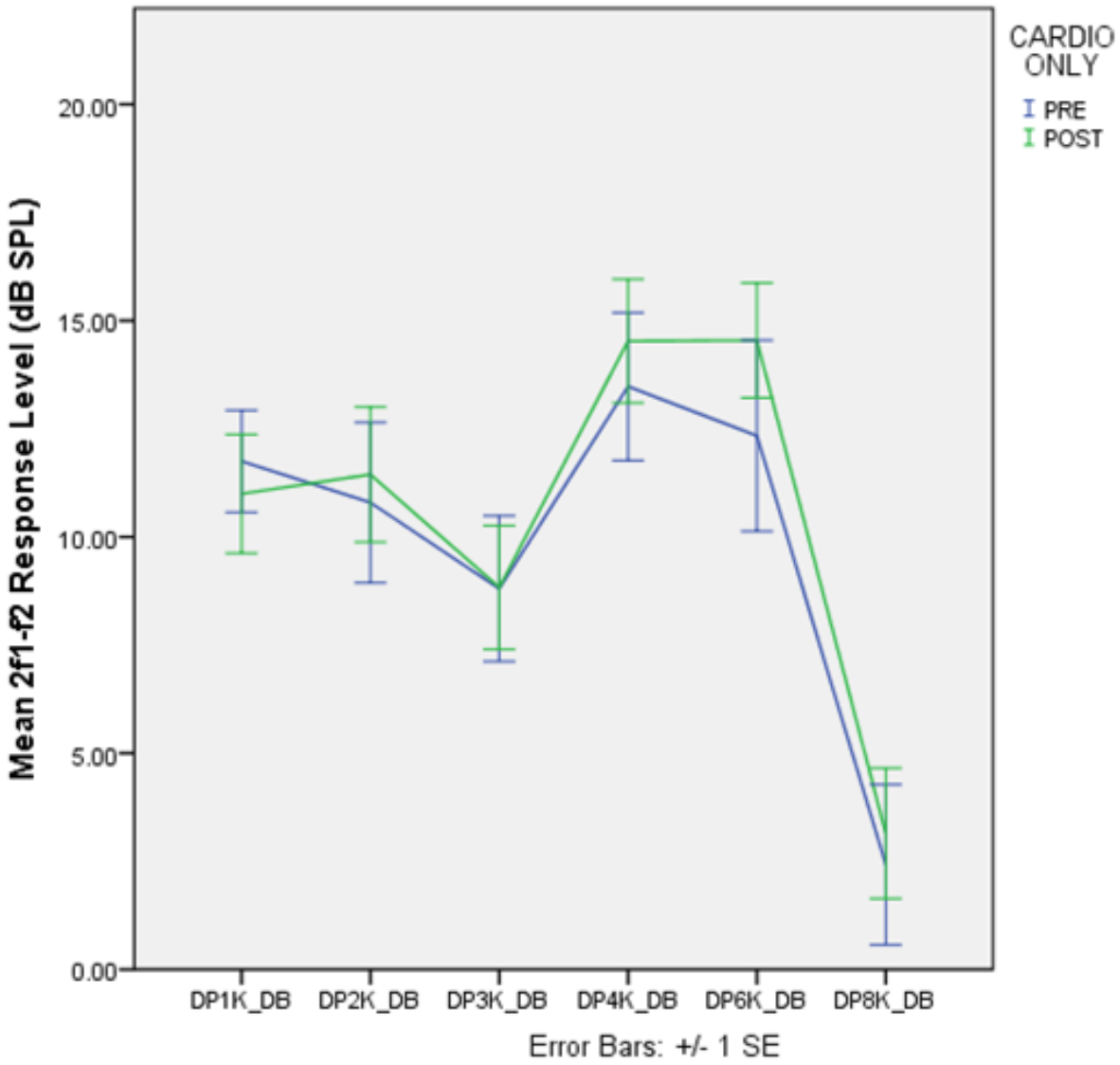

Figure 4.2. Mean $2f_1 - f_2$ DPOAE response levels (dB SPL) comparing the pre-cardio workout and post-cardio workout condition across test frequencies. Error bars indicate +/- 1 standard error around the mean (SE).

The twelve participants performed a one hour cardiovascular workout in isolation on a Cateye ergociser EC-3200 with inserted ear plugs (attenuation level of ± 28 dB) to rule out potential possible external noise. Within the testing area, no external noise emitting devices were present. Thus it can be accepted that in the absence of external noise and presence of inserted ear plugs, any minor external noise was cancelled effectively. Results obtained from both sets of DPOAE amplitudes across frequencies before and after the one hour cardiovascular workout indicated a minor decrease of 0.76 dB SPL in response amplitude, except for 1 kHz. An increase of the DPOAE response level was

observed for all half octave frequency bands between 2 kHz and 8 kHz, with a maximum of 2.21 dB SPL at 6 kHz (Table 4.2).

Repeated measures one-way ANOVA was carried out to compare the $2f_1 - f_2$ response measurements between the pre-workout and post-workout session. Although an increase in the DPOAE response amplitude over the frequency range 2 to 8 kHz in the study population was obtained, no statistically significant effect ($p > .05$) was obtained. Thus, no significant effect of a one hour cardiovascular workout on the DPOAE response amplitude could be demonstrated.

4.3. Sub-aim 3:

To determine the short term effect of simultaneous PMD use and cardiovascular workout on the DPOAE response.

Table 4.3. Condition 3: Pre-exposure, post-exposure, and averaged differences in DPOAE response amplitude (dB SPL) across the different frequencies.

f2 frequency	[PRE] mean level (dB SPL)[SD]	[POST] mean level (dB SPL) [SD]	Post-Pre (dB SPL)
C. CONDITION 3 – COMBINED MUSIC AND WORKOUT EXPOSURE CONDITION			
1 kHz	10.42 [5.7]	10.23 [6.2]	-0.19
2 kHz	8.64 [9.0]	8.26 [6.8]	-0.38
3 kHz	9.56 [4.9]	8.02 [7.2]	-1.54
4 kHz	15.46 [4.8]	13.3 [7.5]	-2.16
6 kHz	13.47 [1.3]	10.57 [9.0]	-2.72
8 kHz	3.11 [1.5]	0.72 [9.1]	-2.39

During the recording of the DPOAE response amplitudes of condition 1, each frequency was recorded separately, ranging from 1 kHz up to 8 kHz. During the recording of condition 3 where the participants were exposed to simultaneous PMD use and cardiovascular workout the pre-exposure DPOAE response amplitudes' mean levels ranged from a minimum of 3.11 dB SPL [SD = 1.5] at 8 kHz up to a maximum DPOAE response amplitude of 15.46 dB SPL [SD = 4.8] at 4 kHz. Following exposure to simultaneous cardiovascular workout and PMD use for one hour the DPOAE response amplitudes' mean levels ranged from a minimum of 0.72 dB SPL [SD = 9.1] at 8 kHz up to a maximum of 13.3 dB SPL [SD = 7.5] at 4 kHz. The difference between the post-exposure DPOAE response amplitudes and pre-exposure response amplitudes ranged from a minimum difference of -0.19 dB SPL at 1 kHz up to a maximum difference of -2.72 dB SPL at 6 kHz.

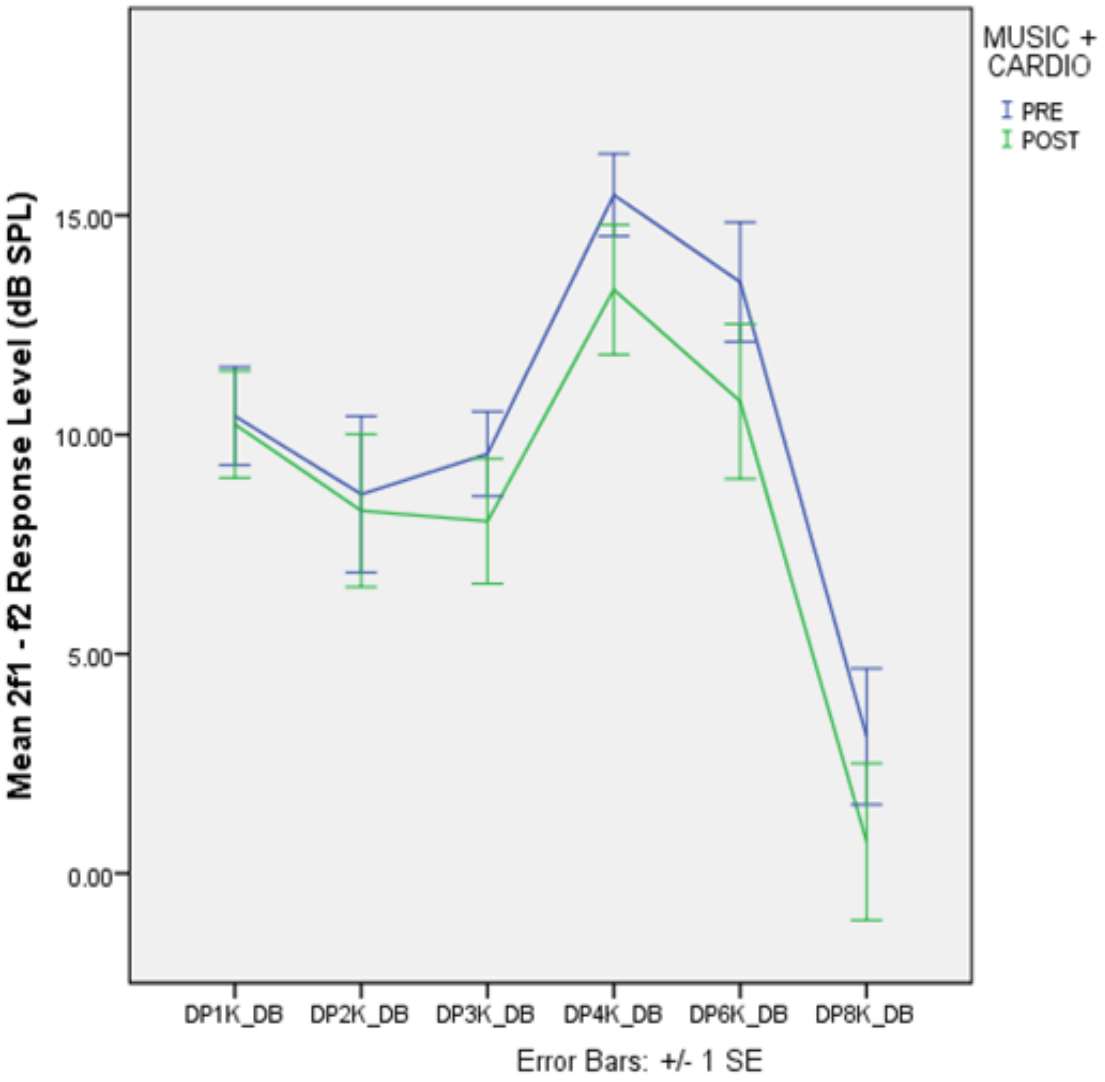

Figure 4.3. Mean $2f_1 - f_2$ DPOAE response levels (dB SPL) between pre-exposure and post-exposure of combined cardiovascular workout and PMD use across test frequencies. Error bars indicate +/- 1 standard error around the mean (SE).

In the final condition, the twelve participants were exposed to one hour simultaneous PMD use and cardiovascular workout. As in condition 1, the participants were exposed via an identical Apple iPod Shuffle PMD to a one hour identical music sample that consisted of a compilation of seventeen music samples. The music compilation's duration was exactly 1 hour and 42 seconds. Participants were instructed in exactly the same manner as in the first condition to adjust the volume to the loudest comfortable volume for the full hour.

The participants were instructed to do one hour cardiovascular workout on a Cateye ergociser EC-3200. Results obtained from both sets of DPOAE amplitudes across frequencies before and after the one hour combined cardiovascular workout and music exposure indicated a clear trend of decrease in response amplitude was observed for all frequencies. This decrease in DPOAE response level was observed for all half octave frequency bands with a maximum of 2.72 dB SPL at 6 kHz (Table 4.3).

Repeated measures one-way ANOVA was carried out to compare the $2f_1 - f_2$ response measurements between the pre-combined workout and music and post-combined workout and music session. Although a trend in decrease in the DPOAE response amplitudes over the high frequency range in the study population was obtained, no statistically significant effect ($p > .05$) was observed. Thus, no significant effect of the combined one hour cardiovascular workout on the DPOAE response amplitude could be demonstrated. In addition to this a two way repro (pre versus post) a session (music only, cardio only, and music and cardio) interaction analysis was carried out. Figure 4.4 shows the graphic output of this response.

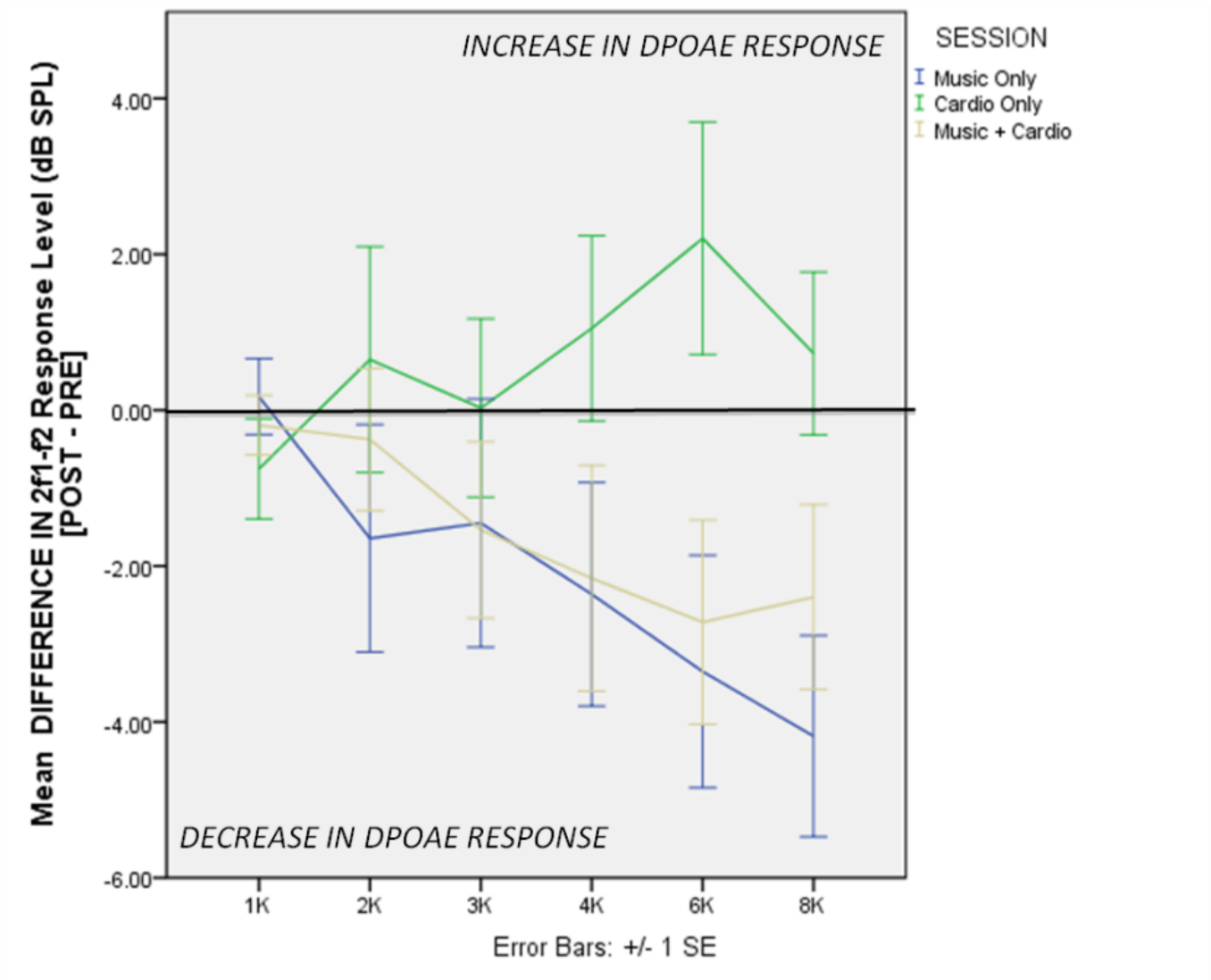

Figure 4.4. Mean $2f_1 - f_2$ DPOAE difference (POST-PRE) response levels (dB SPL) comparing the three different experimental conditions (music only, workout only, combined music and workout) across test frequencies. Error bars indicate +/- 1 standard error around the mean (SE).

Figure 4.4 illustrates the f DPOAE amplitude difference across frequencies before and after over the three experimental sessions (music only, cardiovascular workout only and the combined exposure to music and workout). For the higher frequencies, 4 kHz and higher, a clear different trend in profile between the different testing conditions is shown.

The multivariate ANOVA analysis, with Tukey HSD post-hoc testing, showed highly significant differences for the DPOAE test frequencies 6 kHz ($F = 4.508$, $df = 2$, $p = .014$) , and 8 kHz ($F = 4.448$, $p = .015$) between the three different testing conditions. The analysis demonstrated a strong significant profile difference between the pre-post DPOAE amplitude differences for the higher frequency regions over the different experimental sessions.

Figure 4.4. clearly indicates an increase in the pre-post difference amplitudes after performing cardiovascular workout, whereas a decrease in DPOAE response amplitude is observed for both of the other conditions (music only and the combination of music and cardiovascular workout).

CHAPTER 5

5. DISCUSSION

This study aimed to determine the differential impact and short-term effects of simultaneous PMD use and cardiovascular workout on OHC function. The experimental protocol included three testing conditions of which the effects were measured.

5.1. Sub-aim 1:

To determine the short term effect of isolated exposure to music on a PMD on the DPOAE response.

The current study's results indicated a decrease in DPOAE response amplitude response levels between 2 kHz and 8 kHz after one hour's PMD exposure correlating with the results of previous studies (Bhagat & Davis, 2008; Keppler et al., 2010; Kumar et al., 2009; Zhao et al., 2010). The most visible decreased DPOAE response amplitudes were recorded at 6 kHz and 8 kHz. Although these results were not of statistical significance, a clear trend of decreased DPOAE response amplitudes was observed (Figure 4.1). Previous research has also indicated that cochlear damage due to noise is usually first evident as a notch in the higher frequencies (Bhagat & Davis, 2008; Keppler et al., 2010; Attias et al., 2001; Santos et al., 2007).

It is of importance to discuss the output levels of the PMDs used by the participants during this study. Although a decrease in DPOAE amplitudes were observed after one hour's PMD use, no statistical significant differences were obtained. The latter may be due to the variable of differing output levels used by the participants. In order to obtain ethical clearance for the study, participants were instructed to set the output levels to the maximum comfortable intensity level. These intensity levels were not calculated individually and could have influenced the obtained data.

Effects of PMD use after a time period of one hour were measured by means of DPOAEs. Several previous studies focused on determining whether PMD use place young adults at risk for potential

hearing damage. Zhao et al. (2010), in spite of emphasizing the confusion and controversy regarding hearing loss caused by music exposure, further state that music exposure may possibly lead to the development of MIHL. These statements are based on mechanical and physiological changes that occur in the cochlea whilst listening to high intensity music levels. These may include detachment of OHCs from the basilar membrane due to excessive vibration as well as increased levels of glutamate between the IHCs and auditory nerve causing possible ototoxic effects (Zhao et al., 2010). The latter is however relative to the intensity and duration of music exposure (Zhao et al., 2010). Hoover and Krishnamurti (2010) conducted a study to determine the listening habits of college students with reference to variables including intensity and duration of listening time. These researchers came to the conclusion that the sample of college students' habits of PMD listening is of great concern due to the frequency of PMD use as well as the high intensity of PMD usage among the group (Hoover & Krishnamurti, 2010). Another investigation focused on the prevalence and listening habits of young adults and concluded that the average listening times are between one to three hours daily at a medium to loud volume (Torre, 2008). The lengthened time duration of PMD use alone poses a great threat to the OHCs and cochlear functioning.

Results obtained from a study conducted by Bhagat and Davis (2008) indicated that short-term changes in OAEs may precede the development of a MIHL. Following high intensity music exposure symptomatic effects including TTS can be recorded as measured by DPOAEs supporting the notion of possible early detection of MIHL before evident on the audiogram (Bhagat & Davis, 2008). In accordance to these results a related study indicated the DPOAE amplitudes were decreased in individuals who were exposed to high intensity output levels (Kumar et al., 2009). Keppler et al. (2010) in a similar study to determine short-term effects of PMD use on the auditory system, did not record significant post-exposure changes and that the effects were temporary of nature. These temporary changes may however be indicative of potential long term effects of listening to a PMD (Keppler et al., 2010). Fligor (2009) states that the slight short-term changes observed are not clinically significant. As mentioned previously, most of these studies' outcomes were motivated by the high output levels, listening duration and availability of PMDs.

5.2. Sub-aim 2:

To determine the short term effect of isolated cardiovascular workout on the DPOAE response.

The second testing condition aimed to determine the short-term effects of cardiovascular workout on DPOAEs in isolation. Limited research pertaining to cardiovascular workout and OHC function is available. A study conducted by Engdahl (1996) examining the effect of cardiovascular workout on the DPOAEs and temporary effects of noise on cochlear functioning, concluded that cardiovascular workout significantly increased the noise induced TTS and the effect of noise on DPOAE response amplitudes. In contrast to these findings, Hutchinson et al. (2010) cardiovascular workout and fitness may play a protective role in hearing conservation. OHCs that are under stress from noise or other damaging agents generate proteins that have positive pharmacological effects protecting the cochlea from damage (Hutchinson et al., 2010). These results correlate with the results obtained from this study, as a clear trend of increased DPOAE amplitudes were recorded between 2 kHz and 8 kHz during cardiovascular workout in isolation (Figure 4.2).

5.3. Sub-aim 3:

To determine the short term effect of simultaneous PMD use and cardiovascular workout on the DPOAE response.

Vittitow et al. (1994) concluded that a greater TTS is observed during simultaneous cardiovascular workout and noise exposure in comparison to these testing conditions in isolation with the most visible effects recorded between 3 kHz and 6 kHz. These researchers continue to state that an increase in susceptibility to noise induced TTS as well as an increased potential risk for MIHL may be observed when noise exposure is combined with exercise (Vittitow et al., 1994). Krishnamurti et al. (2003) found no evidence of auditory changes after short-term exposure to exercise and loud music. The latter do in turn acknowledge that hearing acuity may be temporarily reduced after high intensity music exposure and that the physiological responses occurring during exercise may enhance these effects (Krishnamurti et al., 2003). A related study indicated that although a TTS occurred following

simultaneous cardiovascular workout and music exposure, a more significant TTS was observed during music exposure in isolation (Hutchinson et al., 2010).

During this study's final testing condition of combined PMD use and cardiovascular workout, no statistically significant different results were obtained between the DPOAE response amplitude levels (post - pre) of the music only and combined cardiovascular workout and PMD use. A clear trend of decreased DPOAE response levels after simultaneous cardiovascular workout and PMD use were observed between 2 kHz and 8 kHz (Figure 5.3).

Results obtained from analysis of the difference between post-exposure and pre-exposure of all three experimental testing conditions indicated an increase in the pre-post difference amplitudes after performing cardiovascular workout, whereas a significant decrease in DPOAE response amplitude is observed for both of the other conditions (music only and the combination of music and cardiovascular workout) at 6 kHz and 8 kHz. These results indicate the possibility of a potential positive effect of cardiovascular workout on the DPOAEs in contradiction to a potential harmful effect of both PMD use in isolation as well as PMD use combined with cardiovascular workout.

CHAPTER 6

6. CONCLUSION

6.1. Clinical implications and recommendations

Audiologists working in different settings and environments are often faced with diagnostic testing and consequent diagnosis of permanent SNHL. In some instances the cause of a hearing loss may be evident and in most other cases the causes are unknown especially following late diagnosis and progressive onsets. The treatment and management of these hearing losses are not necessarily directly related to the causes, but the causes of these hearing losses may be of use during prevention campaigns to lower the risk of permanent hearing loss for individuals. Prevention of hearing loss is often emphasized in literature as the long term effects of hearing loss may have severe financial and emotional impacts on everyday living.

This study does not demonstrate harmful effects from use of PMDs at higher intensities in combination with cardiovascular workout, but merely a different profile between these testing conditions. These effects can be determined by means of DPOAEs indicating that the OHC function is affected. OHCs are damaged prior to IHC damage which may lead to permanent damage once impaired. Thus DPOAE testing can be used as a preventative measure which is more sensitive to cochlear changes than behavioural audiometry. Results obtained from these tests may be applied during counseling regarding hearing health and possible negative cochlear effects of continuous high intensity PMD use.

6.2. Strengths and limitations of the study

6.2.1. Strengths of the study

After critical evaluation of the strengths of this study the following strengths were identified:
Several previous studies focused on the effects of PMD use on OAEs and overall hearing thresholds. However, limited information is available regarding the effects of cardiovascular workout on OAEs

and even more limited information exists regarding the simultaneous effects of PMD use and cardiovascular workout. Many controversies and confusion currently exists regarding the topic of recreational noise exposure and long term MIHL. This study further emphasizes the need for research surrounding the topic of recreational noise exposure. It was also indicated, despite previous controversies, that high intensity music exposure delivered by means of PMDs may cause a high frequency decrease in DPOAE amplitudes after short term exposure. The results also indicated that cardiovascular workout in isolation may play a protective role in isolation, but that the combined effects are still concerning, especially over a long duration of time.

6.2.2. Limitations of the study

After critical evaluation of the strengths of this study the following limitations were identified:
Individuals tend to vary in the adjustment of the volume of their PMDs. Comfortable loudness levels may differ between individuals and consequently may affect the severity of the short term and long term effects of PMD use. Ethical guidelines state that no harm should come to any participants. Therefore the intensity level could not be fixed at a high intensity level by the researcher. This could have caused variations across the participant sample. Although a decrease in DPOAE amplitudes were observed after one hour's PMD use, no statistical differences were obtained. The latter may be due to the variable of differing output levels used by the participants. These intensity levels were not calculated individually and could have influenced the obtained data. This study was conducted in the absence of external auditory stimuli and consequently the effects may differ when a participant is listening to a PMD in a noisy environment such as in a gymnasium with background music.

When taking into account the cardiovascular aspect of the study, physiological systems may influence the outcomes of the study. The fitness level, blood circulation and blood oxygen saturation levels of each individual may vary and consequently produce different effects with regard to severity. Susceptibility could also contribute to certain responses. In addition to these limitations, the sample size should be increased to ensure a more representative sample.

6.3. Future research

Future research should attempt to evaluate long-term effects of cardiovascular workout on OHC function as well as PMD use over an extended time period. More in-depth assessments of these short-term effects on pure tone audiometry in comparison to DPOAEs could be useful in early identification of potential MIHL. If these short-term effects, as recorded by this study, are not detected by the pure tone audiometry further research could aim to prove that DPOAEs are more sensitive measures for early identification and diagnosis of MIHL. Further research could aim to target a younger population, as children are starting to use PMDs from younger ages, increasing the risk of possible long term damage with the increase in the duration of exposure.

Other possibilities of research could aim to incorporate fitness levels of participants and determine whether fitness levels influence the outcomes of the study.

6.4. Final statement

In spite of the controversial opinions evident in previous research results, evidence has indicated that music exposure for one hour through PMD use does not have a significant short-term effect on DPOAEs, although a clear trend of decreased DPOAE response amplitudes were observed following exposure to PMD use. It was also evident that cardiovascular workout in isolation does indicate a slight increase of DPOAE amplitudes based on the results obtained from this study, although not of statistical significance. The simultaneous exposure to cardiovascular workout and PMD use of this population temporarily induced decreased DPOAE response amplitudes at 6 kHz and 8 kHz although not of statistical significance. Pre-exposure and post-exposure results of the three different testing conditions indicated that increased in DPOAE response amplitudes for the higher frequencies after performing cardiovascular working, whereas a significant decrease in DPOAE response amplitude is observed for both other conditions.

Future research should attempt to evaluate long-term effects of cardiovascular workout on OHC function as well as PMD use over an extended time period. More in-depth assessments regarding short-term effects of pre-determined sound levels should be conducted.

CHAPTER 7

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CHAPTER 8

8. APPENDICES