

The prevalence of hearing loss in adults presenting with cardiovascular disease

A report on a study presented to

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by

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Declaration

I, Trusha Solanki, hereby declare that this research report is my own work except as indicated in the references and acknowledgements. I am responsible for the content of this study and the conclusions presented. No part of this research report has been previously submitted for a degree at any other university/institution.

Signature:  _____

Trusha Solanki

Date: 29 May 2012

Dedication

To my parents and late grandparents... for being my pillars of strength

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I would like to thank my supervisor, Dr. Karin Joubert, for her knowledge, time, support and motivation throughout the process of completing this research study.

For the statistics, I am grateful to Professor Fridjhon for his wisdom and to my brother, Hitesh Solanki, for his invaluable input.

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Abstract

The relationship between cardiovascular disease and hearing loss has already been proven. However literature does not provide information on the prevalence of hearing loss in adults with cardiovascular disease. Previous studies provide contradictory information regarding the audiological characteristics in this population. Data relating to the South African context is minimal. The objectives of this descriptive survey research study were to describe the prevalence of hearing loss in adults with this cardiovascular disease and determine the variables which may influence hearing thresholds in this population. Ninety two individuals diagnosed with coronary artery disease or cardiomyopathy were recruited using a non-probability, purposive sampling strategy. This sample, with an average age of 48 years and five months, consisted of more males than females and more participants with coronary artery disease than cardiomyopathy. Participants underwent a comprehensive audiological evaluation including an otoscopic examination, immittance audiometry, pure-tone audiometry, speech audiometry, as well as distortion product otoacoustic emissions. Content analysis, descriptive statistics, *t*-tests and an analysis of covariance revealed a hearing loss prevalence of 5%. These participants presented with a low frequency sensorineural hearing loss with the right ear being more affected. It was found that duration of cardiovascular disease influenced hearing thresholds. Implications of this study include the importance of prevention and early identification of hearing loss. This highlights the need to establish the role of audiologists within a multi-disciplinary team and the management of individuals with this disease.

Key words: audiological evaluation, cardiomyopathy, cardiovascular disease, coronary artery disease, hearing loss

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List of Abbreviations

AC	Air Conduction
ANCOVA	Analysis of Covariance
ART	Acoustic Reflex Threshold
Ave	Average
BC	Bone Conduction
CAD	Coronary Artery Disease
CM	Cardiomyopathy
CVD	Cardiovascular Disease
dB	Decibels
dB HL	Decibels Hearing Level
DPOAE	Distortion product Otoacoustic Emission
Freq	Frequency
HL	Hearing Loss
Hz	Hertz
LE	Left Ear
Max	Maximum
MCL	Most Comfortable Level
Min	Minimum
OAE	Otoacoustic Emission
PTA	Pure Tone Average
RE	Right Ear
SABS	South African Bureau of Standards
SRT	Speech Reception Threshold
St. Dev	Standard Deviation
UCL	Uncomfortable Loudness Level

CHAPTER 1

INTRODUCTION

This chapter provides a brief background on hearing loss in adults with cardiovascular disease. It also discusses the rationale for this study and provides an outline of the chapters which follow.

1.1 Background

Cardiovascular disease is an umbrella term used to describe many different types of heart diseases. The two most prevalent forms of cardiovascular disease are coronary artery disease and cardiomyopathy.

It is widely accepted that cardiovascular diseases are a significant contributor to the global burden of chronic diseases and is reported to be the number one cause of death globally (Reddy et al., 2006; World Health Organization, 2008). In 2005, the World Health Organization estimated that 36.9 per 1000 males and 22.3 per 1000 females present with cardiovascular disease, of which 80% live in developing countries (Arnold et al. 2005). Data on the prevalence of cardiovascular disease in South Africa is limited; however, a study conducted in rural Limpopo revealed a high prevalence of cardiovascular disease (Alberts, et al., 2005). It has been suggested many rural communities are exposed to similar, significant risk factors known to cause cardiovascular disease. An increase in risk factors almost always results in the heart being unable to perform its function optimally.

The heart performs the crucial function of enabling blood supply to all the parts of the body (Lawless, 2010). Any dysfunction or abnormality of the heart is therefore likely to impact on the entire body (Lawless, 2010). These effects include fatigue, reduced mobility in the limbs, some degree of failure in the functioning of major organs such as the liver and lungs. There is also evidence of some degree of disruption in the functioning of other organs such as the ear (D'Adamo, 2005; Cruickshanks, et al., 1998).

Cardiovascular disease may also impact on the human auditory system (Cruickshanks, et al., 1998). The cochlea is situated in the inner ear and is responsible for

converting sound vibrations into action potentials which can then be transmitted to the auditory cortex for interpretation (Zhen, Shen, He, Long, Madison, & Dallos, 2000). The stria vascularis in the cochlea have a large capillary blood flow. A decrease in the blood supply to the cochlea as a result of cardiovascular disease may result in cochlear degeneration and will disrupt the physical and chemical processes in the cochlea (Schuknecht & Gacek, 1993). This, in turn, may lead to a hearing impairment (Torre, Cruickshanks, Klein, Klein, & Nondhal, 2005).

Research regarding the prevalence of hearing loss in individuals with cardiovascular disease was first described in the 1960's (Rosen & Olin 1965; Spencer, 1973). At the time, many studies reported an association between cardiovascular disease and hearing loss; however, some researchers disagreed (Miller & Ort, 1965; Drettner, Hedstrand, & Klockhoff, 1975). Researchers continued to delve into the association between cardiovascular disease and hearing loss for the next few decades and by the 1990's research confirmed this association and began investigating the nature of hearing loss in cardiovascular disease (Rubinstein, Hildesheimrt, Zohar, & Chilarovitz, 1977; Susmano & Rosenbush, 1988; Gates, Cobb, D'Agostino, & Wolf, 1993; Brant, Gordon-Salant, Pearson, Klein, Morrell, Metter, & Fozard, 1996).

Previous studies have attempted to describe the audiological characteristics of adults with cardiovascular disease, but contradictory results have been reported (Gates et al., 1993; Pratt, Kuller, Talbott, McHugh-Pemu, Buhari, & Xu, 2009). This has resulted in many gaps in the understanding of this disease in relation to its impact on hearing loss in adults. Studies have also aimed to determine which variables influence hearing thresholds in this population. From the numerous studies, age and gender were found to have an effect on hearing thresholds in adults with cardiovascular disease (Pratt et al., 2009; Torre et al., 2005).

Previous studies have also provided limited information on the influence of cardiovascular disease on hearing thresholds since many of them were conducted on the geriatric population only (presbycusis was not excluded). Furthermore, these studies cannot be generalized to the South African context. Because there are no published studies on hearing loss in cardiovascular disease in South Africa, there is a lack of information regarding the percentage of individuals with this disease who present with a

hearing loss and the nature of this hearing loss. This study therefore aimed to determine the prevalence of hearing loss in adults with cardiovascular disease and to determine if age, gender, diagnosis and/or duration of cardiovascular disease influence hearing thresholds in this population.

1.2 Chapter Outline

The study consists of six chapters and appendices. The first chapter provides a brief background on cardiovascular disease and its impact on hearing in the adult population. It also includes the rationale of the study and outlines the content of each chapter in the study

The literature review (chapter two) defines the term cardiovascular disease and focuses on the prevalence of cardiovascular disease in developed and developing countries. The prevalence of hearing loss and the effect of this disease on the auditory system are also presented in relation to previous studies along with possible variables which may influence hearing thresholds in this population.

The methodology of the study is outlined in chapter three. It discusses the phases of the research process, describes the instrumentation and procedures utilized to obtain data and considerations regarding reliability and validity. It further includes the ethical considerations and the rights of the participants in the study. This chapter also outlines the methods of statistical analysis and the parametric measure utilized during the study.

Chapter four presents the results in relation to the aims of the study. It describes the audiological findings, after which it determines the prevalence of hearing loss in adults with cardiovascular disease. The influence of the independent variables is discussed and the results of parametric measures are highlighted.

The discussion chapter (chapter five) provides a summary of the audiological findings and briefly discusses the influence of independent variables on hearing thresholds in this population. The greater part of the chapter focuses on the prevalence of hearing loss found in this study in relation to that of the general population, previous studies and other disorders.

Chapter six concludes the study by providing a brief outline of the results of the study and states the strengths of the study and its weaknesses. It further provides

recommendations for future research and the implications of the results in a clinical setting.

Lastly, the appendices provide valuable information regarding the tools utilized during the data collection and the data recording process. This is important for the replication of the study.

1.3 Conclusion

This chapter discussed the term cardiovascular disease and provided statistics on the prevalence of this disease. It also briefly described the effect of cardiovascular disease on the auditory system and previous research which has focused on this determining an association between the two. The variables which may influence hearing thresholds of adults with cardiovascular disease were also discussed and, by highlighting the gaps in previous studies, summarizes the rationale for this study. Furthermore, an outline of the chapters which follow was also provided.

CHAPTER 2

LITERATURE REVIEW

This chapter defines the term cardiovascular disease and focuses on the prevalence of this disease in developing and developed countries. This chapter also discusses the effect of this disease on the auditory system by analyzing the previous studies and describing the role of the audiologist in this population

2.1 Cardiovascular Disease

Cardiovascular disease is defined as a class of diseases that involve the heart and blood vessels (arteries and veins) (Maton, 1993; Rosendorff, 2005). Technically, the term refers to any disease which affects the cardiovascular system. Cardiovascular disease, an umbrella term, encompasses a wide range of conditions such as coronary artery disease, myocardial infarction, angina pectoris, atrial fibrillation, congestive heart failure, stroke, transient ischemic attack, carotid endarterectomy and congenital heart disease (Pratt et al., 2009).

The most common types of the disease are coronary artery disease and cardiomyopathy (National Heart, Lung & Blood Institute, 2007). Coronary artery disease, also known as coronary heart disease, is an abnormality of the arteries which supply blood, oxygen and nutrients to the heart (Resink, Phillippova, Joshi, Kyriakakis, & Erne, 2007). This is usually caused by atherosclerosis, which is the process whereby a build-up of fatty deposits, plaque, collagen, proteins and/or excess smooth muscle cells cause a narrowing in the arteries to the heart (Suri, Kathuria, & Molinari, 2011; Balch, Stengler, & Balch, 2008). An abnormality or constriction in the arteries to the heart can trigger an injury and may lead to some of the following symptoms: chest pain, shortness of breath, heaviness in the chest, dizziness, profuse sweating, nausea and/or vomiting (American Heart Association, n. d.).

Cardiomyopathy is characterized by the deterioration in the anatomy and/or the function of the myocardium (Trio, de Gregorio, & Ando, 2010; Schultheiss & Kuhl, 1997). The myocardium is a thick, muscular layer forming the wall of the heart. It is

composed of cardiac muscle fibres and is responsible for the contraction of the heart (Holubarsch, 2002). The myocardium may become weak, inflamed or it may lose its ability to circulate blood, resulting in reduced blood flow in the body. Cardiomyopathy may result in arrhythmia, heart murmur, shortness of breath and/or chest pain (National Heart, Lung & Blood Institute, 2007).

The causes of cardiovascular disease are numerous and include hypertension, high blood cholesterol, diabetes, obesity, smoking and genetic conditions (Shah, 2006; Joshi et al., 2009). The World Health Organization reported an increase in risk factors due to lifestyle changes which are, in turn, causing cardiovascular disease (Mackay, Mensah, Mendis, & Greenlund, 2007). These lifestyle changes included physical inactivity, poor diet (due to the increased consumption of processed foods) and an increase in smoking (Machay et al., 2007).

The prognosis of cardiovascular disease is dependent on numerous factors including: age of onset, early identification, type of treatment and the lifestyle modifications after diagnosis (Kapoor & Singh, 1993). Females reportedly have a poorer prognosis than males (Wilkinson & Cockcroft, 1999). Psychosocial factors, depression, socio-economic status and social support also influence prognosis and they are powerful motivating factors in the recovery process (Yusuf, Cairns, Camm, Fallen, & Gersh, 2010).

2.2 Prevalence of Cardiovascular Disease

It has been reported that “Cardiovascular diseases are a major contributor to the global burden of chronic diseases with 29.3% of global deaths and 9.9% of total disease burden being attributed to cardiovascular disease” (Reddy et al., 2006, p. 461). This is confirmed by the World Health Organization who reported that cardiovascular diseases are the number one cause of death globally (World Health Organization, 2008).

The statistics on the prevalence of the disease in developed countries and developing countries appear to be contradictory. A developed country is a country which is considered to have an advanced economy, is highly industrialized and its citizens have a high standard of living (O’Sullivan & Sheffrin, 2003). The International Monetary Fund (2011) reported the following countries (amongst others) to be classified as developed countries: Australia, Belgium, Canada, Germany, Sweden, and the United States of

America. A developing country is defined as a country of low to middle income, average standard of living and in the process of industrialization (O'Sullivan & Sheffrin, 2003). Some of the following countries are classified as developing countries: Algeria, Bangladesh, Brazil, Pakistan, Columbia, South Africa, Sri Lanka and Sierra Leone (International Monetary Fund, 2011).

In developed countries, the prevalence of cardiovascular disease is reported to range between 6% and 23% (Australian Bureau of Statistics, 2006). It has been reported that in the United States of America, an estimated 81,100,000 American adults have one or more type of cardiovascular disease (Lloyd-Jones et al., 2010). In Australia, the prevalence of cardiovascular disease was reportedly 18% in 2004-2005 (Australian Bureau of Statistics, 2006). Independent studies conducted in Germany and Ontario, Canada, revealed an increase of the disease in adults due to an increase in the associated risk factors in adolescents (Flouris, Canham, Faught, & Klentrou, 2007; Muller-Riemenschneider, Nocon, & Willich, 2010).

The World Health Organization (2008) reported that cardiovascular diseases are the number one cause of death globally with low- and middle income countries disproportionately affected. Recent research has indicated that developing countries contribute in excess of 70% of the global burden of this disease (Lopez 1993; Whelton, Brancati, Appel, & Klag, 1995).

While developing countries are reportedly disproportionately affected, data on the prevalence of cardiovascular disease in developing countries have been marked with complications. Statistics on the prevalence of cardiovascular disease have been limited and may not always be accurate.

Studies conducted between the 1960s and 1980s have provided valuable statistical data regarding the prevalence of cardiovascular disease in low income, developing countries like sub-Saharan Africa. These studies reported an increase in the prevalence on non-communicable diseases such as cardiovascular disease globally (Yack, Hawkes, Gould, & Hofman, 2004). Table 1 provides a summary of data which has been compiled and studies which have been conducted on the prevalence of cardiovascular disease in some developing regions.

Table 1

Summary of the Prevalence of Cardiovascular Disease in Developing Countries

Country/Region	Authors	Conclusion regarding the Prevalence of CVD
India	Joshi et al. (2009)	-An increase in disease burden attributed to CVD -An increase in CVD in young adults
	Prabhakaran et al. (2005)	In Delhi: 7.3%
	Mohan et al. (2001)	In Chennai: 11%.
	Reddy et al. (2006)	An increase in the incidence of CVD (especially in the industrial population)
Middle East	Motlagh, O'Donnell, & Yusuf (2009)	An increase in the number of CVD cases been seen in recent years.
Pakistan	Bhopal et al. (1999)	South Asians are reported to have the highest rated of Coronary Heart Disease.
	Dodani et al. (2004)	An increase in the prevalence of CVD, especially in the urban population. There is a great need for increased awareness and prevention programs.
Costa Rica	Monge & Beita (2000)	An increase in the prevalence of CVD in adults between 20-40 years and 70% in the prevalence of CVD risk factors in adolescents. Prevalence of CVD is higher in urban areas. There is a need for prevention measures, especially in young adults.
West Indies	Miller et al. (1989)	In 1989, incidence of CVD in people of African origin was 0.68% and 0.54% among men and women respectively. Analysis of risk factors at the times revealed an expected increase in CVD in the future.
Africa: -Sub-Saharan Africa	Akinboboye et al. (2003)	CVD rates are relatively low compared to rates of the Western countries. In 1990, the burden of CVD was 4.5 million
	Muna (1993)	The prevalence of CVD in Sub-Saharan Africa is increasing.
-East Africa	Akinboboye et al. (2003)	Very low CVD prevalence rates were reported in Kenya, Uganda and Kampala.
-West Africa	Akinboboye et al. (2003)	A low prevalence of CVD in Nigeria, Ghana & Cote d'Ivoire between 1960 and 1979, averaging 2%.
-Central Africa	Mets (1993)	A Prevalence of approximately 1% in Rwanda.
South Africa	Seedat et al. (1992)	Prevalence of CAD in Durban in 1986 is approximately 2.4%.
	Seftel & Kew (1970)	Prevalence rate of CAD in 1970 in Johannesburg General Hospital was 0.6%.
	Schrire (1971)	CAD prevalence rate of 1.4% in the black population in Cape Town in 1970.
	Steyn (2007)	Current rates of prevalence of CVD are unknown.
	Akinboboye et al. (2003)	Increasing prevalence of CVD over the years.
	Alberts et al. (2005)	High Prevalence of CVD in rural black populations in Limpopo.
	Sliwa et al. (2008)	The prevalence of CVD risk factors was extremely high in urban African communities in Soweto.

Note. CVD=Cardiovascular disease; CAD=Coronary artery disease

Overall, reports from East, West and Central Africa have shown similar prevalence rates (Muna, 1993). The prevalence rates in Africa and the West Indies appear to be lower than that of developing countries; however, the prevalence rate in India appears to be similar to that of the United States of America. Whilst the prevalence rates in Table 1 are comparatively lower than those of Western countries including Europe, the context in which the prevalence rates in Table 1 were obtained needs to be taken into account. In many developing countries deaths were not always registered and autopsies were not conducted unless deemed necessary. Furthermore, medical intervention is not always accessible and therefore cases are not always reported. These factors may be contributing to the contradiction in statistics between recent studies and the statistics provided by the World Health Organisation.

The prevalence rate of cardiovascular disease in developing countries appeared to be highest in Asia and in South America. Africa appeared to present with the lowest prevalence rates of the disease. Many studies were unable to provide prevalence rates thereby highlighting the need for further research in this disease. Africa has the lowest output in the world of cardiovascular research (Rosmarakis et al., 2005). Statistics for the prevalence of cardiovascular disease in developing countries, especially Africa, are therefore rare. Data from the 1960s onward consisted largely of hospital records and autopsies conducted. These may not be an accurate reflection of the prevalence of this disease in society. It has, however, been ascertained that the number of individuals at risk for the disease and the incidence of reported cases is increasing each year (Dahlof, 2009).

In South Africa, the prevalence of cardiovascular disease is unknown (Steyn, 2007). Data on the number of heart attacks South Africans suffer do not exist; however, given the limited information available on mortality rates, it can be roughly estimated that approximately 130 heart attacks occur daily in South Africa (Steyn, 2007). This estimate does not include other forms of cardiovascular diseases. A study conducted in Limpopo revealed that there is a high prevalence of cardiovascular disease in the rural black population in that area (Alberts et al., 2005). The results from this study cannot be generalized to other communities in rural areas, although it has been suggested that many rural communities in South Africa are exposed to similar, significant levels of risk factors which could cause this disease.

A study conducted in the heart of Soweto at Chris Hani Baragwanath Hospital focused on understanding the characteristic burden imposed by heart disease in an urban African community (Sliwa et al., 2008). The study ($n = 4164$) found that heart failure (for example, cardiomyopathy) was found to be most common (44% of participants). The prevalence of risk factors for the disease in that population was also found to be extremely high.

The aforementioned studies have also provided prevalence rates of cardiovascular disease on various variables (such as, age and gender). Cardiovascular disease has generally been associated with the geriatric population; however, the increase in early age of onset of the disease globally appears to be causing considerable alarm. It has been estimated that 40-50% of reported cases of this condition are below the age of 70 years (Reddy & Yusuf, 1998), but this appears to be changing. Recent studies have indicated that, for approximately 25% of reported cases, the age of onset appears to be below 40 years (Sreeraman, 2008).

A study conducted in Finland (a developed country) on the adult population revealed that the arteries began to demonstrate some form of abnormality between the ages of 33 and 39 years of age (Raitakari et al., 2003). In 2009, the American Heart Association reported an estimated 81,100,000 American adults to have one or more types of the disease, of which more than 50% were below the age of 60 years (Lloyd-Jones et al., 2010). Another study conducted on American adolescents revealed an increase in the prevalence of risk factors for the disease in the youth (Rodriguez et al., 2006). Similarly, the Australian Bureau of Statistics (2006) reported that the prevalence of cardiovascular disease in Australia increased with age in 2004-2005, 13% in individuals between 35 and 44 years and 23% in individuals between 45-54 years.

A study conducted in India revealed that the age of onset of cardiovascular disease in the industrial population in India is becoming lower (Reddy et al., 2006). This was attributed to lifestyle changes, dietary changes and an increase in risk factors. The aforementioned studies dispel the long believed notion that this disease is associated with the geriatric population only. They also highlighted the need for medical intervention in this high risk population (for example, screening programmes, and increased awareness).

Another variable which may influence the prevalence of cardiovascular disease is gender. Studies conducted in the 1980s and 1990's have indicated that the disease occurs primarily in males; however, recent studies have indicated an increased prevalence in females in recent years, possibly attributed to lifestyle changes. In 2005, the World Health Organisation estimated that 36.9 per 1000 males and 22.3 per 1000 females present with the disease (Arnold et al., 2005). In Australia, overall, the prevalence of cardiovascular disease in females was 20% compared to 16% for males (Australian Bureau of Statistics, 2006).

A study conducted in Limpopo revealed one fifth of females and one third of males in that community to have a high risk for suffering from a cardiovascular event in the next ten years (Alberts et al., 2005). The results from this study cannot be generalized to other black communities in rural areas, although it has been suggested that many rural communities in South Africa are exposed to similar, significant levels of risk factors which could cause this disease. Sliwa et al. (2008) found more females to present with heart failure than males in Soweto. The similarity of these findings allow for the conclusion that gender may be influencing the prevalence rate of cardiovascular disease in recent years.

2.3 Effects of Cardiovascular Disease

The heart is a central organ in the body and performs a crucial function (Lawless, 2010). It is responsible for transporting oxygen and nutrients to the organs of the body and for carrying carbon dioxide and waste products away from the body organs (Gersh, 2000). The symptoms of coronary artery disease and cardiomyopathy may act as warning signs preceding a cardiovascular event (Engstrom, Melander, & Hedblad, 2010).

It has however been reported that cardiovascular disease affects the entire body in many different ways prior to and after such an event (Engstrom et al., 2010). The effects of cardiovascular disease on other major organs, such as the liver and lungs can therefore be far-reaching. Some degree of failure in the functioning of various organs such as the liver, lungs and intestines may be present (D'Adamo, 2005). In addition, an individual with the disease may experience constant fatigue, hypertension, and reduced mobility of the limbs (D'Adamo, 2005). Other effects of the disease may include ulceration and gangrene that may in extreme cases result in amputation (Feiring, 2005). As this disease

causes many bodily functions to be effected, it also has the potential to compromise the auditory system (Wiley, Torre, Cruickshanks, Nondhal, & Tweed, 2001).

2.4 Cardiovascular Disease and the Auditory System

The cochlea receives its blood supply from a tight network of arteries and normal blood supply is crucial for auditory transduction (Mom, Chazel, Gabrillargues, Gigila, & Avan, 2005). The cochlea is supplied by the labyrinthine artery. The labyrinthine artery arises from the meatal loop of the middle cerebral artery or a branch from the basilar artery, which penetrates into the internal acoustic meatus (Mom et al., 2005). Within the cochlea, both spiral and radial arteries are found. The modiolus artery has radial branches which enter the lateral wall of the cochlea, including the stria vascularis. The capillary network of the stria vascularis is extremely rich at the base of the cochlea compared to the apex and has a large capillary blood flow.

A compromised cardiovascular system can impact on the integrity of the human auditory system (Cruickshanks, et al., 1998; Makishima, 1978). The sensitivity of the cochlea to decreased blood supply (ischemia/hypoxia) has been documented since 1961 (Mom et al., 2005). Many animal studies have been conducted and all reported degenerative changes in inner and outer hair cells post hypoxia (Mom, Avan, Bonfils, & Gilian, 1999; Bachor, Selig, Jahnke, Rettinger, & Karmondy, 2001; Iwagaki, Suzuki, & Nakashima, 2000). It is postulated that cardiovascular disease may cause a disruption in the micro-vascular system of the stria vascularis in the cochlea. The decreased blood supply to the cochlea may result in cochlear degeneration (Torre et al., 2005). Degeneration in the stria vascularis affects the physical and chemical processes in the organ of Corti, thereby causing a possible hearing impairment (Schuknecht & Gacek, 1993).

The cochlea is tonotopically organized, as the base of the cochlea is responsible for identifying and transmitting low frequency stimuli and its apex of the cochlea is responsible for high frequency stimuli (Kros & Evans, 2006; Stach, 1998). This allows high sensitivity and frequency selectivity in the cochlea (Stach, 1998). The comparatively limited blood flow to the apex makes the apex of the cochlea vulnerable to degeneration which can present as a possible low frequency sensorineural hearing loss (Nakashima et al., 2003).

Hearing loss as a result of cochlear hypoxia was confirmed in study conducted by Dai, Jiang, and Gu (2000). These findings were supported by other studies which reported absent or reduced distortion product otoacoustic emissions following an ischemic injury to the cochlea (Schweinfurth, Cacace, & Parnes, 1997; Mom, Gilian, & Avan, 2008).

2.5 Hearing Impairment

Hearing impairment in adults is defined as a permanent unaided hearing threshold level of 41dB or greater in the better ear (World Health Organization, 2004). In 1995, the World Health Organisation estimated 120 million individuals to be living with a hearing impairment, 78 million of which were from third-world countries (Solarsh & Hofman, 2006). Recent literature revealed that the number of individuals with a hearing impairment is likely to increase and that the age of onset is likely to decrease (De Sousa, De Castro Junior, Larsson, & Ching, 2009). The world report on disability (World Health Organization, 2011) reported 278 million people worldwide to have moderate to profound hearing impairments. In 2011, the global prevalence of hearing loss was estimated to be 9.8% in females and 12.2% in males, indicating that males have a higher prevalence rate than women (Stevens et al., 2011).

The prevalence of hearing impairment in adults is significantly higher in middle- and low-income countries than in high-income countries (Stevens et al., 2011). In the United States of America, approximately 17% (38 million) of adults report some degree of hearing impairment (National Health Institute on Deafness and Other Communication Disorders, 2008).

The Canadian Hearing Society (2002) reported a prevalence of hearing loss of 20% in adults between 30-39 years of age and 24% in adults between 40-49 years of age. The prevalence of adults in Australia above the age of 26 years is reported to be 11.8% (Mathers, Smith, & Concha, 2000). In 1999, the European Hearing Instrument Manufacturers Association reported approximately 20% of adults in Europe to be having a hearing loss, 64% of which were below the age of 55 years. Shields (2006) reported the incidence of hearing loss to be as high as 25% (10.2 million) in Germany, approximately 14% in Finland, 16% (7.2 million) in Italy, 10% in Denmark and Sweden and only 7% (7.6 million) in France. This indicates a range of prevalence rates amongst developed

countries. Obtaining accurate statistics on the prevalence of hearing loss in developing countries is difficult, because of limited research. In addition, records are scarce, since the majority of cases are not documented. This could be attributed to many individuals in developing countries not having access to medical professional services.

The prevalence rate of hearing loss in Mexico, which is a developing country, ranges from 0.21% (profound hearing loss) to 29%. Latin America presented with higher prevalence rates when compared to Eastern countries such as India and China. Studies conducted in African countries reported lower prevalence rates compared to other developing countries. The prevalence rate appears to be higher in urban settings when compared to rural settings. Table 2 provides a summary of the data available on the prevalence of hearing loss in adults in developing countries.

Table 2

Summary of the Prevalence of Hearing loss in Developing Countries

Country /Region	Authors	Conclusion regarding Prevalence of Hearing Loss
India	Tucci et al. (2009)	10% in rural areas and 6.8% in urban areas
	Mathers et al. (2000)	9.8% in urban Lucknow and 7.3% in rural Lucknow in adults above the age of 26 years
China	Tucci et al. (2009)	19% prevalence of hearing loss
	Mathers et al. (2000)	4% in adults above the age of 26 years
Latin America		
-Mexico	Madriz (2000)	Studies reported an estimated prevalence of 21.07% (however, these statistics are skewed)
-Columbia - Brazil	Montes de Oca (1996)	Study conducted on five indigenous groups revealed approximately 29.3% present with some degree of hearing loss.
	Madriz (2000)	Estimated prevalence of 1.27% in 1995
	Paiva et al. (2011)	Estimated a prevalence of 11.2% in the elderly
Thailand	Prasansuk (2000)	Study conducted in regions in Bangkok and Thailand revealed an overall prevalence of 13.6% of which 8.3% were sensorineural hearing losses
	Mathers et al. (2000)	11.6% in adults above the age of 41 years
Sri Lanka	Mathers et al. (2000)	21.7% in adults above the age of 26 years
Pakistan	Yucci et al. (2009)	Prevalence of 18%.
Africa		
-Nigeria	Mathers et al. (2000)	4.5 % in adults above the age of 41 years
	Tucci et al. (2009)	As high at 60% in certain settings
	Lasisi et at. (2010)	6.1% in the elderly (individuals above the age of 65 years)
- Sierra Leone	Solarsh & Hofman (2006)	0.4% profound hearing loss.
- Swaziland	Solarsh & Hofman (2006)	0.21% profound hearing loss
- South Africa		No statistics available on the adult population.

Note. CVD=cardiovascular disease

2.6 Cardiovascular Disease and Hearing Loss

The debate of an association between cardiovascular disease and hearing loss began in the 1960s; however, limited research is available (Rosen & Olin, 1965; Rubenstein, Hildesheimer, Zohar, & Chillarovitz, 1977; Susmano & Rosenbush, 1988; Cocchiarella, Sharp, & Persky, 1995). An early study conducted by Rosen and Olin (1965) found that individuals with heart disease had poorer hearing sensitivity than individuals of similar age without heart disease had. Further research revealed a significant difference in pure-tone threshold audiometry between apparently healthy

subjects and those presenting with cardiovascular symptoms (Rubenstein et al, 1977; Susmano & Rosenbush, 1988). Susmano and Rosenbush (1988) took the debate further by reporting that the probability of individuals with cardiovascular disease presenting with a hearing loss were eight times higher than that for individuals without the disease. They also indicated that hearing loss appears to be an 'early marker' for individuals with the disease.

Conversely, the results of a study by Miller and Ort (1965) revealed no association between hearing loss and risk factors for cardiovascular disease in the elderly population. Drettner et al. (1975) conducted a study in Sweden to investigate cardiovascular risk factors and hearing loss in 50-year-old men ($n=1000$). The hearing loss the participants presented with was attributed to noise exposure and/or conductive components. Furthermore, they suggested that further research was required to analyse the question concerning a possible relationship between cardiovascular diseases and hearing loss.

The debate continued in the 1990s and researchers began to establish a firmer foothold regarding correlations and results. Gates et al. (1993) conducted a study ($n=1662$) investigating the relation of hearing in the elderly to the presence of cardiovascular disease and cardiovascular risk factors by comparing hearing status, the prevalence of the disease and the presence of associated risk factors. The results revealed that there was a small but significant association between hearing loss and cardiovascular disease. The study also revealed that a low frequency hearing loss was more prevalent than a high frequency hearing loss. The study further reported that gender may influence hearing loss in this population as more females were affected. This was the first study to describe audiological results of individuals with the disease. It did, however, not provide conclusive results and, furthermore, only targeted the geriatric population.

A study conducted by Friedland, Cederberg and Tarima (2009) hypothesized that audiometric patterns can be associated with underlying cardiovascular disease. The results of their study ($n=1168$) indicated that there was a strong correlation between audiometric results and the disease. They furthermore established that patients presenting with a low frequency hearing loss should be regarded as being at risk for the disease and

should be treated accordingly. The study concluded that more research was required to establish other audiometric trends.

Once it had been ascertained that there is a relationship between cardiovascular disease and hearing loss and that the disease poses a risk factor for hearing loss, researchers began attempting to develop a better understanding of this relationship. They began investigating more specific pathologies (for instance, investigating the type of hearing loss and the variables which may influence hearing loss in individuals with the disease). Aimoni et al. (2010) assessed the role of cardiovascular disease in idiopathic, sudden onset sensorineural hearing loss and found that this disease does indeed play a significant role in patients with idiopathic, sudden onset sensorineural hearing loss.

In a study conducted by Yamasoba, Kikuchi and Higo (2001), an association between vertebrobasilar insufficiency and cochlear hearing loss was confirmed. This was supported by Kim and Lee (2009) who found that individuals who suffer from vertebrobasilar ischemic stroke could also present with vertigo and hearing loss.

It was also found that age and gender have a significant influence on hearing loss in individuals with cardiovascular disease (Pratt et al., 2009). In the study by Pratt et al. (2009), the prevalence rate of hearing loss in adults with the disease was reported to increase with age. Males were more likely to present with higher prevalence rates than women were. The results of this study are contradictory to that found by Gates et al. (1993), but both studies concluded that gender influences hearing loss in adults with cardiovascular disease.

The studies referred to above serve to confirm that, despite limited research, there appears to be a strong link between the different types of cardiovascular disease and hearing loss. It is further postulated that gender and age may influence hearing loss in this population; however, more studies in this regard need to be conducted.

2.7 The Audiologist as a Member of the Multi-Disciplinary Team

The role of the audiologist in the diagnosis and management of hearing loss has been well established. Individuals living with hearing loss experience many physical, emotional and social challenges and may therefore present with an array of difficulties such as depression, dependence on others, withdrawal and situation avoidances (Weinstein, 2000). These difficulties, combined with the knowledge of a statistical

increase in the prevalence of hearing loss and the prevalence of cardiovascular disease have significant implications for the role of audiologists in the management of this disease. This highlights the need for early identification and also multidisciplinary assessment and intervention when dealing with hearing loss.

Likewise, individuals living with cardiovascular disease contend with extreme mental stress, depression and anxiety (Kapoor & Singh, 1993). These individuals may experience some of the following: extreme fatigue, failure in the functioning of various organs, complications during pregnancy, and often physical limitations (Kapoor & Singh, 1992). Management of individuals with this disease is, therefore, an intense process which requires the expertise of many medical professionals.

2.8 Conclusion

Cardiovascular disease has been identified as one of the most prevalent chronic diseases that are a major contributor to the global burden of disease. The disease not only affects the heart, but may also have an impact on the liver, lungs, and other parts of the body. It has been ascertained that reduced blood flow to the cochlea causes degeneration in the outer and inner hairs cells and impedes auditory function (Torre, et al., 2005; Schuknecht & Gacek, 1993). Despite this, there is a dearth of information on hearing loss in individuals diagnosed with cardiovascular disease. The majority of studies have been conducted in developed countries such as the United States of America, Australia and those in Europe. There are no known studies regarding cardiovascular disease and hearing loss conducted in South Africa.

The majority of the available research did not utilize comprehensive audiological test batteries to describe the nature of the hearing loss. The current study will therefore utilize a comprehensive audiological test battery to provide a more holistic analysis regarding the nature of hearing loss in individuals with cardiovascular disease. Although some studies have established an association between this disease and hearing loss, they do not provide information regarding the prevalence of hearing loss associated with the disease.

It is also evident that the sample in many of these studies comprised the geriatric population. As a result, the early age of onset of cardiovascular disease in developing countries has been neglected. For this reason the current study will focus on adults

between the ages of 40 years and 55 years, because they may present with different audiological characteristics.

Although previous studies investigating cardiovascular disease and hearing loss have contributed valuable information, it has also raised many questions. These questions specifically relate to the nature of hearing loss in individuals diagnosed with cardiovascular disease and the prevalence of hearing loss in this population. This study therefore aims to determine what the prevalence of hearing loss is in individuals with the disease living in Gauteng.

CHAPTER 3

METHODOLOGY

This chapter discusses the aims of the study and the research design, procedure, instrumentation and data analysis procedures utilized to achieve those aims. This chapter also focuses on the three phases of the research process.

3.1 Research Aims

The primary aim of this study was to determine the prevalence of hearing loss in individuals diagnosed with cardiovascular disease. The null hypothesis being tested is that all adults with the disease present with normal hearing and the alternate hypothesis is that adults with the disease do present with some degree of hearing impairment.

In order to achieve the primary aim, the sub-aims of the study were to (i) to describe audiological findings in these individuals, and (ii) to determine if age, gender, diagnosis and duration of cardiovascular disease influence hearing thresholds.

3.2 Research design

A research design is the structure or plan utilized to gather data to test a hypothesis (White, 2009). A quantitative, descriptive, survey research design was utilized for this study.

In quantitative research, formalized tests and measuring instruments are applied to objectively specify the characteristics of data in numerical terms (Maxwell & Satake, 2006). Data is analysed utilizing statistics and formulae (De Vaus, 2001). A quantitative approach was, therefore, appropriate for the purpose of this study since formalized audiological tests were administered, measuring instruments were utilized and data were analysed using statistics and numeric terms.

Quantitative research is a broad term which encompasses many different types of research designs. One such design is a descriptive, survey research design. The main goal of descriptive research is to describe the characteristics of what is being studied (Mertens, 2009). In descriptive studies, no attempt is made to change behaviour or conditions.

Survey research designs allows for a description to be obtained from a specific group of individuals at a particular time (Gravetter & Forzano, 2009). Survey research designs enable clinical practitioners to obtain more information on certain characteristics of a group of patients/target group which ultimately leads to a better understanding of those individuals (Gravetter & Forzano, 2009; Houser & Bokovoy, 2006). The variables or target group are examined only once and no therapy, intervention or change is implemented (Mertens, 2009; Thomas, 2003). A descriptive, survey research design was applicable to this study as the audiological characteristics of individuals diagnosed with cardiovascular disease were described utilizing frequencies, averages, and variability statistics. The target group was assessed only once and no intervention was provided.

Each research design has its own strengths and weaknesses and a researcher chooses a design based on what is most suited to the research question. A quantitative, descriptive, survey research design allows for greater objectivity, accuracy and reliability of results, replicability and furthermore, it can be relatively cost and time efficient (Levin, 2006; O'Neill, 2008; Tashakkori & Teddlie, 2003). It also decreases researcher bias, since subjects are unknown to the researcher and this enhances the generalization of results because it can include a greater number of subjects (O'Neill, 2008; Tashakkori & Teddlie, 2003).

Although the advantages of this research design appear convincing, the disadvantages are equally numerous. A quantitative, descriptive, survey research design does not allow for comparisons, because there is no control group and no manipulation of variables (that is, no intervention/therapy) thus limiting analysis regarding change (Shipman, 1997; Tashakkori & Teddlie, 2003). Results may further be limited in terms of analysis because they provide numerical descriptions rather than detailed narrative (Bland, 2001). The strengths and weaknesses of this design were taken into consideration when data analysis and implications of the study were discussed.

3.3 Pilot Study

A pilot study is a preliminary study which utilizes the data collection procedures and tools to reveal deficiencies in the proposed research (Lancaster, Dodd, & Williamson,

2004; Boynton, 2005). This allows for modifications to be made prior to commencement of the research (Rosnow & Rosenthal, 2006).

3.3.1 Objectives

The objective of the pilot study was to finalize data collection measurements, procedures and equipment needs. It also aimed to determine the ease of documentation of results and assess the ease of data coding (Table 4).

3.3.2 Participants

The pilot study was conducted on four individuals who met the same selection criteria as for the main study. Three participants were male and one female. Their average age was 48 years and five months (range: 43 – 51 years; standard deviation: 3.7) Three of the participants were diagnosed with coronary artery disease and one participant (a male) with cardiomyopathy. One participant reported experiencing hearing difficulties in noisy environments. The other three participants reported no hearing difficulties.

3.3.3 Procedures

The steps outlined in the main study were followed and all measuring instruments were completed and coded. Participants were recruited from the Out Patient Department at South Rand Hospital. Once it was ascertained that the individuals met the selection criteria informed consent was obtained (Appendix B). Participants could ask questions and make comments at any point whilst completing the questionnaire and also during the testing process. Table 4 indicates the changes which have been made to the questionnaire based on feedback received from the participants.

3.3.4 Results and recommendations

The objectives, materials and equipment, procedures, results and recommendations made after the completion of the pilot study are outlined in Table 4.

*Table 4:
Modifications/Considerations during the Pilot Study*

Objective	Measures and Equipment	Results	Recommendations
1. To evaluate the comprehensiveness and the clarity of the questionnaire	Questionnaire (Appendix A)	Three questions caused confusion among some participants who required further examples and clarification in order to assist them in answering accurately.	The changes to the three questions were made as recommended by the participants.
2. To determine the comprehensiveness of the instructions/terminology	None	The instructions provided for all test procedures were clear, concise and no ambiguity was reported. One participant reported being unsure about when to respond during bone conduction masking; however, after a repeat instruction she was able to respond appropriately.	No changes were required. The researcher needs to ensure that instructions regarding the response of the participants during bone conduction masking are clear.
3. To assess the suitability and ease of use of equipment	<ul style="list-style-type: none"> • Otoscope • Tympanometer • Audiometer • OAE machine 	The equipment utilized during testing was operated with ease and no technical difficulties were encountered. The results provided valuable information which contributed to the basic test battery of an audiological evaluation.	No changes were required.
4. To determine the length of time taken to complete the evaluation	Stopwatch	The data collection procedure took approximately 45 minutes for each participant (including completion of the questionnaire and feedback of results).	Participants need to be informed that the appointment will be scheduled for approximately 45 minutes.
5. To assess the ease of recording results	Data collection forms, for example audiogram, form utilized to record OAE results (Appendix C)	All results were recorded on the data collection form. The results were then printed and attached to the audiological evaluation form.	No changes were recommended.
6. To determine the ease of coding of results	Excel spreadsheet.	Data was coded according to the data definitions A statistician was consulted on the accuracy of the	No changes were recommended.

Objective	Measures and Equipment	Results	Recommendations
		<p>coding on measuring instruments. Although coding of data was time consuming, the coded data allows for quicker and easier analysis of data (for parametric measures and for descriptive statistics).</p>	

Note. OAE=otoacoustic emissions

3.3.5 Summary

Overall, the pilot study determined the feasibility of the test procedures and equipment utilized in this study. It has also highlighted the changes which were required to ensure that the questionnaire and participant instruction was more comprehensive. These modifications were made for data collection during the main study

3.4 Main Study

3.4.1 Participant selection

3.4.1.1 *Sampling strategy*

A non-probability, purposive sampling strategy was utilized for this study. A non-probability sampling strategy is one in which the researcher creates a framework to obtain a sample specific to the selected research design (Baker, 1994). This allows the researcher to select participants who meet specific selection criteria (Burns & Grove, 2001). Purposive sampling is often used in studies of relatively infrequent phenomena such as rare diseases or disorders (Maxwell & Satake, 2006). Advantages of this method of sampling is that “a sample of subjects can be created that appears to have the major characteristics that an investigator wishes to study” as well as to “replicate the proportion of such characteristics found in a targeted population” (Maxwell & Satake, 2006, p. 97). Non-probability sampling may have a weak basis for generalization of results and is prone to biases which can result in an unrepresentative sample being obtained (Fife-Schaw, 2000; Walliman, 2001).

3.4.1.2 *Participant selection criteria*

The participant selection criteria, the rationale for inclusion and information regarding implementation are presented in Table 5.

Table 5

Description of Participant Selection Criteria, Rationale for and Implementation of each Criterion

Criteria for Inclusion	Rationale	Implementation
Cardiologist confirmed diagnosis of coronary artery disease or cardiomyopathy.	In accordance with the aim of the study, individuals presenting with two most prevalent forms of cardiovascular disease, namely coronary artery disease and cardiomyopathy were included in the study.	The researcher reviewed participants' medical records (either the hospital file or written medical reports) to confirm diagnosis.
Male or female	In accordance with the aim of the study, both males and females were included in this study. There are many reported differences in the mortality, prevalence and age of onset of cardiovascular disease in males and females (Rosendorff, 2005). An equal number of males and females were therefore not necessary in this study.	This was confirmed during the case history interview (Appendix A) either by the information in the hospital file/medical reports or by asking the participant their gender.
Aged between 40 years and 54 years and 11 months	Individuals above the age of 55 are at risk of developing a hearing loss due to non-related factors and were, therefore, not included in this study. Presbycusis is a sensorineural hearing loss caused by age-related changes in the ear typically beginning in the sixth decade of life (Weinstein, 2000). Presbycusis usually begins at 60 years and older; however, research has indicated that presbycusis may be beginning in the second half of the fifth decade of life due to lifestyle changes and an increased exposure to noise (Pratt et al., 2009; Desai, Pratt, Lentzner, & Robinson, 2001).	This was confirmed during the case history interview either by the information in the hospital file/medical reports or by asking the participant their age (Appendix A).
Proficient in English– either English first or second language speaker	Participants were required to respond appropriately to Yes/No-questions and provide information regarding their health and hearing status in English. They were also required to repeat words from wordlists in English.	This was determined during the case history interview when the researcher began communicating with participants and they were able to respond appropriately in English to questions about their health.
Criteria for Exclusion	Rationale	Implementation
No history of noise exposure	Noise exposure has been identified as a risk factor for hearing loss (Agrawal, Platz, & Niparko, 2009). Noise exposure is defined as being exposed to a minimum of 85dB average for an 8-hour day (Ahmed et al., 2001; Sriwattanatamma & Breysse, 2000). Excessive noise exposure is known to cause physiological damage to the ear (Agrawal et al., 2009). A history of noise exposure could have influenced the results of the study as those participants may have presented with a noise-induced hearing loss and not a hearing loss related to	This was determined during the case history interview (Appendix A). Participants who reported occupation and recreation related noise exposure were excluded from the study.

cardiovascular disease.	<p>No reported history of exposure to ototoxic medication</p> <p>Specific types of medication can have ototoxic effects on hearing sensitivity that may range from mild to profound in nature (Wiley et al., 2001). These include ethacrynic acid, furosemide, bumetanide and torsemide (Campbell, 2007).</p> <p>Furosemide (Lasix) is a form of medication utilized to treat congestive heart failure (Buckberg 2003). At times, it is also utilized for individuals with cardiomyopathy as it removes excess salt and water from the body (Wojnicz et al., 2001). One of the possible side-effects of furosemide (Lasix) is a sensorineural hearing loss which is reversible once the individual discontinues the medication (Ruggero & Rich, 1991).</p>	<p>During the case history interview, participants were required to inform the researcher of the medication they were taking at the time (Appendix A). Participants utilizing known ototoxic medication (for example medication for tuberculosis) were excluded from the study.</p>
<p>Exclusion of other risk factors known to cause a hearing loss</p>	<p>The risk factors for hearing loss such as diabetes mellitus, trauma to the ear, surgery around the head and/or neck area and any form of head and/or neck cancer are well documented (Agrawal et al., 2009; Aimoni et al., 2010; Gates et al., 1993).</p>	<p>Information regarding the risk factors for hearing loss was obtained during the case history interview. Participants who reported any of these risk factors were excluded from the study.</p>

3.4.2 Participant description

The sample comprised a total of 92 participants ($N = 92$), 60 males and 32 females. The age of participants ranged from 40 years to 54 years and 9 months with an average age of 48 years and five months (standard deviation: 3.70). The duration of cardiovascular disease (from date of diagnosis to date of testing) ranged from 7 months to 4 years and one month with an average of two years and two months (standard deviation: 0.95).

Table 6 provides a summary of the participants in relation to gender and diagnosis.

Table 6

Summary of Participant Description in Relation to Gender and Diagnosis

	Variable			
	Gender		Diagnosis	
	Males	Females	CAD	CM
Number of participants	60	32	58	34

Note. CAD=Coronary Artery Disease; CM=cardiomyopathy

All participants reported the following intervention after being diagnosed with coronary artery disease or cardiomyopathy: diet modification, lifestyle modifications, and medication and follow-up appointments. Forty three percent of participants were hospitalized due to uncontrolled hypertension and received the aforementioned intervention thereafter. Fourteen percent of participants underwent surgery due to cardiac complications.

Eight participants were unable to read and/or write. The information was provided verbally and these participants responded verbally to the questions in the questionnaire. The remainder of the participants demonstrated adequate English proficiency as they were able to respond appropriately to Yes/No-questions and provide information regarding their health and hearing status in English. Those participants were therefore able to complete the case history questionnaire. All participants included in the study were able to follow simple instructions provided in English and were able to repeat English spondee words.

3.4.3 Equipment and measures

The following equipment was utilized during the data collection procedure:

- Sound treated booth
- Heine Mini 2000 otoscope and specula
- A recently calibrated GSI 38 tympanometer with built-in acoustic reflex testing settings
- Probe tips
- A recently calibrated GSI 61 clinical audiometer
- Subject hand-response button
- Test headset (matched set TDH-50P)
- Bone vibrator (B71)
- Test microphone/monitor headset with coiled cord
- Talkback microphone
- Spondee Wordlist (Punch & Howard, 1985)
- National Acoustic Laboratories-Arthur Boothroyd (NAL-AB) wordlist (American Speech-Language and Hearing Association, 1988). The use of these wordlists at supra-threshold levels provides valid and reliable speech discrimination results in speakers of South African English (Wilson, Jones, & Fridjhon, 1998)
- An AudX Oto-Acoustic Machine

In order to meet the requirements posed by the research aims, an audiological test battery was utilized. The use of the test battery approach allows for assessment of all components of the auditory pathway and it enables the cross-check principle to be applied (American Speech-Language and Hearing Association, 2004). The cross-check principle compares independent measures of the test battery to determine if results are consistent and reliable (Jerger & Hayes, 1976; Turner, 2003). The following tests comprised the test battery: otoscopic examination, immittance testing, pure-tone audiometry, speech audiometry and otoacoustic emissions. This test battery was selected because it enabled

an assessment of the integrity of the auditory pathway, allowed for the cross-check principle to be applied and allowed for determining a possible site of lesion. Table 7 provides information regarding the procedures implemented for the audiological evaluation and the rationale for each procedure.

Table 7

The Components of the Test Battery and the Equipment Utilized

Audiological Procedure	Aims and Rationale	Implementation
Otoscopic examination	An otoscopic examination allows the audiologist to assess the integrity of the exterior auditory meatus and the tympanic membrane (King, Coles, Lutman, & Robinson, 1992). A compromise in the integrity of the outer ear (for example impacted wax) may cause a conductive hearing loss.	<p>The otoscopic examination began with visualization of the pinnae and the surrounding area. Abnormalities of the pinnae such as brachial cleft sinuses (pre-auricular pits) or other malformations were documented.</p> <p>In the external auditory meatus, the presence of cerumen, blood/discharge, obstructions, and/or abnormalities such as fistulae, masses, or dehiscences were also documented.</p> <p>An otoscopic examination also allows for the visualization of the tympanic membrane. The tympanic membrane is usually semi-transparent, pearly grey in colour, and the umbo of the malleus and the long process of the incus can be seen through the normal tympanic membrane (Glasscock & Gulya, 2003; Morton, 1993).</p> <p>Results for the otoscopic examination were recorded as one of the following:</p> <ol style="list-style-type: none"> 1. No abnormalities detected: No abnormalities were detected and the relevant structures were observed to be intact. 2. Impacted wax: Participants who presented with impacted wax (that is, the tympanic membrane was not visible) were referred to the Out Patient Department at South Rand Hospital for management. They were tested once the wax was removed.
Immittance audiometry	Immittance audiometry is an objective procedure which assesses the status of middle ear function (Martin & Clark, 2007). A dysfunction in the middle ear causes a conductive hearing loss (Cleaessan Apelman, Touw-Otten, Melker, & Hordijk, 2007). The two components of immittance audiometry are tympanometry and acoustic reflex testing. Tympanometry measures the mobility of the	<p>Tympanometry was conducted bilaterally on all subjects. Tympanograms were analysed utilizing static admittance, the pressure peak and the ear canal volume. Table 8 provides the norms which were utilized for the classification of tympanograms.</p> <p>Ipsilateral acoustic reflex thresholds (ARTs) were also obtained. Acoustic reflexes were obtained using pure-tone stimuli at 500Hz, 1000Hz, and 2000Hz. ARTs at 4000Hz were also obtained however the data was not analyzed. At 4000Hz, many individuals with normal hearing have elevated ARTs due to rapid adaptation. The clinical use of ARTs at this frequency was therefore limited.</p>

Audiological Procedure	Aims and Rationale	Implementation
	<p>tympanic membrane (Hergils, Magnuson & Falk, 1990). The mobility of the eardrum impacts an individual's ability to hear since the tympanic membrane is responsible for the transmission of sound vibration from the external auditory meatus to the ossicles in the middle ear. When the mobility of the tympanic membrane varies from the normal range, disorders of the middle ear can be detected, thereby providing diagnostic information (Clark, Roeser & Mendrygal, 2008).</p> <p>Acoustic reflex testing measures the contraction of the stapedius muscle and the tensor tympani in response to intense auditory stimuli (King et al., 1992; Martin & Clark, 2007). Acoustic reflexes allow for the ear to protect itself from sounds it perceives to be too loud. The presence/absence of acoustic reflexes and the intensity levels at which they occur provide diagnostic audiological data.</p>	<p>Normal ARTs are present between 85-100dB SPL for pure-tones (Gelfand, 2009, p. 223). Participants who presented with levels less than or greater than 85-100dB were considered to have depressed or elevated ARTs respectively.</p>
<p>Pure tone testing</p>	<p>Pure tone testing is a standard hearing test which requires an individual to listen to a series of tones at different frequencies and intensities and ultimately provides information regarding hearing thresholds (Valente, Hosford-Dunn & Roeser, 2000).</p> <p>Pure tone audiometry is the most vital aspect of an audiological assessment as it provides quantifiable results and allows for classification of hearing according to degree, configuration and type (McCormick, 1995).</p>	<p>Pure-tone testing was conducted in a sound treated booth. Participants were required to respond to auditory stimuli to indicate that they have heard a sound (frequency specific beeps). Air conduction and bone conduction pure tone audiometry were conducted for standard audiometric frequencies: 250, 500, 1000, 2000, 4000, and 8000 Hz (8000 Hz was excluded for bone conduction testing in accordance with the American Speech-Language and Hearing Association guidelines (2005)). The bracketing method (Lassman & Aldridge, 1985) was utilized to establish thresholds and results were recorded on an audiogram (Appendix C).</p> <p>The degree of hearing loss was determined utilizing the grading system of the World Health Organization (World Health Organization, 2012). The grade of impairment is based on the calculated average of air conduction thresholds for 500, 1000 and 2000</p>

Audiological Procedure	Aims and Rationale	Implementation
	<p>Pure tone audiometry consists of two procedures: air conduction testing and bone conduction testing. Air conduction testing utilizes a headset and assesses the entire peripheral auditory (Hughes & Pensak, 2007). Bone conduction testing utilizes a bone vibrator and bypasses the conductive component of the ear to stimulate the cochlea, thus providing sensorineural results (Hughes & Pensak, 2007).</p>	<p>Hz. Table 9 provides the World Health Organization's grades of hearing impairment.</p> <p>The nature of hearing loss was classified as:</p> <ol style="list-style-type: none"> 1. Conductive: air conduction thresholds were reduced, but bone conduction thresholds were within normal limits 2. Sensorineural: A hearing loss is sensorineural in nature when both air- and bone-conduction thresholds are elevated but within 10dB of each other (Roeser Valente, & Hosford-Dunn, 2007). Participants who presented with elevated air and bone conduction thresholds but with an air-bone gap of less than 10dB were classified as presenting with a sensorineural hearing loss 3. Mixed: Both air conduction and bone conduction thresholds were reduced and not within normal limits.
<p>Speech audiometry</p>	<p>Speech audiometry consists of two components: speech reception threshold and speech discrimination.</p> <p>The speech reception threshold determines the softest level at which an individual can hear speech/familiar words (Gelfand, 2009).</p>	<p>To obtain a speech reception threshold, participants were instructed to repeat spondee words. The intensity level was decreased in 10dB steps until the participant was unable to respond correctly after which the intensity was increased in 5dB increments and four words were presented at each level. The speech reception threshold was documented as the lowest level at which the participant produced a correct response more than 50% of the time. Two correct responses out of four presentations were documented as a threshold.</p>
<p>Speech discrimination testing is a supra-threshold test which determines how well an individual responds to different levels of loudness. (King et al, 1992). It therefore supplies information regarding the type of sensorineural hearing loss (for example cochlear versus retrocochlear) (Gelfand, 2009). This diagnostic information provides insight regarding the possible site of lesion (Gelfand, 2009).</p>	<p>For the uncomfortable loudness level, the intensity was increased in 5dB increments and the participants responded by saying 'stop' when the sound was felt to be too loud. Individuals with normal hearing should present with an uncomfortable loudness level of between 80dB and 100dB (Kaplan, Gladstone & Lloyd, 1993).</p>	<p>Participants were also required to repeat lists of words at different loudness levels for speech discrimination testing. NAL-AB word lists were utilized for speech discrimination testing and NAL scoring procedures were utilized as described by Dean & McDermott (2000)</p>
<p>When conducting speech audiometry, the difference between the speech reception threshold and the pure tone average (of each</p>	<p>The dynamic range is the difference (in dB) between the uncomfortable loudness level and the speech reception threshold (Gelfand, 2009). The dynamic range, in essence, is an individuals' usable listening range. The dynamic range of each participant was calculated utilizing the following formula:</p>	

Audiological Procedure	Aims and Rationale	Implementation
	<p>ear) is calculated. As both the speech reception threshold and the pure tone average are representative of thresholds, they should not be significantly different (Highes & Pensak, 2007).</p>	<p>Uncomfortable loudness level - speech reception threshold = dynamic range (dB) (Kaplan et al., 1993).</p> <p>The correlation between speech reception threshold and pure tone average was also calculated for each participant for both the right ear and the left ear. The difference (in dB) between the speech reception threshold and the pure tone average of the same ear is the speech reception threshold-pure tone average correlation (Bluestone, 2003). A correlation of 8dB or less is considered to be a good correlation and is indicative of reliable results (Bluestone, 2003; Hergenreder & Tang, 1992).</p>
<p>Distortion product otoacoustic emissions</p>	<p>Otoacoustic emissions (OAEs) are an objective measure that records the electrophysiological responses of the outer hair cell function in the cochlea (Torre et al., 2005). OAEs can be used to detect cochlear dysfunction before it is evident from pure-tone audiometry. OAEs also provide frequency-specific audiological information (Hall, 2000). OAEs, and therefore, play an integral role in the early identification and diagnosis of hearing loss (Lisowska Grzegors, Morawski, & Strojek, 2001).</p> <p>When conducting OAEs, it is important to consider the signal-to-noise ratio. This ratio is the difference (in dB) between the level of the response (in dB) and the level of background noise (in dB) (Robinette & Glatcke, 2002). The signal-to-noise ratio is utilized as a measure of reliability as it provides information regarding the contribution of noise.</p>	<p>The test was conducted in a sound treated booth to ensure reliable results. Participants were instructed to remain silent and still for the duration of this test. Once the test was completed the results were documented on a record sheet (Appendix C).</p> <p>Distortion product otoacoustic emissions were assessed at the following frequencies: 750Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz and 8000Hz. The strength of the OAE (in dB) was recorded along with the pass/refer result. The pass/fail criteria utilized was that of the AudX Adult Standard Screening Protocol which was based on the individual protocol of the instrumentation, signal-to-noise ratio, the strength of the OAE and acceptable false-positive and false-negative rates.</p> <p>A result of an OAE is considered to be reliable if the signal-to-noise ratio is more than 6dB (Robinette & Glatcke, 2002). In situations where noise levels are low and the ratio is more than 6dB it may be possible to miss a hearing loss due to level of the signal (Robinette & Glatcke, 2002). Utilizing a signal-to-noise ratio alone to interpret OAEs is, therefore, not recommended (Robinette & Glatcke, 2002). The AudX Adult Standard Screening Protocol, therefore, utilized the strength of the OAE in determining its pass/fail result.</p>

Note. dB= decibel; ART= acoustic reflex threshold, PTA= pure tone average, SRT= speech reception threshold, OAE= otoacoustic emissions.

Tympanograms were classified as being A, As, Ad, B or C (Clark et al., 2008; Roeser et al., 2007) (Table 8).

Table 8

Classification of Tympanograms

Classification of Tympanogram	Ear Canal Volume (ml³)	Static Admittance (mmho/ml³)	Peak Pressure (daPa)	Clinical Finding
Type A	0.6-1.5	0.3 - 1.4	+50 to -150	Normal middle ear function
Type As	0.6-1.5	< 0.3	+50 to -150	Stiffness on the middle ear system
Type Ad	0.6-1.5	> 1.4	+ 50 to -150	Disarticulation in the middle ear ossicles
Type B	>1.5	< 0.3	No peak	Pathological condition with possible perforated tympanic membrane
Type B	0.6-1.5	< 0.3	No peak	Restricted tympanic membrane mobility
Type C	0.6-1.5	0.3 – 1.4	-150 and higher	Significant negative pressure in the middle ear cavity

The degree of hearing loss of participants was classified utilizing the World Health Organization grading system for hearing impairment as described by Mathers et al. (2000). Table 9 provides the World Health Organization's grades of hearing impairment utilized in the study.

Table 9

World Health Organization's Grades of Hearing Impairment

Grade of Impairment	Audiometric ISO Value
0 (no impairment)	25dB HL or less
1 (slight/mild impairment)	26-40dB HL
2 (moderate impairment)	41-60dB HL
3 (severe impairment)	61-80dB HL
4 (profound impairment including deafness)	81dB HL or greater

Note. dB HL=decibels hearing level

3.4.4 Infection control

Precautions regarding infection control not only reduce but also prevent healthcare associated infections (Garcia-Zapata et al., 2010). Stringent hand hygiene and precautions when utilizing equipment is therefore recommended for safe practice (Garcia-Zapata et al., 2010). The

researcher therefore washed her hands prior to the audiological evaluation of each participant, utilized Dismed D-Germ alcohol antiseptic hand rub when necessary and utilized latex gloves when necessary. Different specula were also utilized for each ear (for each participant) for hygiene purposes. Milton sterilising fluid was utilized on all specula to disinfect them prior to use. The earphones, bone conductor and response button were disinfected with Webcol alcohol prep pads prior to use for each participant.

3.4.5 Data collection procedures

The procedure used during the research process are described below.

Ethical clearance was obtained from the University of Witwatersrand Human Research Ethics Committee (Certificate number: M10736) (Appendix D). Once ethical clearance was obtained, permission was requested from the chief executive officers of the Charlotte Maxeke Johannesburg Academic Hospital (Appendix E) and South Rand Hospital (Appendix F) respectively.

On confirmation of permission, a pilot study was conducted at South Rand Hospital with four individuals who met the selection criteria. The results of these individuals were not included in the main study. Once the modifications from the pilot study were complete, the researcher recruited participants for the main study.

The researcher attended the Out Patient Department at South Rand Hospital and the Cardiology Clinic at Charlotte Maxeke Johannesburg Academic Hospital. With the doctors' and cardiologists' assistance, potential participants for the study were identified. These individuals were approached by the researcher who presented them with a participant information sheet (Appendix B). Individuals who were unable to read and/or write were provided with the information verbally.

Individuals who were willing to participate were required to complete a consent form (Appendix B). Participants who were unable to read and/or write confirmed their consent with a thumb print.

Once participant consent was obtained, the researcher completed the questionnaire with all participants (Appendix A). The information obtained in the case history further determined if an individual met the criteria for inclusion in this study.

Once the case history form was completed by the researcher and it was determined that an individual met the selection criteria, an appointment was made to conduct an audiological evaluation at the South Rand Hospital Audiology Department at a time that was suitable for the participant. For the 43 participants who were obtained at the Out Patient Department at South Rand Hospital, the audiological evaluation was conducted immediately or on the same day.

On completion of the audiological evaluation, participants were provided with feedback regarding the results of the evaluation. Two participants contacted the researcher after their audiological evaluation to request that feedback be provided to a spouse or family member.

For participants who required further audiological management, a follow-up appointment was made at South Rand Hospital or they were referred to a facility/institution that was more convenient for them. Participants who required medical intervention were referred accordingly. These participants were provided with a report of their audiological results (Appendix G).

After the audiological evaluation, participants were thanked verbally and provided with a packet of sweets as a token of appreciation.

All participants who utilized their own transport to attend their appointment for the audiological evaluation were offered R50.00 as compensation; however, only five participants accepted the remuneration.

Once the audiological evaluation was completed, data was captured, encoded and analysed using various statistical measures.

3.4.6 Reliability and validity

3.4.6.1 Reliability

Reliability is the “degree to which a procedure for measuring produces similar outcomes when it is repeated” (Baker, 1994, p. 127). It refers to the consistency or the stability of research findings (Rosnow & Rosenthal, 2006). There are different types of reliability, two of which are equivalent forms reliability and inter-rater reliability:

- Equivalent forms reliability is imperative as participants were assessed only once in this study (Baker, 1994). Equivalent forms reliability concerns determining the degree to which results are consistent (Huck, 2008). This form of reliability utilizes two different measures to determine the same/similar result (Bless, Higson-Smith, & Kagee, 2007). Equivalent forms reliability can be established using the cross-check principle. The cross-check principle is the process whereby the results of one test are compared to another

independent measure (Jerger & Hayes, 1976; Turner, 2003). In this study the speech reception threshold was compared to the pure tone average, as both procedures assess the lowest intensity at which participants can hear a sound (tone or speech sounds). A correlation between the speech reception threshold and the pure tone average of 8dB or less is considered to be indicative of reliable results (Bluestone, 2003; Hergenreder & Tang, 1992).

- Inter-rater reliability is the degree of consistency of two or more individuals recording the same results for the same procedure (Huck, 2008; Rosnow & Rosenthal, 2006). This is usually implemented by having an impartial individual observe and record results for approximately 15% of the experiments/evaluations after which a reliability co-efficient is calculated (Spata, 2003). The researcher ensured that 20% ($n = 18$) of the audiological evaluations were observed and independently recorded by another audiologist, thus contributing to inter-rater reliability. The other audiologist had eight years clinical experience in conducting audiological evaluations. Once the impartial audiologist had observed and independently recorded 20% of the audiological evaluations, inter-rater reliability was calculated as a percentage utilizing the following formula (Jackson, 2009):

$$\text{Inter-rater reliability (\%)} = (\text{Number of agreements} / \text{Number of possible agreements}) \times 100$$

The number of agreements refers to the number of observations/recordings in which both raters have documented/recorded the same result (Jackson, 2009). The number of possible agreements refers to the total number of observations/recordings (Jackson, 2009). Throughout the audiological evaluation, a total of 48 agreements were possible. The sum of 48 comprised observations for otoscopic examination, tympanometry, pure tone audiometry, pure tone average and speech audiometry. Table 10 provides the point/agreement allocation for each audiological procedure.

Table 10

Point Allocation for each Audiological Procedure for Inter-Rater Reliability

Audiological procedure	Components	Number of points/agreements (including right ear and left ear)	
		Right ear	Left ear
Otoscope examination	Otoscope Examination	1	1
Tympanometry	Tympanogram	1	1
Pure tone Audiometry	Air conduction testing (each test frequency)	6	6
	Bone conduction testing (each test frequency)	5	5
	Pure tone average	1	1
Speech audiometry	Speech reception threshold	1	1
	Most comfortable level	1	1
	Uncomfortable loudness level	1	1
	Dynamic range	1	1
	Speech discrimination (including level of presentation and result obtained)	6	6
Total per ear		24	24
Total number of possible agreements		48	

The number of agreements for all 18 participants was added and the sum of 792 agreements was obtained out of a possible 864. This resulted in an inter-rater reliability of 92% indicating a very good inter-rater reliability (Jackson, 2009).

The reliability of the study was further improved as the criteria, the researcher, data collection procedure (test protocol) and the instrumentation used was the same for all participants in this study, thus enhancing consistency. The measures utilized during the audiological evaluation were standardized procedures which were repeatable, thus contributing to reliability.

3.4.6.2 Validity

Validity is the degree to which research results are accurate (Baker, 1994; Huck, 2008). Audiologically, this refers to the ability of a test to detect the disorder for which it was designed (Roeser et al., 2007). There are many different types of validity; however, the two types most appropriate for this study were face validity and content validity.

Face validity refers to the degree to which an instrument/procedure measures what it intends to measure (Rosnow & Rosenthal, 2006). The researcher gave the participant

questionnaire to two qualified audiologists for critique. The two audiologists had six years and four years clinical experience respectively. The two audiologists were, therefore, knowledgeable regarding the content of audiology case history questionnaires and modifications were made based on their recommendations. Both audiologists agreed that the questions in the participant questionnaire were relevant to the study and allowed for specificity and sensitivity regarding participant criteria. This enhanced face validity since the participant questionnaire was in accordance with the aims of the study.

Content validity is the accuracy of procedures and equipment to measure what they claim to measure (Baker, 1994). Calibration of equipment ensures accurate functioning of equipment, thus contributing to the validity of results. All the equipment utilized in the study has been recently calibrated. Calibration standards were in accordance with those prescribed by the South African National Standards (2004) (SABS 0154-1; 0154-2), thereby ensuring that the results were accurate and valid (Appendix H). Furthermore, a pilot study was conducted on four individuals who met the participant selection criteria. This allowed for further modifications to be made, thus enhancing content validity in this study.

3.5 Ethical Considerations

In 1964, the World Medical Association developed the Declaration of Helsinki. This declaration was a set of ethical principles for researchers involved in medical research in human beings (World Medical Association, 2008). The principles are aimed at promoting the safety and well-being of the patient (World Medical Association, 2008). The following principles were adhered to in this study:

- Submission of research protocols for consideration and approval (World Medical Association, 2008). A research proposal was submitted for ethical clearance to the Human Research Ethics Committee (Medical) at University of Witwatersrand (Certificate number: M10736) (Appendix D). Only once ethical clearance was obtained did the study proceed. Furthermore, consent was obtained from South Rand Hospital (Appendix F) and Charlotte Maxeke Johannesburg Academic Hospital (Appendix E) to obtain participants from those sites.
- Participation in medical research should be voluntary (World Medical Association, 2008). Informed consent was obtained from all participants. Individuals willing to participate in this study were required to complete a consent form and only

participants who met the selection criteria were included in the study. Participants were made aware that should they decide not to participate, or decide to withdraw at a later stage; no penalty would be incurred. They also had the right to refuse to answer any particular question/s should they wish.

- Human subjects should be informed of the aims, methods and potential risks of the study and possible discomfort which it may entail (World Medical Association 2008). Participants were provided with an information sheet which outlined the nature of this study, risks and benefits, the procedures and informed participants of their right to withdraw.
- Precautions should be taken to protect the privacy of research subjects and confidentiality regarding personal information should be assured (World Medical Association, 2008). The privacy of participants in this study was considered at all times during and after the data collection process. The participant questionnaire was completed in a private setting, free from interruptions and onlookers. This ensured confidentiality. Anonymity of participants should be ensured from the beginning to ensure confidentiality (Meline, 2006). As each participant was assessed in person, complete anonymity could not be guaranteed. The researcher did, however, maintain confidentiality by not including any identifying information in the research report. Once data was collected, it was coded utilizing participant numbers only. Raw data (containing identifying information) was kept separate from coded data and was stored in a locked cupboard in the researcher's residence for the duration of the study. Thereafter the raw data will be stored in a locked cabinet in the Department of Speech Pathology and Audiology at the University of Witwatersrand for a period of five years. After this period, the raw data will be destroyed.
- Medical research must be conducted by individuals with appropriate training and qualification (World Medical Association, 2008). The researcher is a qualified audiologist with seven years experience clinical experience in the field of Audiology. She therefore has appropriate skills and knowledge to conduct the audiological evaluations on the participants in this study.
- Prior to commencement of a study, risks need to be assessed and satisfactorily managed (World Medical Association, 2008). The risks associated with an

audiological evaluation include only a small possibility of temporary discomfort. The participants were, nonetheless, provided with the researcher's 24-hour contact number should they had any queries.

- Subjects should incur a minimal burden through participation (World Medical Association, 2008). Participants who were not regular patients at South Rand Hospital and who utilized their own means of transport to get to the hospital were offered R50.00 financial compensation for travel expenses on the day of testing. This was done to reduce the inconvenience to participants and to reduce the burden of additional costs. For individuals who did not meet the selection criteria but still requested an audiological evaluation, an appointment was made at the South Rand Hospital. Alternatively, if they preferred, they were referred to a facility that was more convenient for them.

3.6 Analysis of Data

Data were captured and encoded for analysis according to the data definitions. The researcher analysed the data to determine the characteristics of the variables and to determine if the hypothesis had been proven (Dietz & Kalof, 2009). All the data was computerized for statistical analysis on an MS Excel spreadsheet and the XLSTAT (XLSTAT Software, 1995) statistical analysis program (XLSTAT Software, 1995). The results were then analysed using a variety of statistical procedures and displayed in tables and figures.

The researcher employed content analysis, descriptive statistics and parametric measures to analyse the data as data was normally distributed.

Content analysis provides categorical data which lends itself to quantification (Breakwell, 2000). Once the data was collected, similarities or themes were identified (for instance, the number of participants who shared the same biographical information, medical information, audiological information, recommendations). Descriptive analysis allows for the description of quantitative data by calculating means, standard deviations and the range (Babbie, 2010). In this study the mean, median and mode was calculated for each test frequency on the audiogram for all possible combinations of analysis (for example entire sample, age, male/female, type of cardiovascular disease and the duration of the disease). The mean, standard deviation and range was also calculated for speech reception threshold results and for the results of otoacoustic emissions for each frequency.

Various parametric statistical analysis measures were utilized to analyse the data. These included one-tailed *t*-tests, two-tailed *t*-tests and an analysis of co-variance. One-tailed *t*-tests are parametric measures which utilize a hypothesis to compare the mean score of a sample against a normative value or mean (Bland, 2001; Dalgaard, 2008). This test was appropriate for this study, since the aim of the study was to determine if there was a significant difference in the hearing abilities of individuals with cardiovascular disease compared to those without the disease. This *t*-test enabled the researcher to analyse the pure-tone results and to compare them to the norms for normal hearing. This *t*-test also allowed for the comparison of subgroups within the sample to be compared to the norms (for example participants with coronary artery disease/cardiomyopathy, males, and females).

A two-tailed *t*-test compares the mean of two samples and determines if the differences between the two are statistically significant (Steinberg, 2011). Two-tailed *t*-tests are often utilized to compare males and females or to compare two different test groups with the null hypothesis. In this study, the two-tailed *t*-tests were utilized to compare males to females and participants with coronary artery disease to participants with cardiomyopathy.

An analysis of co-variance is a technique which lies between analysis of variance and regression analysis. It is a form of multiple linear regression which is also known as the general linear model (Howell, 1997). Analysis of co-variance allows for precise comparisons between groups by accounting for the variation of important prognostic variables (for example when comparing two linear regression lines) (Borm, Fransen, & Lemmens, 2007). As opposed to other methods of data analysis for quantitative analysis, the analysis of co-variance has three variables: the independent variable, the dependent variable and the co-variate. In this study, the dependent variable was the hearing level at each frequency and the independent variable was cardiovascular disease. The co-variants were age, gender and duration of cardiovascular disease. The analysis of co-variance calculated the degree to which age, gender and duration of the disease impacted on hearing in individuals with this disease. It also calculated the combination of these variables and the statistical probability of each combination influencing hearing in individuals with the disease.

A confidence level of 99% ($\alpha=0.01$) was utilized for all tests. Confidence levels reduce the uncertainty of the results obtained during the data analysis process (Siegel, 2012). Confidence levels therefore determine the success rate of the test being utilized (Moore, 2010). Whilst 95% is commonly utilized when analysing data, a confidence level of 99% is

recommended in medical research as it allows for surety of results. A 99% confidence level is also recommended for large samples as this reduces the probability of results being attributed to deviations and random errors (Siegel, 2012). The use of a 99% confidence level was therefore appropriate for this study.

3.7 Conclusion

This chapter described the methodology of the research. It included the aim of the research and a description of the research design and phases. A description of the pilot study that indicated problem areas and recommendations followed. The main study was discussed with respect to participant selection criteria and description, as well as equipment and measuring instruments. Finally data collection procedures and analysis were discussed.

CHAPTER 4

RESULTS

4.1 Introduction

The results of the study are presented in this chapter in relation to the aims of the study. This chapter commences with a description of the audiological findings after which the four independent variables are discussed. Data was organized, analysed and interpreted with a view on drawing conclusions regarding the prevalence of hearing loss in individuals with the disease.

4.2 Description of the Audiological Findings

4.2.1 Case history according to participant questionnaire

The participant questionnaire provided relevant information about participants' perception of their hearing abilities. The primary complaint of many participants was difficulty hearing in noise. Forty percent of the participants ($n = 44$) reported that they experience hearing difficulties. This included difficulty hearing in noise ($n = 32$), difficulty hearing in all situations ($n = 10$), and difficulty hearing female voices ($n = 2$). Figure 1 illustrates the percentage of participants who reported each type of difficulty.

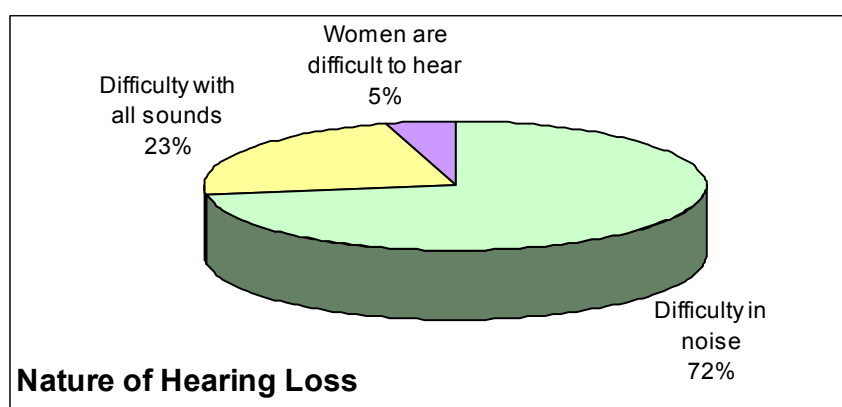


Figure 1. The percentage of participants who reported each type of hearing difficulty

These participants also indicated the laterality of the hearing difficulties they experience. Twenty three percent ($n = 10$) reported the right ear to be worse, 16% ($n = 7$) reported the left ear to be worse, whilst 61% ($n = 27$) reported the hearing ability of both ears to be similar.

The onset of the hearing difficulties prior to testing in this study ranged between one and three years. Sixty one percent of participants ($n = 27$) reported experiencing hearing difficulties for between one and two years and 39% ($n = 17$) reported experiencing hearing difficulties for two to three years. Sixteen percent ($n = 7$) of the participants who reported hearing difficulties stated that their hearing had deteriorated since being diagnosed with cardiovascular disease.

Thirty four percent of the participants ($n = 31$) reported experiencing tinnitus. Of these participants all reported experiencing constant, high frequency tinnitus bilaterally. Sixty one percent ($n = 19$) reported their tinnitus to be worse in the morning, whilst 39% ($n = 12$) reported it to be worse at night prior to going to sleep. Other difficulties reported by some participants included asthma, arthritis and/or visual difficulties.

4.2.2 Otoscopic examination

An otoscopic examination revealed that the majority of participants (73%; $n = 67$ in the right ear and 78%; $n = 72$ in the left ear) presented with unobstructed ear canals and healthy tympanic membranes. Partially occluding, soft cerumen was observed in 27% ($n = 25$) of participants in the right ear and in 22% ($n = 20$) in the left ear. The presence of the cerumen did not interfere with the audiological evaluation. Of the 92 participants, three presented with impacted cerumen. They were referred to the Out Patient Department at South Rand Hospital for management. The cerumen was removed, after which the audiological evaluation was conducted.

4.2.3 Immittance audiometry

Immittance audiometry comprised tympanometry and ipsi-lateral acoustic reflexes. The tympanometry results indicated that 99% ($n = 91$) and 96% ($n = 88$) of participants presented with a normal type A tympanogram in the right ear and left ear respectively. Type C tympanograms were recorded for one percent ($n = 1$) and four percent ($n = 4$) in the right ear and left ear respectively. Participants with type C tympanograms were included from the study. These results indicate that middle ear pathology does not significantly contribute to hearing loss in adults with cardiovascular disease.

The results of the ipsi-lateral acoustic reflexes are presented in Table 11. Only the results of the participants who obtained acoustic reflexes at each test frequency in the right ear and the

left ear are provided. Normal acoustic reflexes thresholds are between 85dB and 100dB, whilst acoustic reflexes thresholds greater than 100dB are considered to be elevated (Gelfand, 2009)

Table 11

Results of Participants who Obtained Acoustic Reflexes

Reflexes obtained by participants	Percentage of Participants in Whom Ipsi-Lateral Acoustic Reflexes were Recorded % (n)							
	Right Ear				Left Ear			
	500Hz	1000Hz	2000Hz	4000Hz	500Hz	1000Hz	2000Hz	4000Hz
AR obtained	67(62)	55(51)	61(56)	24(22)	65(60)	53(49)	65(60)	15(14)
90dB	15(9)	0(0)	0(0)	0(0)	17(10)	10(5)	0(0)	0(0)
95dB	13(8)	45(23)	46(26)	0(0)	22(13)	0(0)	18(11)	0(0)
100dB	44(27)	33(17)	23(13)	64(14)	45(27)	45(22)	37(22)	0(0)
105dB	29(18)	22(11)	30(17)	36(8)	17(10)	45(22)	45(27)	100(14)
Average AR (in dB)	99.35	98.2	99.2	101.8	98.8	101.2	101.3	105
Range (in dB)	90-105	90-105	90-105	100-105	90-105	90-105	95-105	-
St. Dev (in dB)	4.99	3.94	4.34	2.46	4.79	4.51	3.78	-

Note. AR= acoustic reflex; dB=decibel; St. Dev=standard deviation; Hz=hertz

None of the participants obtained acoustic reflexes less than 85dB bilaterally. The difference between the percentage of participants who obtained acoustic reflexes in the right ear and the left ear ranges from one percent (at 500Hz) to nine percent (at 4000Hz). The average of the reflexes increased bilaterally with each frequency. The average was greater than 100dB for 4000Hz in the right ear and 1000Hz, 2000Hz and 4000Hz in the left ear. The percentage of participants who obtained a reflex greater than 100dB also increased with each test frequency and the percentage of participants who obtained a reflex greater than 100dB was higher in the left ear at 1000Hz, 2000Hz, and 4000Hz.

4.2.4 Pure tone audiometry

4.2.4.1 Air conduction

Air conduction thresholds were obtained for all participants. Thresholds less than 25dB are considered to be within normal limits. Thresholds greater than 25dB are considered elevated and indicate some degree of hearing impairment (Mathers et al., 2000). A difference of 10dB or less between air conduction and bone conduction thresholds (at each frequency) is indicative of a sensorineural hearing loss only if both thresholds are greater than 25dB. A difference of more than 10dB indicates a conductive/mixed component (Roeser et al., 2007).

More than 60% of participants obtained all air conduction thresholds less than 25dB, indicating normal hearing in those participants (Table 12).

Table 12

Results of Participants with Normal Air Conduction Thresholds at All Test Frequencies

	Air Conduction Thresholds % (n)		
	Right Ear	Left Ear	Bilateral
All thresholds <25dB	64 (58)	55 (51)	66 (61)

Air conduction results revealed that many participants presented with hearing within normal limits for all but one frequency. Average thresholds less than 25dB were obtained at 500Hz, 1000Hz, 2000Hz, 4000Hz and 8000Hz in both ears. The average threshold for 250Hz was 36.25dB in the right ear and 28.10dB in the left ear. Sixty three percent of participants ($n = 58$) obtained a threshold of more than 25dB at 250Hz in the right ear and 55% ($n = 51$) in the left ear. Thirty eight percent of participants ($n = 35$) obtained a threshold greater than 25dB at 500Hz in the right ear and fifty percent ($n = 46$) in the left ear. The percentage of participants who

obtained thresholds greater than 25dB decreased with each frequency octave. This proves that the participants in this sample presented with a low frequency hearing loss.

The average of the pure tone average was 20.27dB for the right ear and 17.71dB for the left ear (Table 13). Although this was less than 25dB bilaterally, 11% of participants ($n = 10$) obtained a pure tone average greater than 25dB in the right ear and five percent ($n = 5$) in the left ear. This indicates that the prevalence of hearing loss in this population is 11% in the right ear and five percent in the left ear. Of the 11% who presented with an elevated pure tone average in the right ear, 50% ($n = 5$) presented with a moderate hearing loss and 50% ($n = 5$) presented with a mild hearing loss. All participants who presented with an elevated pure tone average in the left ear presented with a mild hearing loss.

A one-tail t -test was conducted at each frequency for air conduction thresholds to determine if the difference between the average threshold obtained and the norm of 25dB is statistically significant. The null hypothesis being tested was, the sample has normal hearing. The alternate hypothesis was that the sample has impaired hearing (that is, the mean of the sample is significantly greater than 25dB). The p -value determined if the null hypothesis was rejected. At 250Hz in the right ear, a p -value of <0.0001 was obtained. This implies that the difference between the average of the sample, when compared to normal hearing thresholds, was statistically significant at 250Hz in the right ear. The null hypothesis was, therefore, rejected at that frequency. The differences were deemed not significant at all other frequencies in the right ear and at all test frequencies in the left ear; and the null hypothesis was, therefore, not rejected. While the t -test results did not reject the null hypothesis at any other test frequencies and the difference between participants' averages and the norm were deemed statistically insignificant, 38% of participants ($n = 35$) obtained a threshold greater than 25dB in the right ear and 23% of participants ($n = 21$) in the left ear at 500Hz for air conduction thresholds. The standard deviation was higher in the low frequencies in both the right ear and the left due to an increase in the range. The air conduction thresholds, pure tone audiometry and t -test results are presented in Table 13.

Table 13

Results of Air Conduction Thresholds, the Pure Tone Average and Results of the t-Test at Each Test Frequency

	Air Conduction Thresholds													
	Right Ear (in dB)							Left Ear (in dB)						
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	PTA	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	PTA
Ave(dB)	36.25	24.73	18.91	16.74	16.25	20.27	20.27	28.10	20.92	15.98	17.28	15.11	16.63	17.71
St. Dev (dB)	14.14	11.89	8.05	6.04	4.84	5.52	8.25	14.62	9.92	7.27	6.65	6.42	4.64	6.43
Range (dB)	15-60	10-55	5-40	5-30	5-30	10-35	6.6-41.6	5-50	5-45	5-35	5-35	5-25	5-25	10-35
p-value	<0.0001*	0.5865	1.0000	1.0000	1.0000	1.0000	-	0.0225	0.9999	1.0000	1.0000	1.0000	1.0000	-
>25dB (%)	63	38	11	5	0	5	11	55	23	5	5	0	0	5

Note. *significant at confidence level of 99%; Ave=average; St. Dev=standard deviation; dB=decibel; PTA=pure tone average; Hz=hertz

4.2.4.2 Bone conduction

The percentage of participants who presented with normal bone conduction thresholds at all test frequencies is presented in Table 14. The average bone conduction threshold for 250Hz in the right ear was greater than 25dB and the average in the left ear was less than 25dB. Sixty two percent of participants ($n = 57$) obtained a threshold greater than 25dB at 250Hz in the right ear compared to 50% of participants ($n = 46$) in the left ear.

Table 14

Results of Participants with Normal Bone Conduction Thresholds at All Test Frequencies

	Bone Conduction Thresholds %(n)		
	Right Ear	Left Ear	Bilateral
All thresholds <25dB	62(57)	50(46)	66(61)

Note. dB=decibel

Thirty three percent of participants ($n = 30$) obtained a threshold greater than 25dB at 500Hz in the right ear compared to 11% of participants ($n = 10$) in the left ear, resulting in a difference of more than 20%. The percentage of participants who obtained thresholds greater than 25dB decreased with each frequency octave, indicating a low frequency sensorineural hearing loss.

More than 60% of participants obtained thresholds less than 25dB at all test frequencies, indicating normal hearing in those participants.

A one-tail t -test was conducted at each frequency for bone conduction thresholds to determine if the difference between the average threshold obtained and the norm of 25dB is statistically significant. At 250Hz in the right ear, a p -value of 0.0003 was obtained. This implies that the difference between the averages of the sample compared to normal hearing thresholds was statistically significant at 250Hz in the right ear. The null hypothesis that the sample has normal hearing for bone conduction thresholds in the right ear was, therefore, rejected at 250Hz. At all other frequencies the differences were deemed not significant in both the right ear and the left ear. The null hypothesis was, therefore, not rejected. While the t -test results did not reject H_0 at all other test frequencies and the difference between participants' averages and the norm were deemed

statistically insignificant, 50% of participants ($n = 46$) obtained thresholds greater than 25dB at 250Hz in the left ear. The average thresholds for the bone conduction results and the results of the t -tests are presented in Table 15.

Table 15

Results of Bone Conduction Thresholds and the t-Test at Each Test Frequency

	Bone conduction thresholds									
	Right Ear (in dB)					Left Ear (in dB)				
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Ave (dB)	30.05	21.52	15.49	13.70	12.61	24.13	16.63	12.39	13.59	10.33
St. Dev (dB)	13.80	12.98	7.45	7.80	5.16	14.04	9.58	6.18	6.77	6.66
Range (dB)	5-50	5-55	0-30	0-35	0-20	0-50	5-40	0-25	5-35	0-25
p-value	0.0003*	0.9941	1.0000	1.0000	1.0000	0.7231	1.0000	1.0000	1.0000	1.0000
>25dB (%)	62	33	5	5	0	50	11	0	5	0

Note. *==significant at a confidence level of 99%; Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

4.2.4.3 Air conduction and bone conduction

All bone conduction thresholds were less than air conduction thresholds for all participants at all test frequencies. The difference between air conduction and bone conduction thresholds range between 0dB and 10dB indicating a sensorineural hearing loss. The difference in averages between air conduction and bone conduction thresholds is presented in Figure 2 (right ear) and Figure 3 (left ear).

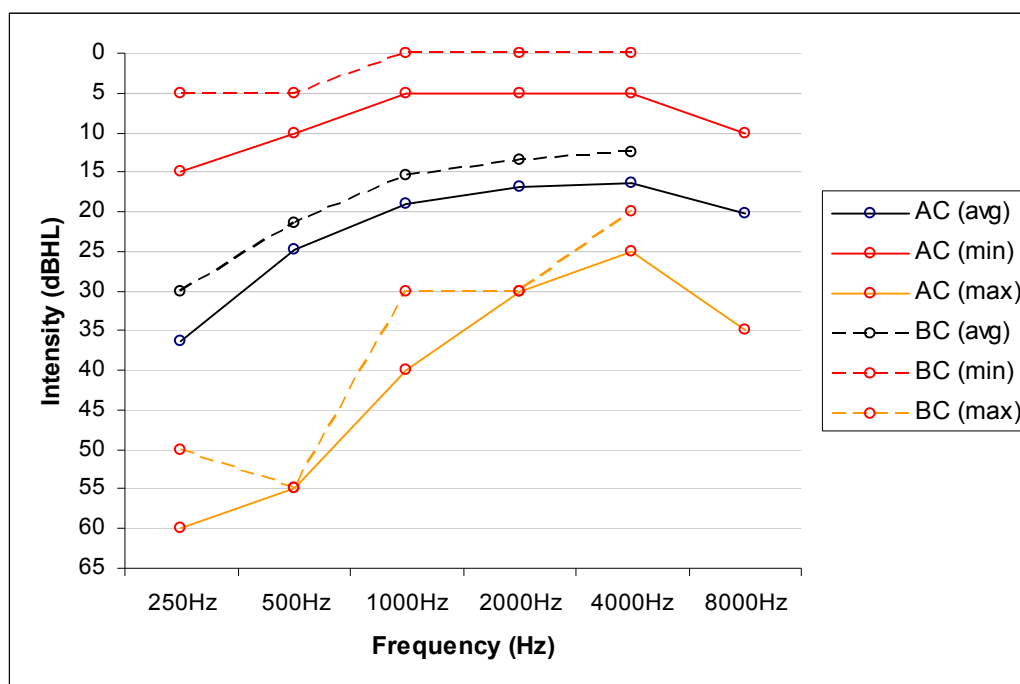


Figure 2. The range (in dB) and the average (in dB) for air conduction and bone conduction thresholds at each test frequency in the right ear

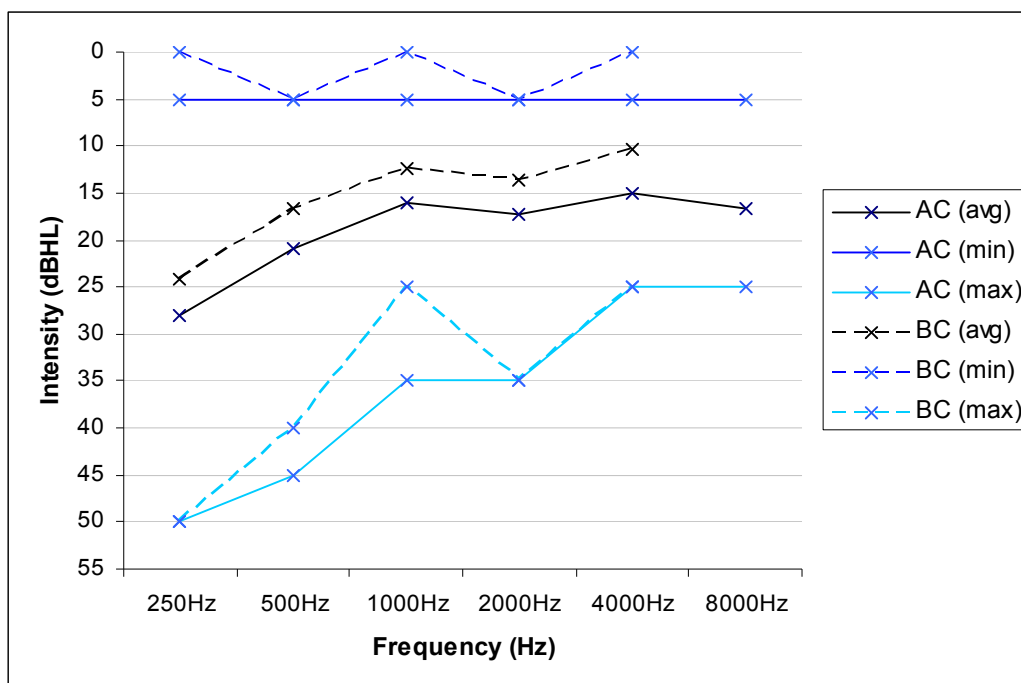


Figure 3. The range (in dB) and the average (in dB) for air conduction and bone conduction thresholds at each test frequency in the left ear

The average difference between air conduction and bone conduction thresholds is less than 6dB for all test frequencies bilaterally. The difference between air conduction and bone conduction thresholds ranged from 0dB to 15dB with the biggest range of 15dB recorded at 250Hz in the right ear. Only one participant presented with a difference of 15dB, indicating a conductive hearing loss in the right ear at 250Hz. The remaining participants who presented with elevated thresholds presented with a low frequency sensorineural hearing loss. The difference in averages is presented in Table 16.

Table 16

Results of the Average Difference between Air Conduction and Bone Conduction

	Right Ear					Left Ear				
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Ave(dB)	6.20	3.21	3.42	3.32	3.64	3.97	4.29	3.59	3.70	4.78
St. Dev (dB)	3.81	2.83	3.77	3.34	3.56	3.60	2.41	2.81	3.70	4.25
Range (in dB)	0 - 15	0 - 10	0 - 10	0 - 10	0 - 10	0 - 10	0 - 10	0 - 10	0 - 15	0 - 10

Note. Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

4.2.5 Speech audiometry

Speech audiometry comprised speech reception threshold, most comfortable level, uncomfortable loudness level, the dynamic range ($n = 10$) and speech discrimination levels. The average, standard deviation, minimum value, maximum value, the range and the mode was calculated for each component of speech audiometry. In addition, the correlation between the speech reception threshold and the pure tone average was calculated. Table 17 presents the results for the speech reception threshold, the most comfortable level, the uncomfortable loudness level, dynamic range and the difference between the speech reception threshold and the pure tone average.

The average speech reception threshold in the right ear was 3.1dB more than the speech reception threshold in the left ear. Both the right ear and the left ear had a range of 35dB for the speech reception threshold. The average most comfortable level was 26.9dB more than the speech reception threshold in the right ear and 30.32dB in the left ear. The average most comfortable level was between 25-30dB greater than the average for speech reception threshold even for participants with elevated pure-tone thresholds. The most comfortable level falls between 40-55dB greater than the speech reception threshold (Kaplan et al., 1993). The most comfortable levels fell less than 40dB for 10% of participants ($n = 10$) in the left ear. None of the participants presented with a most comfortable level of less than 40dB in the right ear. A low most comfortable level (when compared to the speech reception threshold) is suggestive a cochlear site of lesion (Kaplan et al., 1993).

The range of uncomfortable loudness level in the right ear and the left ear was equal (10dB). The average uncomfortable loudness level was 75dB higher than the speech reception threshold in the right ear and 76dB in the left ear. The average difference between the speech reception threshold and pure tone average was less than 5dB bilaterally with the range being 5.1dB higher in the left ear. Seventeen percent of participants ($n = 16$) reported their uncomfortable loudness level to be beyond the limits of the audiometer. As a result, the dynamic range for those participants could not be calculated. Speech discrimination at the last level (uncomfortable loudness level minus 10dB) could also not be conducted for those participants. The results in Table 17 exclude

those participants in the analysis for uncomfortable loudness level, dynamic range and level 3 for speech discrimination.

Table 17

Results for Speech Audiometry and the Correlation between Speech Reception Threshold and Pure Tone Average Difference (n = 76)

	Speech Reception Threshold		Most Comfortable Level		Uncomfortable Loudness Level		Dynamic Range		SRT-PTA difference	
	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
Average (dB)	23.21	20.11	50.11	50.43	98.89	96.64	79.09	79.27	3.51	3.38
St. Dev (dB)	8.50	7.45	10.22	9.94	2.78	2.99	6.32	3.53	1.16	1.93
Range (dB)	10-45	10-40	40-74	40-80	90-100	90-100	60-90	75-85	1.7-5	0-8.4

Note. Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz, SRT=speech reception threshold; PTA=pure tone average

The dynamic range for individuals with normal hearing is 80-100dB (Roeser Valente, & Hosford-Dunn, 2000). The average dynamic range for participants in this study was 70dB in the right ear and 61dB in the left ear. This indicated a reduced dynamic range for the participants with a low frequency hearing loss in this study.

None of the participants presented with rollover bilaterally. The results for speech discrimination testing are presented in Table 18.

Table 18

Results for Speech Discrimination

	SRT + 10dB (Level 1)		SRT + 25dB (Level 2)		UCL-10dB (Level 3)	
	Right	Left	Right	Left	Right	Left
Average (%)	27.42	35.54	78.40	76.45	96.94	96.93
St. Dev (%)	13.98	18.35	11.50	13.46	3.70	3.60
Range (%)	7-64	7-77	44-97	50-97	80-100	88-100

Note. St. Dev=standard deviation; SRT=speech reception threshold; dB=decibel

Significant rollover is seen in individuals with retro-cochlear pathology and in neural presbycusis (Gelfand, 2009; Kaplan et al., 1993). Individuals with cochlear pathology present with no decline or less than 20% decline as intensity increases (Roeser et al., 2000). Participants in this study, therefore, did not present with a hearing loss which was caused by retro-cochlear pathology and the results indicate that the pathology may be cochlear in nature.

4.2.6 Distortion product otoacoustic emissions

Distortion product otoacoustic emissions were tested at 750Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz and 8000Hz bilaterally. The average, standard deviation, minimum, maximum, range, mode and percentage of participants who passed this test were calculated at each test frequency for the right ear and the left ear. Table 19 provides the results for the distortion product otoacoustic emissions for each ear.

Table 19

The Average (in dB), Standard Deviation (in dB), Range (in dB), and Percentage (%) of Participants who Passed the Distortion Product Otoacoustic Emissions at Each Test Frequency

	Right Ear							Left Ear						
	750Hz	1000 Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz	750Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000 Hz	8000H z
Ave (dB)	-5.49	-2.62	0.23	1.58	1.90	2.26	1.60	-3.91	-0.21	1.75	2.65	2.21	2.04	1.90
SD (dB)	7.37	6.34	5.39	2.85	2.35	2.35	1.77	6.37	2.81	2.54	2.27	1.82	1.82	1.70
Range (dB)	-20 - 2	-20 - 3	-19 - 7	-6 - 7	-4 - 7	-4 - 7	-1 - 5	-19 - 2	-10 - 3	-3 - 6	-2 - 6	-1 - 7	-1 - 5	-1 - 6
Participants obtained a fail result % (n)	30(8)	17 (16)	5(5)	0(0)	0(0)	0(0)	0(0)	23(21)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)

Note. Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

The difference between the average at 750Hz for the right ear and for the left ear is 1.58dB, with the right ear being worse. The range decreased with each increasing octave with 750Hz having the biggest range bilaterally. Sixty six percent of participants ($n = 61$) passed all test frequencies bilaterally, 70% ($n = 64$) passed all test frequencies in the right ear and 77% ($n = 71$) passed all test frequencies in the left ear.

A two-tailed t -test was conducted to compare the difference between distortion product otoacoustic emissions in the right ear to those in the left ear at each test frequency. The null hypothesis was, there is no difference between distortion product otoacoustic emissions in the right ear and in the left ear. The alternate hypothesis was that there is a difference between distortion product otoacoustic emissions in the right ear and the left ear. Table 20 provides the results at each test frequency in the right ear and left ear.

Table 20

Results of the two-tailed t-Test comparing Distortion Product Otoacoustic Emissions in the Right Ear and Left Ear

	750Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
P-Value	0.0001*	<0.0001*	0.0009*	<0.0001*	0.1659	0.30062	0.1648

Note. *= significant difference at a confidence level of 99%.

Results from t -test revealed that the null hypothesis, namely, that the distortion product otoacoustic emissions in the right ear and the left ear would be equal, was rejected at 750Hz, 1000Hz, 2000Hz and 3000Hz, indicating a significant difference between the right ear and the left ear at those frequencies.

As distortion product otoacoustic emissions provide frequency specific information based on discrete frequency stimuli, they are often compared to audiometric configurations. In individuals with sensorineural hearing loss, distortion product otoacoustic emissions often reduced or eliminated only for the stimulus frequency regions which coincide with the impaired region (Gaskill & Brown, 1990; Stover, Gorga, Neely, & Montoya, 1996). The correlation between pure tones and distortion product otoacoustic emissions was, therefore, calculated to determine a possible relationship between pure tone values and the emissions. A standard correlation co-efficient was calculated for

1000Hz, 2000Hz, 4000Hz and 8000Hz for pure tones and distortion product otoacoustic emissions. A correlation co-efficient was also calculated comparing 500Hz (pure tones) and 750Hz (distortion product otoacoustic emissions). Table 21 provides the correlation co-efficient at each frequency and for 500Hz/750Hz for the right ear and left ear.

Table 21

The Correlation Co-efficient (between Pure Tones and Distortion Product Otoacoustic Emissions) at Each Frequency and for 500Hz-750Hz for the Right Ear and the Left Ear

	<i>r</i>				
	500/750Hz	1000Hz	2000Hz	4000Hz	8000Hz
Right ear	-0.791	-0.729	-0.591	-0.433	-0.416
Left ear	-0.730	-0.601	-0.249	-0.520	0.007

Note. *r*= correlation co-efficient; Hz=hertz

The correlation co-efficient in the right ear decreased as the frequency increased. The correlation between pure tones and distortion product otoacoustic emissions is therefore higher in the low frequencies in the right ear (Figures 4, 5, 6 and 7). The positive correlation was obtained at 8000Hz in the left ear. A negative correlation indicates an increase in one variable as the other variable decreases (Surhone, Timpledon, & Marseken, 2010). A negative correlation was obtained at all other test frequencies indicating a decrease in emissions as pure tone values increase. The correlation co-efficient was highest at 500/750Hz (Right Ear: $r = -0.791$, Left Ear: $r = -0.730$) and at 1000Hz (Right Ear: $r = -0.729$, Left Ear: $r = -0.601$). A correlation coefficient between 0.7 and 0.9 is considered strong/high and a correlation coefficient between 0.4 and 0.7 is considered to be moderate (Surhone et al., 2010). The negative correlation at 250Hz in the right and left ear and at 100Hz in the right ear was therefore high.

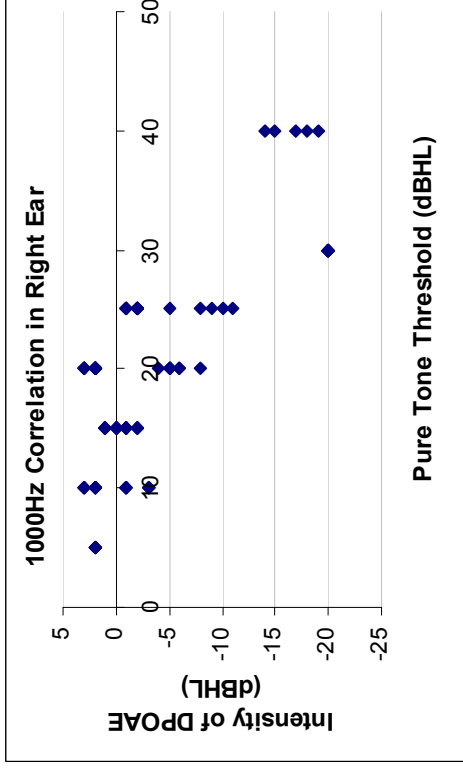
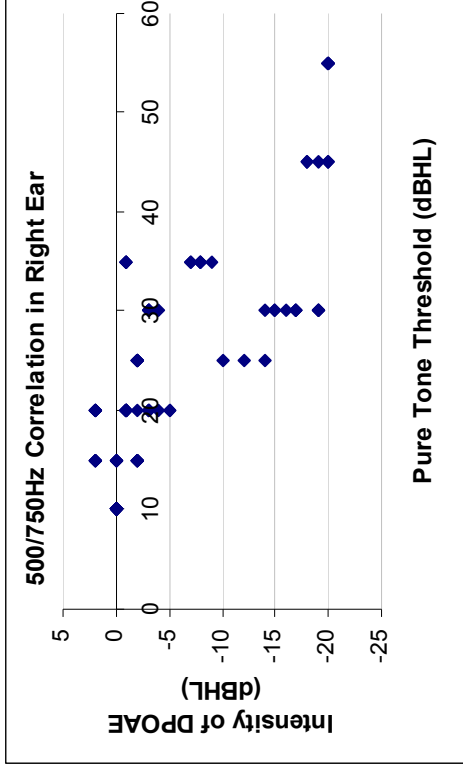


Figure 4 and Figure 5. The correlation between pure tones and distortion product otoacoustic emissions at 500/750Hz and 1000Hz respectively in the right ear

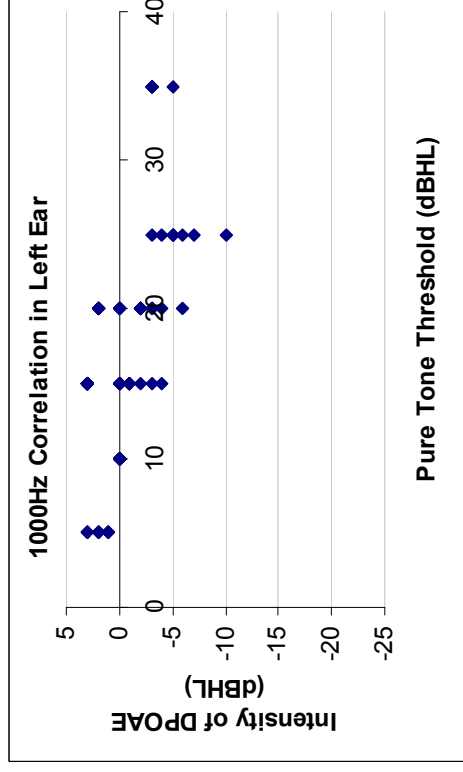
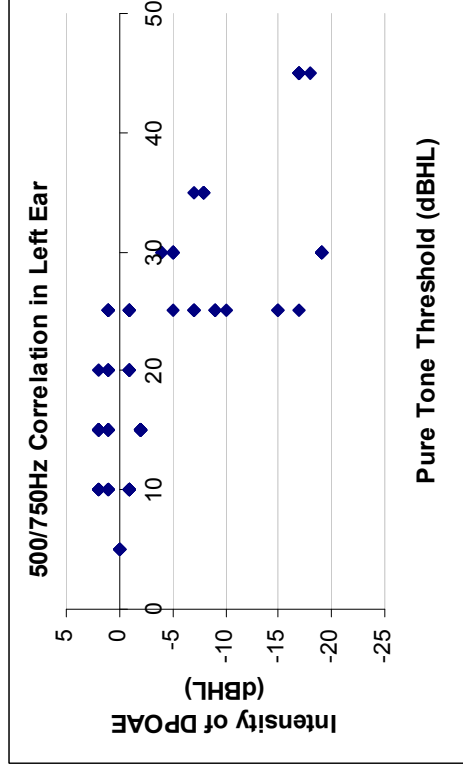


Figure 6 and Figure 7. The correlation between pure tones and distortion product otoacoustic emissions at 500/750Hz and 1000Hz respectively in the left ear

Distortion product otoacoustic emissions of participants in the current study revealed the low frequencies to be affected. Low frequency involvement indicated the apex of the cochlear to be a possible site of lesion (Kros & Evans, 2006; Stach, 1998).

4.2.7 Summary of audiological findings

The results of the audiological evaluation revealed the outer and middle ear to have minimally influenced hearing thresholds in this sample. Pure tone results revealed that participants presented with a low frequency sensorineural hearing loss. Speech discrimination results and distortion product otoacoustic emissions results confirmed a possible site of lesion to be the cochlea. The prevalence of bilateral hearing loss was five percent ($n = 4$). The prevalence of unilateral hearing loss was 11% ($n = 10$) in the right ear and five percent ($n = 5$) in the left ear. Of the 11% of the participants who presented with a hearing loss in the right ear, half presented with a moderate hearing loss whilst the other half presented with a mild hearing loss. All 5% of participants who obtained a pure tone average of greater than 25dB in the left ear presented with a mild hearing loss. This revealed that the prevalence of hearing loss in the current study may be higher in the right ear as they presented with more elevated thresholds in the right ear than the left ear.

4.3 Independent Variables

The four independent variables in this study were (i) age, (ii) gender, (iii) diagnosis and (iv) duration of cardiovascular disease. The correlation co-efficient was calculated and *t*-test were conducted for these variables. In order to determine the influence of these variables on hearing thresholds and to determine the interaction between these variables and their impact on hearing thresholds an analysis of co-variance was further conducted.

4.3.1 Age

The ages of the 92 participants ranged from 40 years to 54 years and zero months (average: 48 years and five months; standard deviation: 3.70). Forty percent of participants ($n = 37$) were between 45 years and 48 years and 11 months of age. Figure 8 illustrates the number of participants in three age categories: 40 to 44 years, 45 to 49 years and 50 to 55 years.

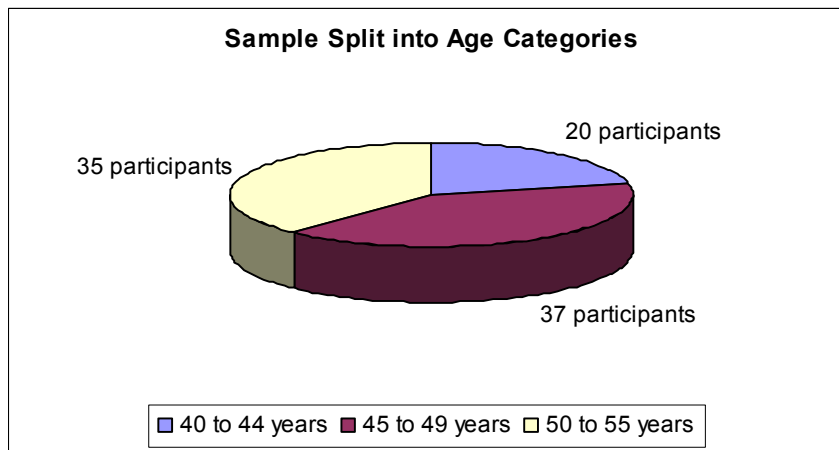


Figure 8. The number of participants between the ages of 40 and 44 years, 45 and 49 years and, 50 and 55 years

Of the 37 participants aged between 45 years and 49 years, 12 participants were 49 years old and 10 participants were 45 years of age. Figure 9 illustrates the age distribution of participants (rounded to the nearest year).

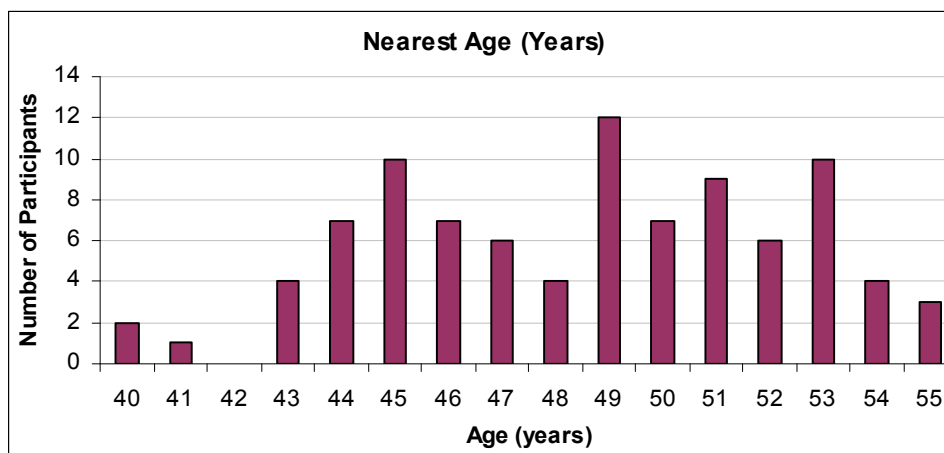


Figure 9. The age distribution of participants (rounded to the nearest year)

4.3.2 Gender

The study included 92 participants: 60 males and 32 females.

4.3.2.1 Males

The average at 250Hz for air conduction and bone conduction thresholds in the right ear were greater than 25dB, whilst the left ear it was less than 25dB (Table 13 and

Table 15). The difference in the average between air conduction and bone conduction ranged from 3.16dB to 6.09dB in the right ear and from 3.59dB to 4.75dB in the left ear (Table 16). The average of air conduction and bone conduction thresholds decreased with each frequency.

Air conduction results revealed that 37 males had a threshold greater than 25dB at 250Hz in the right ear and in the left ear respectively. The percentage of males who obtained a threshold greater than 25dB decreased with each frequency. None of the participants obtained thresholds greater than 25dB at 4000HZ and 8000HZ.

A one-tail *t*-test was conducted at each frequency for air conduction and bone conduction thresholds to determine if the difference between the average threshold obtained and the norm of 25dB was statistically significant. The null hypothesis being tested was, the males of the sample have normal hearing. The alternate hypothesis being that the males of the sample have impaired hearing. The *p*-value determined if the null hypothesis was rejected. At 250Hz in the right ear, a *p*-value of <0.0001 (air conduction) and 0.0005 (bone conduction) was obtained. This implies that the difference between the average of male participants in the study when compared to normal hearing thresholds was statistically significant at 250Hz for the right ear. The null hypothesis was therefore rejected at 250Hz. The differences were deemed not significant at all other frequencies in the right ear and all test frequencies in the left ear and the null hypothesis was, therefore, not rejected. While the difference between participants' averages and the norm were deemed statistically insignificant, 38% of participants ($n = 35$) obtained a threshold greater than 25dB in the right ear and 23% ($n = 21$) in the left ear at 500Hz. The air conduction thresholds, bone conduction thresholds and *t*-test results for males are presented in Table 22.

Table 22

The Air Conduction Thresholds, Bone Conduction Thresholds and t-Test Results for Males

	Right Ear						Left Ear					
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
Ave (in dB)	36.92	25.08	19	17.42	15.92	19.92	28.92	21.33	16.58	16.92	13.83	16.25
St. Dev (in dB)	13.69	11.91	7	5.56	4.56	5.33	14.29	9.34	7.28	6.38	5.85	4.57
Range (in dB)	15-60	10-55	10-40	5-30	5-25	10-35	5-50	5-45	5-35	5-35	5-25	5-25
>25dB (%)	63.33	38.33	10	6.67	0	3.33	61.67	23.33	6.67	3.33	0	0
p-value	0.0001*	0.4785	1.0000	1.0000	1.0000	1.0000	0.0190	0.9982	1.0000	1.0000	1.0000	1.0000
Ave (in dB)	30.83	21.92	15.42	14.17	12.25	-	24.75	16.83	12.92	13.33	9.08	-
St. Dev (in dB)	12.96	13.02	7.38	6.52	5.24	-	13.82	8.92	6.20	6.29	6.86	-
Range (in dB)	10-50	5-55	0-30	5-30	0-20	-	0-50	5-40	0-25	5-35	0-25	-
>25dB (%)	63.33	35.00	3.33	6.67	0	-	55	10	0	3.33	0	-
p-value	0.0005*	0.9642	1.0000	1.0000	1.0000	-	0.5555	1.0000	1.0000	1.0000	1.0000	-

Note: * = significant at a confidence level of 99%; AC=air conduction; BC=bone conduction; Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

4.3.2.2 Females

The average at 250Hz for air conduction and bone conduction thresholds in the right ear was greater than 25dB. In the left ear, the air conduction and bone conduction thresholds were less than 25dB (Table 15). The difference in the average between air conduction and bone conduction ranged from 2.67dB to 6.41dB in the right ear and from 1.17dB to 5.17dB in the left ear across all frequencies. The average of air conduction and air conduction thresholds decreased with each frequency. Sixty two percent of females ($n = 20$) showed an air conduction thresholds greater than 25dB at 250Hz in the right ear and 43% ($n = 14$) in the left ear. The difference between the right ear and the left ear increased for bone conduction thresholds with 59% ($n = 19$) obtaining thresholds greater than 25dB in the right ear compared to 40% ($n = 13$) in the left. The percentage of females who obtained a threshold greater than 25dB decreased with each frequency with none obtaining thresholds greater than 25dB at 4000HZ and 8000Hz.

A one-tail *t*-test was conducted at each frequency for both air conduction and bone conduction thresholds to determine if the difference between the average threshold obtained and the norm of 25dB is statistically significant. At 250Hz, a *p*-value of 0.0004 was obtained for air conduction thresholds in the right ear. This implies that the difference between the average of females, when compared to normal hearing thresholds, was statistically significant at 250Hz in the right ear for air conduction thresholds. The null hypothesis that female participants in the sample have normal hearing at 250Hz for air conduction thresholds was therefore rejected for the right ear. The differences were deemed not significant at all other frequencies in the right ear and all test frequencies in the left ear and the null hypothesis was, therefore, not rejected. While the difference between participants' averages and the norm were deemed statistically insignificant, 38% of females ($n = 5$) obtained air conduction thresholds greater than 25dB at 500Hz in the right ear and 22% ($n = 7$) in the left ear. The air conduction thresholds, bone conduction thresholds and *t*-test results for females are presented in Table 23.

Table 23

The Air Conduction Thresholds, Bone Conduction Thresholds and t-Test Results for Females

	Right Ear					Left Ear					
	250Hz	500Hz	1000Hz	2000Hz	8000Hz	250Hz	500Hz	1000Hz	2000Hz	8000Hz	
Ave (in dB)	35.00	24.06	18.75	15.47	16.88	20.94	26.56	20.16	14.84	17.50	17.34
St. Dev (in dB)	15.19	12.01	9.59	6.76	5.35	5.88	15.32	11.03	7.24	7.17	6.84
Range (in dB)	15-60	10-55	5-40	5-30	5-20	5-35	5-50	10-45	5-35	10-35	5-25
>25dB (%)	62.50	37.50	12.50	3.13	0	9.38	43.75	21.88	3.13	9.38	0
p-value	0.0004*	0.6691	0.9996	1.0000	1.0000	0.9998	0.2840	0.9907	1.0000	1.0000	1.0000
Ave (in dB)	28.59	20.78	15.63	12.03	13.28	-	22.97	16.25	11.41	14.06	12.66
St. Dev (in dB)	15.36	13.08	7.70	8.02	5.02	-	14.58	10.85	6.12	7.67	5.68
Range (in dB)	5-50	5-55	5-30	0-30	0-20	-	5-50	5-40	0-25	10-35	0-25
>25dB (%)	59.38	28.13	9.38	3.13	0	-	40.63	12.50	0	9.38	0
p-value	0.0976	0.9611	1.0000	1.0000	1.0000	-	0.7816	1.0000	1.0000	1.0000	1.0000

Note: *=significant at a confidence level of 99%; AC=air conduction; BC=bone conduction; Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

4.3.2.3 Males and Females

Air conduction thresholds for males were higher than those of females at all test frequencies except 2000Hz in the left ear, and 4000Hz and 8000Hz bilaterally. Figures 10 and 11 illustrate the difference in averages between males and females for air conduction testing for the right ear and the left ear respectively.

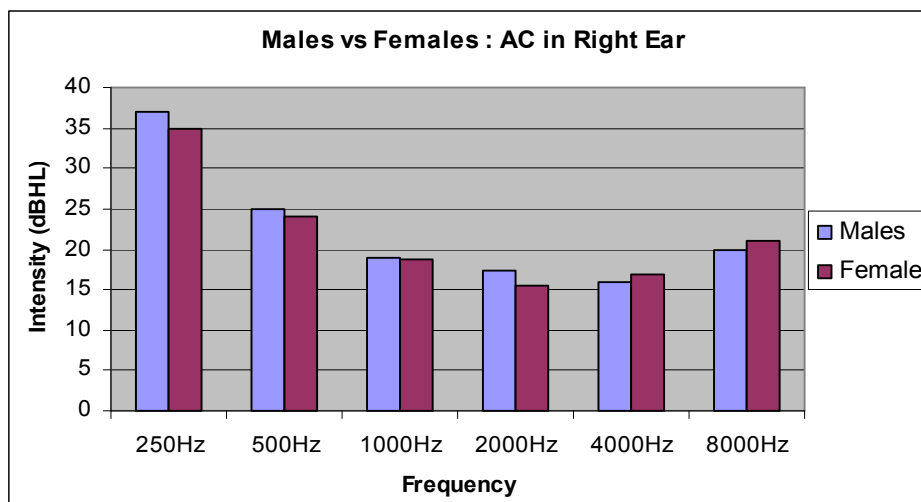


Figure 10. The averages of males and females for air conduction testing for the right ear

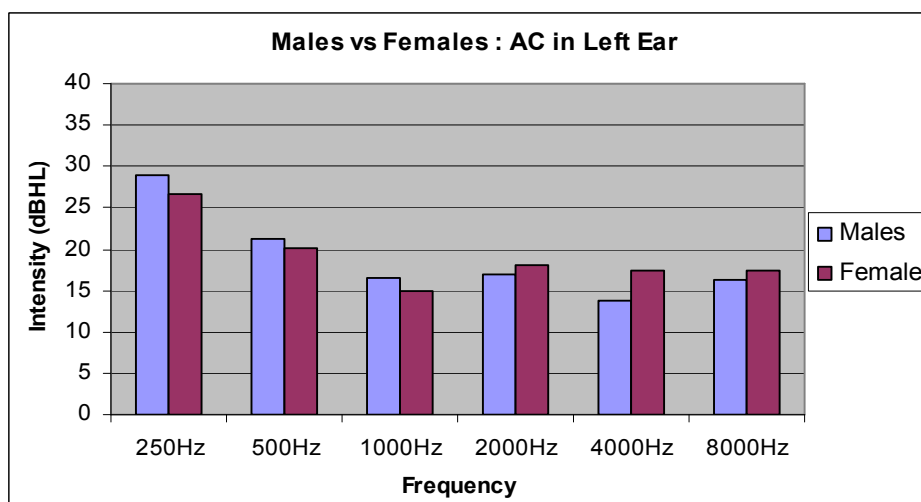


Figure 11. The averages of males and females for air conduction testing for the left ear

The percentage of males who obtained air conduction thresholds greater than 25dB at 250Hz in the left ear was 18% more than that of females and 14% for bone

conduction thresholds. The difference in the average of males and females for air conduction thresholds ranged from 0.25dB to 1.92dB in right ear and from 1.02dB to 3.67dB in the left. The difference in the average of males and females for bone conduction thresholds ranged from 0.21dB to 2.24dB in right ear and from 0.73dB to 3.58dB in the left. Females obtained a greater average at 4000Hz bilaterally for both air conduction and bone conduction thresholds.

A two-tailed *t*-test was conducted to compare the difference between males and females for air conduction and bone conduction thresholds. The null hypothesis was, there is no difference between males and females for air conduction and for bone conduction thresholds and the alternate hypothesis being there is a difference between males and females for air conduction and for bone conduction thresholds. A p-value of 0.0083 was obtained for air conduction thresholds at 4000HZ in the left ear. The null hypothesis of thresholds for males and females being equal was rejected at 4000Hz for air conduction thresholds in the left ear. The difference between males and females for air conduction thresholds at 4000Hz was therefore statistically significant. The null hypothesis was not rejected for all other test frequencies for air conduction thresholds and all test frequencies for bone conduction thresholds bilaterally. Table 24 presents the results of the *t*-test for air conduction and bone conduction thresholds.

Table 24

The t-test Results for Air Conduction and Bone Conduction Thresholds Comparing Males and Females

	<i>P</i> -value	Right Ear					Left Ear						
		250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
AC		0.5397	0.6972	0.8880	0.1417	0.3686	0.4008	0.4649	0.5904	0.2769	0.4727	0.0083*	0.2835
BC		0.4614	0.6918	0.8992	0.1712	0.3642	-	0.5650	0.7827	0.2664	0.6252	0.0135	-

Note. *=significant at a confidence level of 99%; AC=air conduction; BC=bone conduction; Hz=hertz

4.3.3 Diagnosis

Of the 92 participants, 58 were diagnosed with coronary artery disease and 34 with cardiomyopathy. Of the 58 participants diagnosed with coronary artery disease, 38 were male and 20 female. Of the 34 participants diagnosed with cardiomyopathy, 22 were male and 12 female. Figure 12 provides the percentages of males and females who presented with each diagnosis.

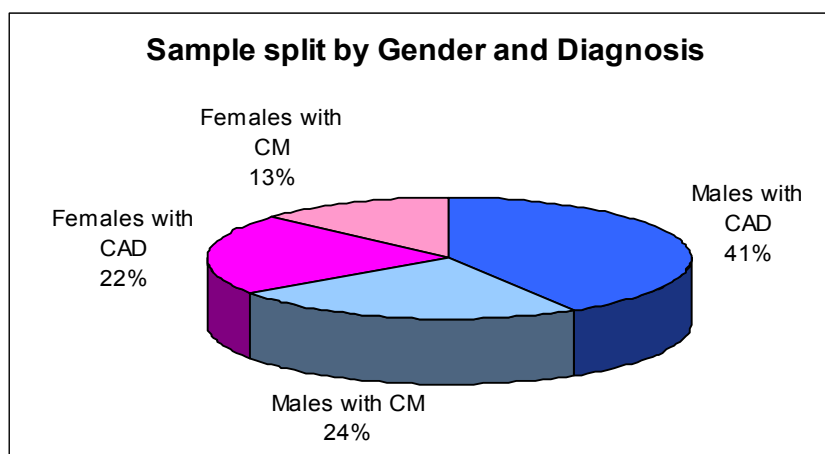


Figure 12. Percentage of males and females who presented with each diagnosis (coronary artery disease or cardiomyopathy).

4.3.3.1 Coronary artery disease

In participants with coronary artery disease, the average at 250Hz for air conduction thresholds was greater than 25dB bilaterally. The average for bone conduction thresholds were greater than 25dB in the right ear and less than 25dB in the left (Table 25). The difference in the average between air conduction and bone conduction ranged from 3.19dB to 6.03dB in the right ear and from 3.27dB to 5.17dB in the left ear. The average of air conduction and bone conduction thresholds decreased with each frequency. Fifty nine percent of participants ($n = 34$) obtained an air conduction threshold greater than 25dB at 250Hz in the right ear compared to 50% ($n = 29$) in the left ear. At 250Hz, the percentage of participants who obtained a bone conduction threshold greater than 25dB was 16% higher in the right ear compared to that of the left ear. The percentage of participants who obtained a threshold greater than 25dB decreased with each frequency with no participants obtaining thresholds greater than 25dB at 4000HZ and 8000Hz bilaterally.

A one-tail *t*-test was conducted to determine if the difference between the average threshold obtained and the norm of 25dB is statistically significant for participants with coronary artery disease. A *t*-test was conducted at each frequency for both air conduction and bone conduction thresholds. The null hypothesis being tested was, participants with coronary artery disease have normal hearing. The alternate hypothesis was that participants with coronary artery disease have impaired hearing. The *p*-value determined if the null hypothesis was accepted or rejected.

At 250Hz, a *p*-value of <0.0001 was obtained for air conduction thresholds in the right ear. This implies that there is a statistically significant difference between the average air conduction thresholds of the sample, when compared to normal hearing thresholds, at 250Hz in the right ear. The null hypothesis that participants with coronary artery disease have normal hearing for air conduction thresholds was therefore rejected for 250Hz in the right ear. The differences were deemed not significant at all other frequencies in the right ear and all test frequencies in the left ear and the null hypothesis was therefore not rejected. While the difference between participants' averages and the norm were deemed statistically insignificant, 33% of participants (*n* = 19) obtained thresholds greater than 25dB at 500Hz in the right ear and 23% (*n* = 13) in the left ear for air conduction thresholds. Thirty five percent of participants (*n* = 20) obtained thresholds greater than 25dB at 500Hz in the right ear and 13% (*n* = 7) in the left ear for bone conduction thresholds. Table 25 provides the results regarding air conduction thresholds, bone conduction thresholds and the *t*-test for participants with coronary artery disease.

Table 25

Air conduction Thresholds, Bone Conduction Thresholds and Results of the t-Test for Participants with Coronary Artery Disease (n = 58)

	Right Ear					Left Ear						
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
Ave (in dB)	35	23.97	18.71	16.64	15.95	20.34	27.41	20.69	15.43	17.33	15.34	16.81
St. Dev (in dB)	14.57	11.99	8.51	6.31	5.17	5.76	14.93	10.41	7.39	6.96	6.68	5.02
Range (in dB)	15-60	10-55	5-40	5-30	5-25	10-35	5-50	5-45	5-35	5-35	5-25	5-25
P-value	0.0001*	0.7432	1.0000	1.0000	1.0000	1.0000	0.1117	0.9987	1.0000	1.0000	1.0000	1.0000
>25dB (%)	58.62	32.76	12.07	5.17	0	6.90	50	22.41	5.17	6.90	0	0
Ave (in dB)	28.97	21.03	15.43	13.45	12.16	-	23.36	16.29	12.16	13.97	10.17	-
St. Dev (in dB)	14.07	13.14	7.68	7.27	5.39	-	14.58	10.02	6.36	7.12	6.69	-
Range (in dB)	5-50	5-55	0-30	0-30	0-20	-	0-50	5-40	0-25	5-25	0-25	-
P-value	0.0181	0.9874	1.0000	1.0000	1.0000	-	0.8021	1.0000	1.0000	1.0000	1.0000	-
>25dB (%)	56.90	29.31	6.90	5.17	0	-	44.83	12.07	0	0	0	-

Note: *=significant at a confidence level of 99%; AC=air conduction; BC=bone conduction; Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

4.3.3.2 *Cardiomyopathy*

For participants with cardiomyopathy, the average air conduction and bone conduction thresholds at 250Hz was greater than 25dB bilaterally. The difference in the average between air conduction and bone conduction ranged from 3.38dB to 6.47dB in the right ear and from 3.82dB to 4.27dB in the left ear (Table 26). The difference in the average of air conduction and bone conduction thresholds decreased with each frequency. Of the 34 participants with cardiomyopathy, 71% ($n = 24$) obtained a threshold greater than 25dB at 250Hz in the right ear compared to 65% ($n = 22$) in the left ear for air conduction thresholds. At 250Hz, the percentage of participants who obtained a bone conduction threshold greater than 25dB was 12% higher in the right ear than in the left ear. The percentage participants who obtained a threshold greater than 25dB decreased with each frequency with none of the participants obtaining air conduction and bone conduction thresholds greater than 25dB at 4000HZ and 8000Hz bilaterally.

A one-tail t -test was conducted to determine if the difference between the average threshold obtained and the norm of 25dB was statistically significant for participants with cardiomyopathy. A t -test was conducted at each frequency for both air conduction and bone conduction thresholds. The null hypothesis being tested was, participants with cardiomyopathy have normal hearing. The alternate hypothesis was that participants with cardiomyopathy have impaired hearing.

At 250Hz, a p -value of <0.0001 was obtained for air conduction thresholds and a p -value of 0.0024 for BC thresholds in the right ear. This implies that the difference between the average of the sample, when compared to normal hearing thresholds, was statistically significant at 250Hz in the right ear for both air conduction and bone conduction thresholds. The null hypothesis that participants with cardiomyopathy have normal hearing at 250Hz was rejected for the right ear. The differences were deemed not significant at all other frequencies in the right ear and all test frequencies in the left ear and the null hypothesis was, therefore, not rejected. While the difference between participants' averages and the norm were deemed statistically insignificant, 47% of participants ($n = 16$) obtained air conduction thresholds greater than 25dB at 500Hz in the right ear and 24% ($n = 8$) in the left ear. Thirty eight percent of participants ($n = 13$) obtained bone conduction thresholds greater than 25dB at 500HZ in the right ear and 9%

($n = 3$) in the left ear. Furthermore, 59% of participants ($n = 20$) obtained a threshold greater than 25dB at 250Hz for bone conduction thresholds in the left ear. Table 26 provides the results for air conduction thresholds, bone conduction thresholds and the t -test for participants with cardiomyopathy.

Table 26

Air Conduction Thresholds, Bone Conduction Thresholds and Results of the t-Test for Participants with Cardiomyopathy (n = 34)

	Right Ear					Left Ear						
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
Ave (in dB)	38.38	26.03	19.26	16.91	16.76	20.15	29.26	21.32	16.91	17.21	14.71	16.32
St. Dev (in dB)	13.41	11.79	7.30	5.64	4.24	5.15	14.20	9.15	7.07	6.18	6.02	3.95
AC Range (in dB)	15-60	10-55	5-40	5-30	5-25	10-35	5-50	5-45	5-35	5-35	5-25	5-25
p-value	<0.0001*	0.3071	1.0000	1.0000	1.0000	1.0000	0.0446	0.9873	1.0000	1.0000	1.0000	1.0000
>25dB (%)	58.62	32.76	12.07	5.17	0	6.90	50	22.41	5.17	6.90	0	0
Ave (in dB)	31.91	22.35	15.59	13.38	13.38	-	25.44	17.21	12.79	12.94	10.59	-
St. Dev (in dB)	13.32	12.86	7.15	6.93	4.72	-	13.16	8.89	5.93	6.17	6.72	-
BC Range (in dB)	5-50	5-55	0-30	0-30	0-20	-	0-50	5-40	0-25	5-25	0-25	-
p-value	0.0024*	0.8806	1.0000	1.0000	1.0000	-	0.4231	1.0000	1.0000	1.0000	1.0000	-
>25dB (%)	70.59	38.24	2.94	5.88	0	-	58.82	8.82	0	0	0	-

Note. *=significant at a confidence level of 99%; AC=air conduction; BC=bone conduction; Ave=average; St. Dev=standard deviation; dB=decibel; Hz=hertz

4.3.3.3 Coronary artery disease and cardiomyopathy

Air conduction and bone conduction thresholds for participants with coronary artery disease were higher than those with cardiomyopathy in the low frequencies bilaterally. The percentage of participants with cardiomyopathy who obtained air conduction thresholds greater than 25dB at 250Hz in the right ear was 12% higher than that of participants with coronary artery disease and 14% for bone conduction thresholds. In the left ear, the percentage of participants with cardiomyopathy who obtained air conduction thresholds greater than 25dB at 250Hz in the left ear was 15% higher than the percentage of participants with coronary artery disease and 14% for bone conduction thresholds. The percentage of participants who obtained thresholds greater than 25dB decreased with each frequency for air conduction and bone conduction thresholds bilaterally.

Figures 13 and 14 illustrate the difference in averages between participants with coronary artery disease and participants with cardiomyopathy for air conduction testing for the right and the left ear respectively.

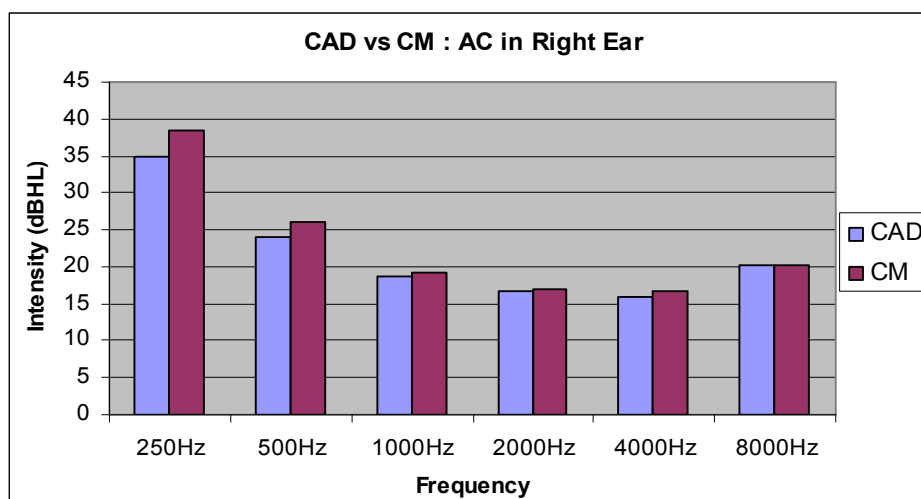


Figure 13. The averages of participants with coronary artery disease and participants with cardiomyopathy for air conduction testing for the right ear

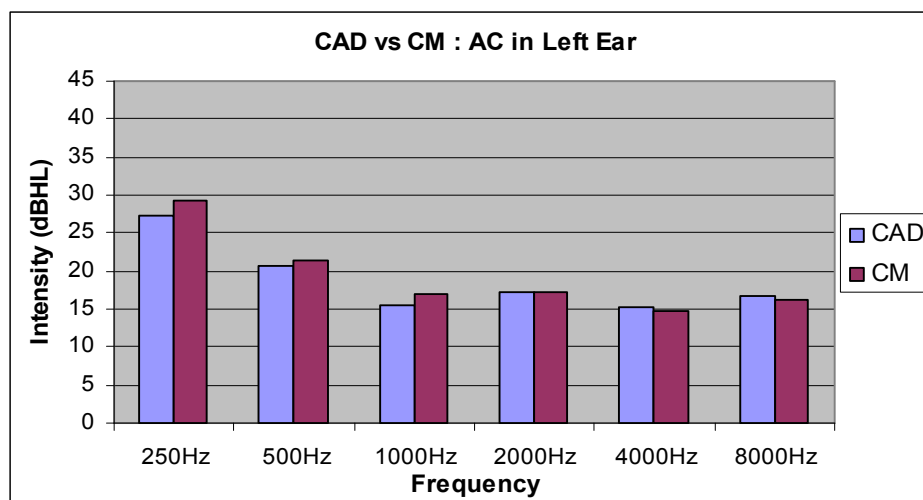


Figure 14. The averages of participants with coronary artery disease and participants with cardiomyopathy for air conduction testing for the left ear

A two-tailed t -test was conducted to compare the difference in air conduction and bone conduction thresholds between participants with coronary artery disease and cardiomyopathy. The null hypothesis was, there is no difference between the two diagnoses for air conduction and for bone conduction thresholds. The alternate hypothesis being there is a difference between the two diagnoses for air conduction and for bone conduction thresholds. Results from the two-tailed t -test revealed that the null hypothesis of no difference in thresholds for the two diagnoses being equal was not rejected for all test frequencies for air conduction thresholds and bone conduction thresholds. The results therefore indicate that there was not a significant difference between participants with coronary artery disease and participants with cardiomyopathy for all test frequencies.

4.3.4 Duration of cardiovascular disease

The average duration of cardiovascular disease (from date of diagnosis to date of testing) was two years and two months (range: 7 months to four years and one month; standard deviation: 0.95). The majority of participants who presented with duration of between one and two years were aged between 43 and 50 years. The majority of participants who presented with duration of between three and four years were aged between 49 and 54 years. Figure 15 illustrates the distribution of duration of

cardiovascular disease and the age of participants. Figure 16 illustrates the number of participants in groups with age rounded off to the nearest six months.

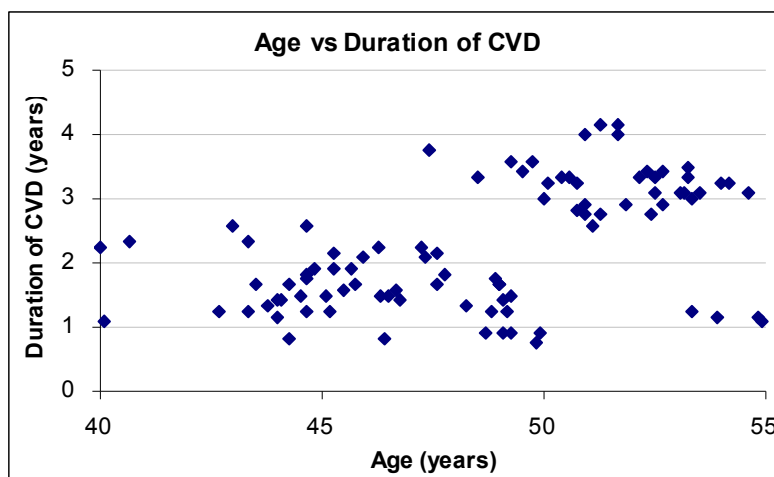


Figure 15. Distribution of participants according to duration of cardiovascular disease and age

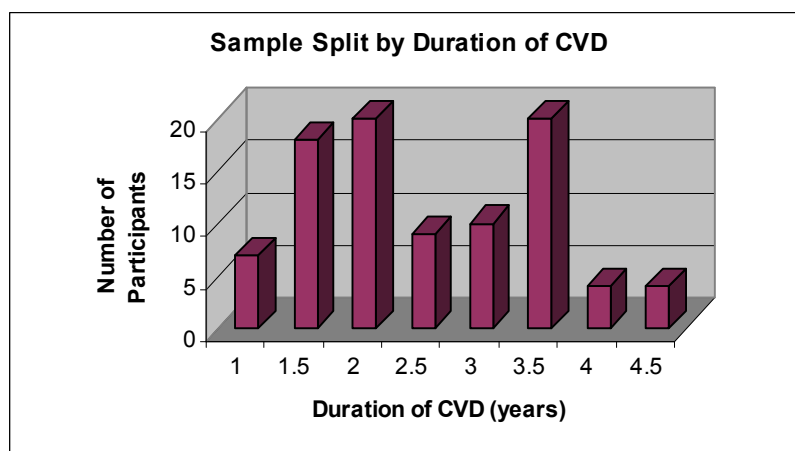


Figure 16. The number of participants who presented within each duration group of cardiovascular disease (rounded off to the nearest six months)

4.4 Analysis of Co-Variance for Independent Variables

An analysis of co-variance was conducted at each test frequency for air conduction and bone conduction thresholds. The Type III SS (sum of squares) model of analysis was utilized. The Type III SS model is an appropriate measure as it assesses the effect of each factor and the interactions thereof on a specified entity (Roberts & Ilard,

2003). The model calculated an f -value. The lower the probability associated to the f -value, the bigger the influence of the variable or combination. The analysis of co-variance also assessed the influence of the interaction of variables on pure tone thresholds. Results of the analysis of co-variance (f -values) for the variables and the interactions are presented in Table 27 for air conduction thresholds and in Table 28 for bone conduction thresholds.

Table 27

Results of the Analysis of Co-Variance for Air Conduction Thresholds

Variable	Air Conduction (<i>Pr>F</i>)											
	Right Ear					Left Ear						
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	8000Hz
Age	0.5381	0.8567	0.1074	0.2314	0.2005	0.8494	0.9338	0.7835	0.1059	0.5460	0.1391	0.6102
Duration of CVD	<0.0001*	<0.0001*	<0.0001*	<0.0001*	0.0002*	0.0133	<0.0001*	<0.0001*	<0.0001*	0.0028*	0.0621	0.1267
Diagnosis	0.9757	0.8689	0.9812	0.8030	0.5487	0.9582	0.8862	0.8003	0.8804	0.5320	0.4314	0.9606
Gender	0.5426	0.3095	0.9575	0.7039	0.3724	0.4830	0.2291	0.6635	0.3633	0.6203	0.0149*	0.7348
Diagnosis & Gender	0.3937	0.3392	0.0404	0.8175	0.4229	0.0500	0.8303	0.1589	0.0705	0.1055	0.2857	0.9084
Age & Diagnosis	0.8802	0.7840	0.9592	0.8394	0.5009	0.9465	0.8769	0.7617	0.8062	0.4748	0.4711	0.9993
Age & Gender	0.4723	0.2735	0.7621	0.7924	0.3875	0.3829	0.1888	0.5756	0.4486	0.5851	0.0278	0.7732
Duration of CVD & Diagnosis	0.4955	0.4433	0.8888	0.6930	0.4529	0.5649	0.8199	0.4352	0.4109	0.2677	0.8478	0.9557
Duration of CVD & Gender	0.4926	0.4469	0.1765	0.9676	0.5468	0.1321	0.3151	0.4899	0.9865	0.4757	0.6242	0.7906

Note: *=significant influence on pure tone thresholds at 99%; CVD=cardiovascular disease; Hz=hertz

Table 28

Results of the Analysis of Co-Variance for Bone Conduction Thresholds

Variable	Bone Conduction ($P > F$)									
	Right Ear					Left Ear				
	250Hz	500Hz	1000Hz	2000Hz	4000Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
Age	0.1795	0.3011	0.0260	0.7702	0.3829	0.7978	0.0833	0.7092	0.3698	0.0855
Duration of CVD	0.0001*	<0.0001*	0.0201*	0.0023*	0.0182	<0.0001*	<0.0001*	0.0002*	0.0004*	0.5749
Diagnosis	0.9645	0.8158	0.8980	0.6229	0.5118	0.9234	0.6107	0.9593	0.6681	0.3312
Gender	0.7683	0.2118	0.6290	0.2969	0.1045	0.3582	0.4876	0.2235	0.8470	0.0076*
Diagnosis & Gender	0.5720	0.3212	0.1487	0.1887	0.6469	0.7785	0.1480	0.1368	0.0449	0.8493
Age & Diagnosis	0.9149	0.7569	0.9877	0.6615	0.6126	0.9936	0.5824	0.9449	0.7002	0.3047
Age & Gender	0.6484	0.2034	0.4657	0.3379	0.1093	0.2983	0.3900	0.2741	0.7858	0.0156
Duration of CVD & Diagnosis	0.6934	0.4772	0.8903	0.6319	0.7201	0.5851	0.3802	0.6921	0.4673	0.4740
Duration of CVD & Gender	0.4165	0.5875	0.1088	0.6387	0.3022	0.3274	0.2536	0.7961	0.5134	0.6173

Note. * = significant influence on pure tone thresholds; CVD = cardiovascular disease; Hz = hertz

The analysis of co-variance was conducted to determine the influence of each variable on hearing thresholds and to determine the effect of the combinations/interactions of variables on hearing thresholds. The following results were obtained:

4.4.1 Age

An analysis of co-variance was conducted at each test frequency for air conduction thresholds (Table 27) and bone conduction thresholds (Table 28). The f -value for age ranged from 0.0260 to 0.9338 indicating that age (individually and in combination with all quantifiable variables) did significantly impact hearing thresholds at all test frequencies for air conduction and bone conduction thresholds.

4.4.2 Gender

An analysis of co-variance was conducted at each test frequency for air conduction thresholds (Table 27) and bone conduction thresholds (Table 28). In the left ear, an f -value of 0.0149 was obtained for air conduction thresholds at 4000Hz and 0.0076 for bone conduction thresholds at 4000Hz. These values indicated that gender, as an individual variable, had a significant influence on air conduction and bone conduction thresholds at 4000Hz in the left ear. It was found that gender, when assessed with various combinations of the quantifiable variables in the study, did not influence hearing thresholds at all test frequencies.

A Bonferroni correction was also conducted to determine the probability of the significance of gender on hearing thresholds. The Bonferroni correction ($\alpha=0.01$) was conducted at all test frequencies for air and bone conduction thresholds bilaterally. There was a statistically significant difference at 4000Hz in the left ear. Table 29 provides the result of the Bonferroni correction at 4000Hz in the left ear.

Table 29

The Analysis of the Difference between Males and Females at 4000Hz in the Left Ear for Air Conduction and Bone Conduction Thresholds

	Categories	Difference	Standardized difference	Critical value	Pr.> Diff
AC	2 ~ 1	3.667	2.746	2.637	0.007*
BC	2 ~ 1	3.573	2.656	2.637	0.009*

Note. *=significant at confidence level of 99%; AC=air conduction; BC=bone conduction; 2=gender; 1=hearing thresholds

The Bonferroni correction also concluded that gender significantly influenced air conduction and bone conduction thresholds at 4000Hz in the left ear.

4.4.3 Diagnosis

In order to determine the influence of diagnosis on air conduction and bone conduction thresholds, an analysis of co-variance was conducted at each test frequency for air conduction thresholds (Tables 27 and 28). The f -value for diagnosis ranged from 0.4314 to 0.9812 indicating that diagnosis, individually and in combination with all quantifiable variables, did not significantly impact on air conduction and bone conduction thresholds across the frequency range.

4.4.4 Duration of cardiovascular disease

In order to determine the influence of the duration of cardiovascular disease on air conduction and bone conduction thresholds, an analysis of co-variance was conducted at each test frequency. In the right ear, statistically significant results were obtained for air conduction thresholds at 250Hz, 500Hz, 1000Hz, 2000Hz and 4000Hz. In the left ear, statistically significant results were obtained for air conduction thresholds at 250Hz, 500Hz, 1000Hz and 2000Hz. The f -value was also significant for bone conduction thresholds at 250Hz, 500Hz, 1000Hz and 2000Hz bilaterally. This indicated that duration of cardiovascular disease, as an individual variable, had significant influence on hearing thresholds at the aforementioned frequencies bilaterally. Duration of cardiovascular disease, when assessed with various combinations of the quantifiable variables, did not influence hearing thresholds at all test frequencies.

4.4.5 Interaction of independent variables

The analysis of co-variance assessed the influence of the combinations of variables at each test frequency for air conduction thresholds and for bone conduction thresholds (Tables 27 and 28). The results from the analysis of co-variance concluded that there were no interactions which significantly influenced hearing thresholds at all test frequencies.

4.5 Conclusion

This chapter highlighted the results of the study and were organized, analysed and described in relation to the aims of the study. The results revealed outer ear pathologies and middle ear pathologies to have minimal influence on hearing thresholds in individuals with cardiovascular disease. A low frequency, sensorineural hearing loss was prominent in participants who presented with elevated pure tone thresholds. This was further confirmed by distortion product otoacoustic emissions

Age and diagnosis, as independent variables, were found to have minimal influence on pure tone thresholds and no significant difference was noted in its interaction with other variables. Conversely, gender was found to significantly influence air conduction and bone conduction thresholds at 4000Hz in the left ear. These results indicate that, whilst gender may not influence hearing thresholds in the right ear, there were significant differences between the results for males and females at 4000Hz in the left ear.

Most importantly, duration of cardiovascular disease (as an individual variable) was found to influence pure tone thresholds in this sample.

Based on the results, the prevalence of a bilateral hearing loss was five percent. The prevalence of hearing loss was 11% in the right ear and five percent in the left ear, indicating the prevalence of hearing loss to be higher in the right ear than in the left.

CHAPTER 5

DISCUSSION OF RESULTS

This chapter provides a summary of the findings of the study and the influence of the independent variables. It also includes a discussion of these results in relation to the literature. Data is interpreted so that conclusions can be drawn on the prevalence of hearing loss in individuals with coronary artery disease and cardiomyopathy.

5.1. Summary of Audiological Findings

Results revealed that 48% of the participants in the study reported experiencing hearing difficulties. Of those participants, 89% presented with increased thresholds in at least one frequency in at least one ear. This high correlation suggests fairly accurate self-reported of hearing difficulty experienced.

These findings are supported by the literature (Nondhal, 1998; Sindhusake et al., 2001; Voeks, Gallagher, Langer, & Drinka, 1993). In a study conducted by Nandhal (1998), the percentage of self-reported and of actual assessed hearing loss was within three percent thus indicating accuracy in self-reported hearing loss. Similarly, Sindhusake et al. (2001) reported an 11% difference between self-reported hearing loss and a hearing loss confirmed by pure tone audiometry. A slightly higher difference of 15% was reported by Voeks et al. (1993). Interestingly, Gomes, Hwang, Sobotova and Stark (2001) found variable degrees of agreement between self-reported hearing loss and audiometric hearing loss. Agreement ranged from 27% to 88% depending on the frequency range being tested. These findings support the inclusion of questions regarding perceived hearing difficulties in screening programs as it would be beneficial in identifying adults with cardiovascular disease who may present with a hearing loss.

The majority of participants in the current study did not present with any abnormalities during the otoscopic examination that would impact on hearing thresholds. This confirms the findings of a study that investigated the prevalence of hearing loss in elderly individuals with cardiovascular disease. In that study, less than one percent of participants failed the otoscopic examination in one or both ears (Pratt et al., 2009). Similarly, Torre et al. (2005) found 1% ($n = 5$) of their participants presented with

cerumen. It can therefore be postulated that outer ear pathologies do not have a significant influence on hearing thresholds in adults with cardiovascular disease.

More than 95% of participants in the current study presented with type A tympanograms bilaterally indicating normal middle ear functioning. It can therefore be postulated that middle ear pathology only contributed minimally to hearing loss in adults with coronary artery disease and cardiomyopathy. A study conducted in the United States of America also revealed a low prevalence of abnormal middle ear function, as only eight percent of those participants presented with some form of conductive involvement (Cruikshanks et al., 1998).

Acoustic reflexes thresholds are affected by degree of hearing loss (Gelfand, Schwander, & Silman, 1990). Gelfand et al. (1990) found that acoustic reflex thresholds are the same for individuals with normal hearing and those with sensorineural hearing loss with pure tone thresholds are less than 50dB HL. A typical pattern associated with cochlear hearing loss includes type A tympanograms and normal reflex thresholds (providing air conduction thresholds do not exceed 50dB HL) (Gulya, Minor, & Poe, 2010)

Ninety two percent of participants in the current study presented with pure tone thresholds less than 50dB HL. Interestingly, twenty one of those participants obtained elevated acoustic reflex thresholds. These results, therefore, indicate that the majority of participants with thresholds between 25dB HL and 50dB HL presented with a cochlear pathology.

The results from pure tone testing revealed that 89% ($n = 81$) of the participants presented with hearing within normal limits bilaterally based on pure tone averages (pure tone average < 25dB). However, only 66% ($n = 61$) of these participants presented with all thresholds across all frequencies less than 25dB. Of the participants who presented with a hearing loss, 98% ($n = 31$) presented with a low frequency sensorineural hearing loss.

These findings are supported by the results of the speech audiometry measures conducted. In the current study, a speech reception threshold-pure tone average difference of less than 5dB was obtained, indicating reliable results.

Of the participants who presented with a hearing loss, speech discrimination testing confirmed the cochlear nature of the hearing loss in the 96% of those participants.

All participants' performance improved as the intensity was increased, with the majority obtaining between 90% and 100%, indicating normal ability to detect words (Kaplan et al., 1993). Individuals with cochlear pathology present with no decline or less than 20% decline as intensity increases (Roeser et al., 2000). The results of the current study, therefore, indicate that participants present with a hearing loss which is cochlear in nature.

Distortion product otoacoustic emissions, an electrophysiological measure, revealed that the otoacoustic emissions' strength increased with each increase in frequency bilaterally. This indicates that otoacoustic emissions were weakest in the lower frequencies. This corresponds with the pure-tone thresholds obtained in the current study that also revealed a hearing loss in the low frequencies for some participants. As distortion product otoacoustic emissions provide frequency specific information based on discrete frequency stimuli, they are often compared to audiometric configurations. In individuals with sensorineural hearing loss, distortion product otoacoustic emissions are often reduced or eliminated only for the stimulus-frequency regions which coincide with the impaired region (Gaskill & Brown, 1990; Stover, Gorga, Neely, & Montoya, 1996).

It is postulated that impairment in blood flow to the cochlea as a result of changes in blood pressure, blood flow and oxygen-carrying capacity may alter hearing (Lassman & Aldridge, 1985). This impairment will ultimately result in a sensorineural hearing loss (Nakashima et al., 2003). The capillary network at the base of the cochlea is greater than at the apex, where the outer hair cells which are sensitive to low frequency sounds are situated. The hypothesis is therefore that blood flow to the apex may be compromised in these participants with cardiovascular disease. Further research is however required to determine the impact of cardiovascular disease on the blood flow to the cochlea and the chemical changes in the organ of Corti.

Previous studies investigating cardiovascular disease and hearing impairment have reported conflicting results. Some studies found a low frequency hearing loss to be more prevalent in individuals with the disease (Friedland et al., 2009; Gates et al., 1993). Gates et al. (1993) conducted a study ($n = 1662$) on the geriatric population and included participants with either coronary artery disease, intermittent claudication (a clinical feature of individuals with peripheral arterial disease (Abela, 2004)) or exposure to

cardiovascular disease risk factors. The results revealed that participants presented with a low frequency sensorineural hearing loss. They postulated that the low frequency hearing loss may be associated with microvascular disease leading to atrophy of the stria vascularis. Friedland et al. (2009) investigated a possible link between audiometric measures and underlying cardiovascular disease in the geriatric population. The study ($n=1168$) found a strong correlation between low frequency hearing loss, cardiovascular disease and risk factors. The results also revealed a significant association between hearing loss and the following types of cardiovascular disease: peripheral vascular disease, coronary artery disease and myocardial infarction.

Conversely, another study concluded that 55% of elderly individuals with cardiovascular disease between the ages of 72 years and 96 years ($n = 548$) presented with a high frequency hearing loss with normal hearing thresholds in the low frequencies (Pratt et al, 2009). These participants presented with an array of cardiovascular diagnoses (for example, myocardial infarction, angina pectoris, atrial fibrillation) and exposure to risk factors such as smoking and increased stress. The study also concluded that the prevalence of hearing loss in adults with cardiovascular disease increased with age. In addition, individuals exposed to risk factors known to cause hearing loss were also included in the study (for example, exposure to noise, treatment for cancer and ingesting ototoxic medication).

Similar findings were reported in a study by Torre et al. (2005) conducted on older adults (43 years to 84 years) with a range of diagnoses (angina, myocardial infarction and stroke). Torre et al. (2005) found normal thresholds in the low frequencies with 55% of female and 70% of male participants presenting with a high frequency sensorineural hearing loss.

5.2 Independent Variables

The four independent variables in this study were (i) age, (ii) gender, (iii) diagnosis, and (iv) the duration of cardiovascular disease.

5.2.1 Age

As no statistically significant results were obtained, age did not impact on hearing thresholds of participants with coronary artery disease and cardiomyopathy in this study. There is an abundance of literature which reported hearing thresholds to be worse as age increases (Pratt et al., 2009; Cruickshanks, 1998; Agrawal Platz, & Niparko, 2008; Wallhagen, Strawbridge, Cohen, & Kaplan, 1997; Zhan, Cruickshanks, Klein, et al., 2009). Similarly, an increase in the prevalence of hearing loss in adults with cardiovascular disease reportedly increased with age (Pratt et al., 2009). The prevalence rate increased from 42% (in the 7th decade of life) to 71% in the 8th decade of life. It is important to note that this study included the geriatric population and the effect of presbycusis must, therefore, be taken into account.

5.2.2 Gender

The results revealed that gender only had a significant influence on pure tone air conduction thresholds at 4000Hz in the left ear; however test results did not indicate whether it was males or females who were more affected at that frequency.

Whilst gender did not influence pure tone thresholds at most frequencies in this study, previous studies have found a significant difference between males and females (Torre et al., 2005; Pratt et al., 2009; Wallhagen et al., 1997; Zhan et al., 2009; Wiley et al., 2001). Females were found to present with lower thresholds and pure tone averages when compared to males (Torre et al., 2005; Pratt et al., 2009; Wallhagen et al., 1997; Zhan et al., 2009; Wiley et al., 2001). Torre et al. (2005) utilized distortion product otoacoustic emissions in addition to pure tone audiometry and reported that males have reduced emission strength when compared to that of females. This was attributed to increased noise exposure in males. Other possible causes for the differences in males and females include differences in stress levels, lifestyle, diet and exposure to more risk factors known to cause hearing loss (for example, smoking, hypertension) (Wiley et al., 2001; Pratt et al., 2009; Torre et al., 2005). Whilst the literature indicates that males may present with more severe hearing impairments when compared to females, both males and females with a history of cardiovascular disease are equally likely to present with a low frequency hearing loss (Gates et al., 1993).

The aforementioned studies provide general results across the frequency range; however, none provide insight regarding possible gender differences regarding audiometric results at 4000Hz. Although Torre et al. (2005) found the distortion product otoacoustic emissions in males with cardiovascular disease to be weakest at 4000Hz, the results were determined utilizing only the combined average of emissions of the right ear and the left ear and no ear specific information was provided. As no significant difference was found at 4000Hz for distortion product otoacoustic emissions in the current study, this statistically significant result needs to be interpreted with caution.

5.2.3 Diagnosis

Results revealed no significant influence of diagnosis (individually and in combination with other independent variables) on hearing thresholds. These results indicated that participants with cardiovascular disease, irrespective of a diagnosis of coronary artery disease or cardiomyopathy, presented with significantly elevated thresholds at 250Hz in the right ear. Previous studies investigating hearing loss in individuals with different types of cardiovascular disease have reported prevalence rates, ranging from 6% to 20%. However, no significant differences in diagnoses have been reported.

In a study conducted on the geriatric population diagnosed with myocardial infarction, Gates et al. (1993) found no influence on hearing in females. However males with a history of coronary artery disease or heart attack were twice as likely to present with a low frequency hearing loss.

5.2.4 Duration of cardiovascular disease

The most significant finding was that the duration of cardiovascular disease significantly influenced all air conduction thresholds in the right ear, and 250Hz, 500Hz, 1000Hz and 2000Hz in the left ear. Similarly, duration significantly influenced bone conduction thresholds at 250Hz, 1000Hz and 2000Hz bilaterally. The correlation coefficient ($r = 0.486$) between duration of cardiovascular disease and age indicated that the combination of duration of the disease and age may influence hearing thresholds.

Although previous studies investigating cardiovascular disease and hearing loss have all described participants as having a history of cardiovascular disease, none

provided detail regarding the duration, age of onset and severity of disorder (Torre et al., 2005; Pratt et al., 2009; Gates et al., 1993).

From the audiological findings and the results from the independent variables, it is evident that the area of cardiovascular disease and hearing loss comprises many aspects. However, understanding all the facets of this topic would not be possible without understanding the prevalence of hearing loss in this population.

5.3 Prevalence of Hearing Loss in Cardiovascular Disease

The prevalence of hearing loss (based on a pure tone average greater than 25dB bilaterally) in this study was 5%. The prevalence of hearing loss was 11% in the right ear and 5% in the left. In the right ear, a mild hearing loss was found in 5% of the sample and a moderate hearing loss was found in 6% of the sample. All participants who presented with an elevated pure tone average in the left ear presented with a mild hearing loss. Many studies have provided tentative results regarding the prevalence rate of hearing loss in the general population (including various age groups).

In the United States of America, the prevalence of hearing loss in the general population between 40 and 49 years of age is reported as 6% (Agrawal et al., 2008). The prevalence increased to 15% in individuals between the ages of 50 and 59 years. Similarly, Australia appeared to have a prevalence of a mild hearing loss in 5% of individuals between the ages of 15 to 50 (Hogan, O'Loughlin, Miller, & Kendig, 2009). The prevalence increased to 28% (mild hearing loss) in individuals between the ages of 51 and 60 years, and to 12% in individuals with a moderate hearing loss. Similar estimates were found in Great Britain (Hogan et al., 2009). The results of the current study are similar to the findings of the previous studies.

The prevalence of hearing loss in developing countries has not been extensively researched and is not as well documented as that of developed countries. The reported prevalence rates in India, Thailand, Bangkok and Brazil are similar to that found in the current study. Whilst no statistics are available regarding the adult population in South Africa, the percentage of participants who presented with a hearing loss in the current study is similar to the prevalence of the aforementioned African countries such as Nigeria (Mathers et al., 2000; Lasisi et al., 2010). These statistics indicate that the prevalence of

hearing loss in the current study (regarding cardiovascular disease) is congruent with that expected in other countries.

Whilst the prevalence reported in these studies are similar to the prevalence of hearing loss in adults with cardiovascular disease, previous studies reported a high frequency hearing loss as opposed to the low frequency hearing loss found in the current study. The nature of the hearing loss is, therefore, contradictory.

The prevalence of hearing loss in individuals with cardiovascular disease has not been extensively researched; however, the few studies which have been conducted have made tentative suggestions regarding the prevalence in specific populations with this disease. Research indicates that the prevalence of hearing loss in adults with any form of cardiovascular disease range from six percent to as high as 50%. The prevalence of unilateral hearing loss in individuals with vertebro-basilar insufficiency is reported as 20% (Yamasoba, 2001). Another study reported a prevalence of approximately 50% percent in a geriatric population with the disease (Pratt et al., 2009). The prevalence of hearing loss in older adults with myocardial infarction ranged from six percent to 13% (Torre et al., 2005). It was also reported that for older adults with angina, the prevalence is between seven percent and 10% (Torre et al., 2005).

The aforementioned percentages do not greatly differ from the studies conducted on the general population in both developed countries and developing countries; they are, however, slightly higher than those found in the current study. This indicates that the prevalence of hearing loss in adults with cardiovascular disease is not significantly higher than the prevalence of hearing loss in the general population.

5.4 Conclusion

This chapter highlighted the results of the research. The audiological evaluation revealed a low frequency, sensorineural hearing loss with the right ear being worst effected. Results from acoustic reflexes, pure tone thresholds and distortion product otoacoustic emissions indicate a cochlear site of lesion.

The prevalence of hearing loss in the current study appeared to be similar to that of the general population. When compared to the prevalence rates of hearing loss in disorders known to cause hearing impairment, the prevalence rate of the current study was significantly lower.

The results of the current study supported the findings of previous studies regarding the influence of gender on hearing thresholds. Whilst the duration of cardiovascular disease influenced pure tone thresholds in this study, previous literature does not support these findings.

CHAPTER 6

CONCLUSION

6.1 Introduction

This study investigated the prevalence of hearing loss in adults with cardiovascular disease, described the audiological findings of the participants and determined which variables influence pure tone thresholds. This chapter summarizes the findings of the study. Thereafter, it focuses on the strengths and limitations of the study, the recommendations for future research and the implications of the results in a clinical setting.

6.2 Summary of Results

The results of this study have provided insight regarding the prevalence of hearing loss in adults aged between 45 and 54 years with coronary artery disease and cardiomyopathy.

Thirty four percent of participants with cardiovascular disease in the current study presented with thresholds greater than 25dB at 250Hz bilaterally indicating low frequency involvement. This was confirmed by distortion product otoacoustic emission results, indicating the apex of the cochlea to be a possible site of lesion. Of the four independent variables studied, the age of participants and their diagnosis did not influence pure tone thresholds. Gender, as an individual variable, influenced air conduction pure tone thresholds at 4000Hz in the left ear; however, in combination with other variables, gender influenced pure tone thresholds marginally. Duration of cardiovascular disease significantly influenced pure tone thresholds in the low and mid frequencies bilaterally.

6.3 Strengths of the Study

- This study has utilized a quantitative, descriptive, survey research design which ensured that the results were objective, accurate and reliable. As the researcher did not know any of the participants, researcher bias was minimized, enhancing the reliability of results. A reliability co-efficient was calculated and a score of

92% was obtained this indicating good inter-rater reliability. Reliability was further enhanced by applying the cross-check principle to compare the speech reception threshold and pure tone average results.

- A comprehensive test battery was utilized to evaluate participants, thereby ensuring that different components of the auditory pathway were assessed. This allowed for the identification of a possible site of lesion.
- A large sample size was utilized thus allowing for some degree of generalization of results to the general population of individuals diagnosed with cardiovascular disease.
- Stringent inclusion/exclusion criteria allowed for the exclusion of extraneous variables (for example, noise exposure, ototoxicity, and diabetes mellitus) which may influence hearing thresholds. This ensured that results were valid and hearing thresholds could, therefore, be more likely attributed to the influence of cardiovascular disease.
- This study excluded individuals below 40 years of age and above 55 years of age. This allowed for the exclusion of presbycusis which may have influenced hearing thresholds.

6.4 Limitations

Whilst this study has provided valuable information regarding the audiological presentation of individuals with cardiovascular disease, the limitations of this study need to be taken into account:

- As this study included only individuals diagnosed with coronary artery disease or cardiomyopathy, results of this sample may therefore not be representative of the general population and consequently results cannot be generalized to all individuals with cardiovascular disease.
- Because this study excluded individuals below 40 years of age and above 55 years of age, the results may not be representative of the general adult population. Results should be interpreted with caution, as they cannot be generalized to all adults with cardiovascular disease.
- This study comprised of 92 participants. This sample size is not representative of the general population and results cannot be generalized.

- Whilst a comprehensive test battery was utilized to assess participants, contralateral acoustic reflexes were not included in the test battery. Distortion product otoacoustic emissions below 750Hz were another significant component which was omitted due limited accessibility to equipment. Distortion product otoacoustic emissions below 750Hz would have provided valuable low frequency data. The exclusion of the two aforementioned tests resulted in a limitation of analysis of results however; as a comprehensive test battery was utilized, assessment of the various elements of the auditory pathway was still possible.
- Furthermore, distortion product otoacoustic emission results in the low frequencies should be interpreted with caution as the influence of environmental noise needs to be considered (Hall, 2000).
- The research design of this study was a survey research design. As a result, it did not allow for analysis regarding possible hearing loss prior to diagnosis of cardiovascular disease. Furthermore, it did not enable analysis regarding progression of hearing loss over time.
- The maximum duration of cardiovascular disease of participants in this study was four years. Since the duration of cardiovascular disease was found to significantly influence hearing thresholds in this study, the maximum duration of four years limited the analysis of the interaction between duration of the disease and hearing thresholds.

6.5 Implications

Individuals living with hearing loss experience many emotional and social challenges. Similarly, individuals with cardiovascular disease experience many of the same challenges; however, living with this disease brings its own physical and mental challenges. When faced with an individual presenting with both a cardiovascular disease and a hearing loss, it is imperative that the medical team is aware of these challenges. Referral to the appropriate professionals (for example, a psychologist, or an audiologist) for further assessment, and management is therefore essential.

The information from this study may encourage the inclusion of audiologists in the multi-disciplinary cardiovascular disease team to manage the audiological complaints of patients with cardiovascular disease.

More specifically, the results of this study serve to increase the audiologist's knowledge regarding the presentation of hearing loss in adults with coronary artery disease and cardiomyopathy.

It is well known that prevention and early identification of a disease are key elements in any medical profession (Foody, 2001). This highlights the need for the implementation of early identification programmes, targeting individuals with cardiovascular disease that include hearing screening and information sessions for medical personnel working in cardiology departments.

6.6 Recommendations for Future Research

The results revealed a variety of interesting trends. Preliminary answers and many more questions were raised that will need to be answered in the following type of future research:

- The replication of this study on individuals that present with other types of cardiovascular disease would expand the research in the field of hearing loss and this disease.
- This study can be replicated, following individuals with cardiovascular disease longitudinally from the time of diagnosis in a prospective study. This will provide valuable information regarding the interaction between the two variables and the predictive model in calculating possible hearing loss. It would further allow for the investigation of the progression of hearing loss in individuals with cardiovascular disease over time.
- The influence of duration of cardiovascular disease requires further investigation as the maximum duration for the current study was four years and duration of this disease was found to influence hearing thresholds.
- Future studies should also expand on the audiological test battery used in the current study to include contra-lateral acoustic reflexes and low frequency distortion product otoacoustic emissions.
- The difference in results between the right ear and the left ear requires further investigation as this was a pattern identified in the results of several tests.

- The replication of this study in other South African populations will contribute valuable information in understanding the audiological presentation in adults with cardiovascular disease in South Africa.

6.7. Conclusion

This chapter summarized the rationale and the results of the research as described in Chapter 4. By means of a critical evaluation of the research, combined with a discussion of the study's strengths and weaknesses, the validity of the study is established and the clinical implications of the research were pointed out.

Given the dearth of information on cardiovascular disease and its influence on hearing thresholds, the groundwork has been laid for future, more in-depth research to replicate, refine, and expand the current study in various ways that could be generalized beyond the specific population who participated in this study.

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Appendix A: Questionnaire for participants (case history interview)

Questionnaire for Participants:

(to be completed by researcher based on participant's verbal/Sign Language input)

Participant Number: _____
 Date of Completion: _____ Date of Birth: _____
 Age: _____ Gender: Male / Female (please circle)

Section A: Hearing:

1. Do you have <i>hearing</i> difficulties?	Yes	No	
2. If yes, please describe the nature of your <i>hearing</i> difficulty (e.g. difficulty hearing in noise, environmental sounds are too soft)			
3. If you have <i>hearing</i> problems, which ear is it difficult for you to hear?	Right	Left	Both
4. If you have <i>hearing</i> difficulties, how many months/years has it been since you noticed the problem?			
5. Has your <i>hearing</i> changed since you have been diagnosed with a heart condition?	Yes	No	
6. If yes, please explain how it has changed (e.g. has it gotten worse?)			

Section B: Heart:

1. Do you have <i>heart</i> problems?	Yes	No
2. If you have <i>heart</i> problems, when was the problem first noticed?		
3. What is your medical diagnosis?		
4. What medication are you currently taking for your <i>heart</i> problems?		
5. Do you have Hypertension (high blood pressure)?	Yes	No
6. A) If yes, what medication are you currently taking?		
B) For how many months/years have you been taking hypertensive medication?		
C) Does your blood pressure fluctuate?	Yes	No

Section C: General

(Please circle and provide details where necessary)

Do you have any of the following?

1. A ringing/buzzing sound in the ear/s? Yes / No

If yes, please answer the following:

- A. Which ear is it in? _____
- B. Is it there all the time or only sometimes? _____
- C. Which time of the day/night is it worse? _____
- D. Is the sound a sharp ringing (e.g. like a bee buzzing/telephone ringing) or
a _____ booming _____ sound?

2. Dizziness or feeling off balanced? Yes / No

If yes, please answer the following:

- A. When do you get dizzy (e.g. with quick movements, whilst walking)?

- B. How often to you get a dizzy spell (e.g. daily/once a week/once a
month/with all sudden movements)? _____
- C. Do you get dizzy only when your blood pressure is high? _____

3. Have you been exposed to excessive or very loud noise (e.g. working in a factory with machines or hearing the sound of a gunshot)?

If yes, please answer the following:

- A. What is the nature of the sounds you have been exposed to (e.g. machines)? _____
- B. For how many months/years have you been exposed to loud sounds?

- C. Have you used earmuff or any form of ear protection when exposed to
loud sounds? _____

4. Do you have diabetes? Yes / No

5. Do you have kidney problems? Yes / No

6. Do you have cancer? Yes / No

If yes, please answer the following:

- A. Have you been for chemotherapy? _____
- B. Have you been for radiation therapy? _____
- C. Have you experienced pain in your ears since the cancer? _____
- D. What changes have you noticed in your hearing since your diagnosis and
treatment? _____
- E. Does your hearing fluctuate from day-to-day? _____

F. Do you notice a difference in hearing in one ear compared to the other ear? _____

7. Do you currently smoke? Yes / No

A. If yes, how many cigarettes do you smoke a day? _____

B. How many months/years have you been smoking for? _____

8. Have you had surgery/an operation around the head/neck region? Yes / No

If yes, please answer the following:

A. What was the reason for the surgery? _____

B. What was the procedure called? _____

C. What was the outcome of the surgery? _____

D. Did you notice any hearing difficulties after the surgery? _____

9. Have you had an injury around the head/neck region? Yes / No

If yes, please answer the following:

A. What was the nature of the trauma? _____

B. Did you notice any hearing difficulties after the trauma? _____

10. Does anyone in your family have a hearing loss? Yes / No

If yes, please answer the following:

A. How are you related to them? _____

B. At what age did they begin having hearing difficulties? _____

C. Was the hearing loss due to a medical condition? If so please provide details _____

11. Are you taking any medication for other health reasons? Yes / No

If yes, please answer the following:

A. What is the name/s of the medication? _____

B. What is the reason for taking this medication? _____

C. Has your hearing changed since you began taking this medication? If yes, how has it changed (e.g. has it gotten worse)? _____

Section D: To be completed by the researcher

(Information to be obtained from participants' medical records)

1. Diagnosis and aetiology:

2. Date of diagnosis/length of CVD:

3. Treatment received (nature of intervention/length/operation or procedures/hospitalization/strategies/lifestyle modifications):

4. Medication (name and function, dosage and schedule, onset, changes in medication):

5. Symptoms:

6. Time of onset of symptoms:

7. Changes in symptoms:

8. Other medical history (e.g. visual difficulties, asthma, etc):

Appendix B: Participant information sheet and informed consent form

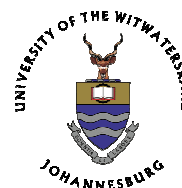


**SPEECH PATHOLOGY AND AUDIOLOGY
School of Human & Community Development**

Faculty of Humanities

University of the Witwatersrand

Private Bag 3, WITS, 2050
Tel: (011) 717 4565 Fax: (011) 717 4572



Participant Informed Consent Form

Good Day.

My name is Trusha Solanki and I am currently completing a Masters degree in Audiology at the University of Witwatersrand. As a requirement of the course, I will be completing a research project on the topic of cardiovascular disease and hearing loss.

This study aims to investigate the impact of cardiovascular disease on hearing. The results will be important for audiologists in terms of playing a more active role in the management of individuals with cardiovascular disease.

I hereby invite you to participate in this study. Should you agree to be a participant in this study, you would be requested to complete a case history form and undergo a hearing test at South Rand Hospital. This process will take approximately 40-50 minutes. You would have to travel to South Rand Hospital on the day of your hearing test. If you do not have a means of transport but would still like to participate in the study, please inform the researcher and transport arrangements can be made. If you are able to travel to the hospital using your own transport, you will be offered R50.00 financial compensation for your travelling expenses on the day of the hearing test.

Your participation is voluntary and all the information you provide will be anonymous and confidential. There will be no identifying information on the case history form and the assessment forms and all personal information will be viewed only by the researcher.

If you decide to participate and then withdraw from the study, there will be no penalty or negative consequences. Refusal to participate will involve no penalty/loss of benefits.

There is no direct benefit from participating in this study however you will get information regarding the status of your hearing. The information from this study will be valuable in the assessment of individuals with cardiovascular disease. There are no known risks associated with your participation in this research.

Should you wish to know the results of your hearing test, please inform the researcher and the results will be discussed on the day of the hearing test. The results of your hearing test may or may not indicate a hearing loss. If a hearing loss is detected, it may impact on your quality of life, your communication and your emotional well-being. A counsellor will, therefore, be available if you would like to discuss your hearing loss further. An audiologist will also be available to discuss ‘the way forward’ regarding your hearing loss. You may also request a report of your results which will then be posted to you. Any recommendations which are made will be based on the results of your individual hearing test. You are not obligated to follow through with the recommendations. You may also request that the results of your hearing test are not discussed with you.

Your medical and previous audiological records (if applicable) will help in getting a diagnosis and an in-depth medical history. I would, therefore, appreciate your consent to access your medical and audiological results.

Should you wish to participate in this study, please complete and sign the informed consent form below.

Should you need further information or have any queries about this study, don't hesitate to contact me on 083 455 7770 / (011) 888-9655 or email at tsolanki9@gmail.com. Alternatively you can contact Anisa Keshav from the Human Research Ethics Committee

Office at the University of Witwatersrand on (011) 717-1234 or you can email her at anisa.keshav@wits.co.za.

Thank you for your time and interest.

Yours faithfully,

Trusha Solanki

Consent Form:

I consent to participate in this study. I have received, read and understood the above-mentioned information and understand the nature, risks and purpose of this study.

I have been informed of the fact that the results of this study will be included in a research report but it will not contain any identifying information. I have also had sufficient opportunity to ask questions.

I agree to participate voluntarily and understand that I may refuse to answer any particular questions or withdraw from the study at any time without any negative consequences/penalties.

I have had sufficient opportunity to ask questions and of my own free will declare myself prepared to participate in this study.

Name of Participant: _____ Date: _____

Signature: _____

Researcher

I here within confirm that the above participant has been fully informed about the nature, conduct and risks of the research study on “The Prevalence of Hearing Loss in Older Adults Presenting with Cardiovascular Disease”

Name of Researcher: _____ Date: _____

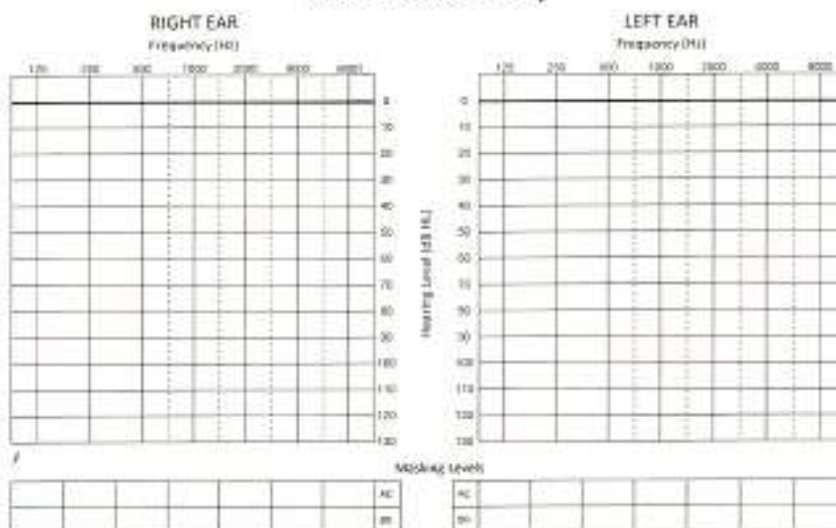
Signature: _____

Appendix C: Data collection forms (results for basic test battery and form utilized to record otoacoustic emission results)

SOUTH RAND HOSPITAL AUDIOLOGY DEPARTMENT

Name: _____ Age: _____ DOB: _____
 Referred by: _____ Audiologist: _____ Date: _____

Pure Tone Audiometry



	RIGHT		LEFT	
	RESPONSE	NO RESPONSE	RESPONSE	NO RESPONSE
AC - Unmasked	○	○	×	×
AC - Masked	△	△	□	□
BC - Unmasked	<	<	>	>
BC - Masked	⌈	⌈	⌋	⌋
F - Free Field	F		F	
Other				

Pure Tone Average

RIGHT	LEFT
dB HL	dB HL

Test Reliability

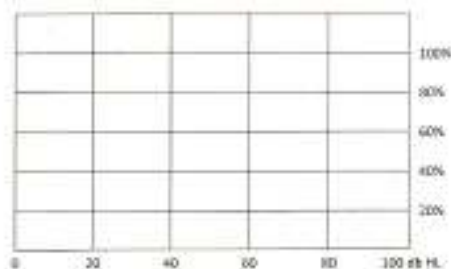
Good	
Fair	
Poor	

Speech Audiometry

	SRT	MCL	TD	DR	MAXIMUM LEVEL		
					70%	50%	25%
R							
L							
F							

	Materials	SL	HL	N	MAXIMUM LEVEL		
					70%	50%	25%
R							
L							
F							

Performance Intensity Function



Otoscopic

Tympanometry

	RIGHT	LEFT
Type		
Static compl.	ml	ml
ECV	ml	ml
MEP	ml/s	ml/s

Acoustic Reflexes

	IPSJ - R	IPSJ - L	CONTRA - R	CONTRA - L
500 Hz				
1000 Hz				
2000 Hz				
4000 Hz				

Results & Recommendations

 Audiologist
 SOUTH RAND HOSPITAL
 (011) 681 2124 / 2070

OTOACOUSTIC EMISSION (OAE) REPORT

Patient name: _____

Date of Birth: _____

Ear: _____

Type of OAE: _____

Protocol: _____

Results:

	Right Ear						
	750Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
OAE (dB)							
Noise Floor (dB)							
Pass/fail							

	Left Ear						
	750Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
OAE (dB)							
Noise Floor (dB)							
Pass/fail							

Comments:

**Appendix D: Ethical clearance certificate from the Human Research Ethics
Committee (Medical) at the University of Witwatersrand**

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
 Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
 R14/49 Miss Terisha N Solanki

<u>CLEARANCE CERTIFICATE</u>	M18726
<u>PROJECT</u>	The Prevalence of Hearing Loss in Adults Presenting with Cardiovascular Disease
<u>INVESTIGATORS</u>	Miss Terisha N Solanki
<u>DEPARTMENT</u>	Speech Pathology & Audiology
<u>DATE CONSIDERED</u>	30/07/2010
<u>DECISION OF THE COMMITTEE*</u>	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 13/10/2010

CHAIRPERSON


 (Professor PE Clouston-Jones)

*Guidelines for written 'informed consent' attached where applicable
 cc: Supervisor: Dr K Joubert

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10004, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress report.

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

**Appendix E: Letter of permission from Charlotte Maxeke Johannesburg
Academic Hospital**



University of Limpopo
PO Box 2028, Medunmetse, 0301
www.unilimpopo.ac.za



Office of the CEO
Enquiries: M. Motjelele
(011) 488-3793
(011) 488-3753

09 June 2010

Trusha Solanki
MA Audiologist Student

Dear Trusha

RE: Permission to conduct research to "Determine the prevalence of hearing loss in adults with cardiovascular disease."

Your research has been provisionally approved. Please note that you can only resume with your study after you have obtained ethical clearance from the wits committee which you should submit to the CEO's office for final approval.

Yours sincerely

Dr. Barney Selebano
Chief Executive Officer

Appendix F: Letters of permission from South Rand Hospital



Department of Health
 Lefapha la Maphele
 Departement van Gesondheid
 Umnyango wezeMpilo
SOUTH RAND HOSPITAL
ROSETTENVILLE
 Chief Executive Office

Enq: Ms. P. Ngwenya
 Tel: 011 681 2002

Ms. Trusha Solanki
 MA Audiology Student

Dear Trusha Solanki

**RE: PERMISSION TO CONDUCT RESEARCH TO "DETERMINE THE
 PREVALENCE OF HEARING LOSS IN ADULTS WITH
 CARDIOVASCULAR DISEASE."**

Your research has been provisionally approved. Please note that you can only resume your study after you have obtained clearance from the University of Witwatersrand Ethics Committee.

Yours Sincerely





Mrs. M.C. Makhetha
 Chief Executive Officer

29/04/2010
 Date

South Rand Hospital, 1st Floor Admin Block
 Private bag X 1
 Rosettenville 2130
 Tel: 011 681 2002/ Fax: 011 681 2140

SOUTH RAND HOSPITAL**SPEECH THERAPY AND AUDIOLOGY DEPARTMENT**

Private Bag X1
Rosettenville
2130

Pb: (011) 681-2124
Fax: (011) 435-0038

7 June, 2010

To Whom It May Concern

RE: PERMISSION TO USE AUDIOLOGICAL EQUIPMENT

This letter serves to confirm that Trusha Solanki has been granted permission to use the audiological equipment at South Rand Hospital to conduct her research.

Any questions or queries, please do not hesitate to contact me



Dina Lilian
Head of Department
Speech Therapist & Audiologist



Appendix G: Template of report provided to participants

SOUTH RAND HOSPITAL
Audiology Department

Name: _____ Date: _____
Date of Birth: _____ Age: _____
Examiner: _____ Referred by: _____
Diagnosis: _____

Case History: _____

Otoscopic Examination

Right Ear: _____
Left Ear: _____

Immittance Audiometry

Right Ear: _____

Left Ear: _____

Pure Tone Audiometry

Right Ear: _____

Left Ear: _____

PTA: Right Ear _____ Left Ear _____

Speech Audiometry

Right Ear: _____

Left Ear: _____

DPOAEs

Right Ear: _____

Left Ear: _____

Summary of Results

Recommendations

If you have any questions, or require further information, do not hesitate to contact me on 083 455 7770.

Thank you,

T. Solanki

Speech Therapist & Audiologist

Appendix H: Certificates of calibration of equipment



Ear Institute, 1240 Webb Str. Queenswood Pretoria. Tel: (012) 333-3131 Fax: (012) 333-2298

H.A.S.S. Industrial (Pty) Ltd

Certificate of Calibration No. B AS041517/11

This certificate is issued in accordance with the conditions for calibration of the instrument as described by the manufacturer or the South African Bureau of Standards (SABS 0154-1; 0154-2) were applicable. It is a correct record of measurements made. Copyright protected. This certificate may not be reproduced, except with the prior written approval of H.A.S.S. Industrial (Pty) Ltd.

Calibrated for:	South Rand Hospital Friars Hill Street Rosettenville Johannesburg Gauteng 2134	
Calibration of:	GSI 38 V2	
Manufacturer:	GSI	
Serial Number:	AS041517	
Calibration procedure:	Complete probe, reflex and pressure calibration as described in the manufacturer's specification.	
Traceability:	The calibration was performed using instruments traceable to national standards.	
Date of Calibration:	2011-02-09	Cal. Due Date: 2012-02-09
Results:	The instrument complies with the requirements for use as specified by the manufacturer.	
Remarks:	None	
Calibrated by:	Retief Ross	 Signature

NOTE: The values in this certificate are correct at the time of calibration. Subsequently the accuracy will depend on such factors as the care exercised in the handling and use of the instrument and the frequency of use. Re-calibration should be performed annually to ensure that the instrument's accuracy remains within the desired limits.



Ear Institute, 1240 Webb Str. Queenswood Pretoria. Tel: (012) 333-3131 Fax: (012) 333-2298

H.A.S.S. Industrial (Pty) Ltd

Certificate of Calibration No. B AA073110/10

This certificate is issued in accordance with the conditions of the South African Bureau of Standards (SABS 0154-1; 0154-2). It is a correct record of measurements made. Copyright protected. This certificate may not be reproduced, except with the prior written approval of H.A.S.S. Industrial (Pty) Ltd.

Calibrated for:	South Rand Hospital Friars Hill Street Rosettenville Johannesburg Gauteng 2134		
Calibration of:	GSI 61		
Manufacturer:	GSI		
Serial Number:	AA073110		
Calibration procedure:	Complete diagnostic calibration: Audiometer (GSI 61), Earphones (TDH 50: Right s/n C 68020; Left s/n C68019), Bone Vibrator (B71) Free Field (Standard 90 dB sound field).		
Traceability:	The calibration was performed using instruments traceable to national standards.		
Date of Calibration:	2011-02-09	Cal. Due Date:	2012-02-09
Results:	The instrument complies with the requirements for use of a Type 1 Audiometer. (Air, Bone & Free Field).		
Remarks:	None		
Calibrated by:	Retief Roos	 Signature	

NOTE: The values in this certificate are correct at the time of calibration. Subsequently the accuracy will depend on such factors as the care exercised in the handling and use of the instrument and the frequency of use. Re-calibration should be performed annually to ensure that the instrument's accuracy remains within the desired limits.