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DEPARTMENT OF SPEECH PATHOLOGY & AUDIOLOGY

EARLY DETECTION OF HEARING LOSS: EXPLORING RISK-BASED HEARING SCREENING WITHIN A DEVELOPING COUNTRY CONTEXT

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A RESEARCH THESIS SUBMITTED FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN AUDIOLOGY
IN THE FACULTY OF HUMANITIES
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DECLARATION

I, Amisha Kanji, hereby declare that this submission is my own original work and that the assistance which I have received is detailed in the Acknowledgements of this report. To the best of my knowledge and belief, this submission contains no material which has been accepted for the award of any other degree or diploma at any other university or institute of higher learning, except where due acknowledgement and reference has been made in the text. I am responsible for the study and conclusions reached.

_____ _____

Amisha Kanji Date

SCHOLARLY ACTIVITIES

The current researcher was involved in the following scholarly activities within the field of Early Hearing Detection and Intervention (EHDI):

Health Professions Council of South Africa (HPCSA), EHDI Task Team which involved:

- Defining and developing the nature and standards of the EHDI hearing screening programme
- Updating the HPCSA EHDI position statement
- Developing a curriculum for education and training in EHDI hearing screening
- Defining qualifications, roles and responsibilities of various personnel
- Developing guidelines for the implementation of hearing screening for EHDI including referral pathways and follow-up

Aspects emanating from the execution of tasks by the team were presented at a conference as:

Schlesinger, D., de Kock, T., & Kanji, A. (2014). The Current State of Affairs: EHDI in South Africa: HPCSA EHDI Task Team. Oral presentation at *ENT/SAAA/SASLHA Conference*, Cape Town.

Parts of this thesis have been presented at scientific conferences and accepted in journals as:

- Kanji, A., & Khoza-Shangase, K. (2016). Feasibility of Newborn Hearing Screening in a public hospital setting in South Africa: A pilot study. *South African Journal of Communication Disorders,* In Press
- Kanji, A. & Khoza-Shangase, K. (2016). TEOAE, DPOAE, AABR: Exploring a suitable combination for risk-based newborn hearing screening in a developing country context. *Abstract submitted to the HEAL conference, Cernobbio (Lake Como), Italy-June 2-4, 2016* (poster presentation)
- Kanji, A., & Khoza-Shangase, K. (2016). Factors associated with follow-up return rate in a risk-based newborn hearing screening programme. *Abstract submitted to the HEAL conference, Cernobbio (Lake Como), Italy- June 2-4, 2016* (oral presentation)

The following supervised, unpublished, undergraduate research studies emanated from the current study:

- Krabbenhoft, K. (2015). Audiological follow-up in a risk-based hearing screening program: influencing factors
- Farr, K. (2015). Hearing screening and audiological monitoring practices in newborns and infants with risk factors for hearing loss

Other publications and conference presentations within the field of EHDI include:

- Kanji, A., Khoza-Shangase, K., & Ballot, D. (2010). Hearing screening follow-up return rate in a Very Low Birth Weight Project: A Retrospective Record Review. *South African Journal of Child Heath*, Vol 4(4):95-99.
- Kanji, A. (2011). Newborn Hearing Screening: Is there a need to revisit targeted hearing screening in some developing countries? Oral presentation at the 6th Australasian Newborn Hearing Screening Conference, Fremantle.
- Kanji, A., & Khoza-Shangase, K. (2012). The occurrence of high-risk factors for hearing loss in very-low-birth-weight neonates: A retrospective exploratory study of targeted hearing screening. *South African Journal of Communication Disorders*, Vol 59(1): 3-7
- Kanji A., & Kara, R. (2013). Pediatric physicians' referral of children aged 0-3 years for audiological evaluation in the public health care sector. *Audiology Research*, Vol 3:e7:48-51
- Kanji, A., & Opperman, J. (2015). Audiological practices and findings post HPCSA position statement: Assessment of children aged 0 - 35 months. *South African Journal of Child Health*, Vol 9 (2): 38-40

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LIST OF ABBREVIATIONS

AABR	Automated Auditory Brainstem Response
AAP	American Academy of Pediatrics
ABR	Auditory Brainstem Response
ACOG	The American Congress of Obstetricians and Gynecologists
AIDS	Acquired Immunodeficiency Syndrome
APGAR	Activity Pulse Grimace Appearance Respiration
ASHA	American Speech-Language-Hearing Association
ASSR	Auditory Steady State Response
BBA	Born Before Admission
CASLPA	Canadian Association of Speech-Language Pathologists and Audiologists
CIOMS	Council for International Organizations of Medical Sciences
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
CPAP	Continuous Positive Airway Pressure
CPS	Canadian Paediatric Society
dB	Decibel
dBA	A-weighted decibel
dBHL	Decibel Hearing Level
dBnHL	Decibel above Normal Hearing Level
dBSPL	Decibel Sound Pressure Level
dl	decilitre
DoH	Department of Health
DPOAE	Distortion Product Otoacoustic Emission
EBT	Exchange Blood Transfusion
ECI	Early Childhood Intervention
ECMO	Extracorporeal Membrane Oxygenation
EEG	Electroencephalogram
EHDI	Early Hearing Detection and Intervention
ELBW	Extremely Low Birth Weight
FN	False-negative
FP	False-positive
HIE	Hypoxic Ischemic Encephalopathy
HIV	Human Immunodeficiency Virus
HPCSA	Health Professions Council of South Africa
HRR	High Risk Register
HSRC	Human Sciences Research Council
Hz	Hertz
IMCI	Integrated Management of Childhood Illnesses
IPPV	Intermittent Positive Pressure Ventilation
IQR	Interquartile Range
IVH	Interventricular haemorrhage
JCIH	Joint Committee on Infant Hearing
kHz	Kilohertz

KMC	Kangaroo Mother Care
LBW	Low Birth Weight
MADHS	Michigan Association for Deaf, Hearing and Speech Services
MDGs	Millennium Developmental Goals
mg	milligram
MOU	Midwife Obstetric Unit
NEC	Necrotizing Enterocolitis
NHI	National Health Insurance
NHS	Newborn Hearing Screening
NICU	Neonatal Intensive Care Unit
NNFU	Neonatal Follow-up Clinic
NNJ	Neonatal Jaundice
OAE	Otoacoustic Emissions
PCEHL	Permanent Congenital and Early-onset Hearing Loss
PCHL	Permanent Congenital Hearing Loss
PHC	Primary Health Care
PPHN	Pulmonary Hypertension of the Newborn
PTT	Phototherapy
RDS	Respiratory Distress Syndrome
RMMCH	Rahima Moosa Mother and Child Hospital
RVD	Retroviral Disease
SANC	South African Nursing Council
SASLHA	South African Speech-Language-Hearing Association
sd	Standard Deviation
SLH	Speech-Language-Hearing
TEOAE	Transient Evoked Otoacoustic Emission
TN	True-negative
TNHS	Targeted Newborn Hearing Screening
TORCH	Taxoplasmosis, Syphilis, Rubella, Cytomegalovirus, Herpes
TP	True-positive
TTN	Transient Tachypnea of the Newborn
UNHS	Universal Newborn Hearing Screening
VLBW	Very Low Birth Weight
VRA	Visual Reinforcement Audiometry
WHO	World Health Organisation
WMA	World Medical Association

LIST OF APPENDICES

Appendix A: Medical Ethics Research Committee Clearance Certificate

Appendix B: Letter of permission from Chief Executive Officer at Charlotte Maxeke Johannesburg Academic Hospital

Appendix C: Letter of permission from Department of Paediatrics at Charlotte Maxeke Johannesburg Academic Hospital

Appendix D: Letter of permission from Chief Executive Officer at Rahima Moosa Mother and Child Hospital

Appendix E: Letter of permission from Head of Department of Speech Pathology and Audiology at Rahima Moosa Mother and Child Hospital

Appendix F: Data collection form for initial hearing screening

Appendix G: Data collection form for repeat hearing screening

Appendix H: Data collection form for diagnostic assessment

Appendix I: Information and Consent Form for Charlotte Maxeke Johannesburg Academic Hospital

Appendix J: Information and Consent Form for Rahima Moosa Mother and Child Hospital

DEFINITION OF TERMS: GLOSSARY

Acquired: not inherited at birth but developing after birth

Congenital: present at or before birth

Developed contexts: an industrialised, more economically developed country

Developing contexts: a country that is not yet highly industrialised

Disability: an umbrella term that includes impairments and limitations and restrictions to activity and participation

Distraction screening: a behavioural means of screening hearing of babies between six to nine months of age, requiring them to locate and turn towards a quiet sound of interest that is presented at ear level outside the visual field.

Early term: gestational age of 37 to 38 weeks

Etiology: a cause or set of causes of a disease or condition

Extremely low birth weight: birth weight less than or equal to 999 grams

False-negative: a test result that incorrectly indicates that a particular condition is absent

False-positive: a test result that incorrectly indicates that a particular condition is present

Full term: gestational age of 39 to 40 weeks

Gestational age: term used to describe the length of pregnancy

Impairment: a term used to describe problems in body structure or function that differ from the general population and may be the result of an underlying pathology

Incidence: the number of newly diagnosed cases of a particular condition during a given period of time

Infant: a young baby from birth to 24 months of age

Initial hearing screening: the first hearing screening conducted in hospital

Late term: gestational age of 41 weeks

Low birth weight: a birth weight between 1500 grams and 2499 grams

Mortality: another term for death

Mid-level worker: Health care providers, who have less training and are not professionals, but render health care in communities and hospitals

N: used to represent the total sample

n: used to represent some of the sample and/or the final sample

Newborn or neonate: term used for babies from birth until four weeks

Preterm: gestational age less than 37 weeks

Prevalence: the total number of diagnosed cases of a particular condition existing in a population

Primary prevention: strategies or interventions designed to prevent a disease or condition from occurring

Repeat hearing screening: the second hearing screening conducted six weeks post discharge at the first neonatal follow-up visit

Rescreening: the third hearing screening that was conducted three weeks after the repeat hearing screening when middle ear pathology was suspected

Risk factor: a characteristic or condition that increases the likelihood of one developing a disease

Secondary prevention: strategies used to assist with earlier identification and management of a condition in order to prevent adverse consequences

Sensitivity: the ability of a test to detect the condition when the condition is present

Specificity: the ability of a test to correctly identify those without the condition when the condition is absent

Tertiary prevention: strategies or interventions designed to stop the progress of a disease or condition

Transient middle ear effusion: short-term episodes of fluid in the middle ear

True-negative: a test result that correctly indicates the absence of a condition and represents the specificity of a test or measure

True-positive: a test result that correctly indicates the presence of a condition and represents the sensitivity of a test or measure

Very low birth weight: birth weight between 1000 grams and 1499 grams

ABSTRACT

Purpose: The main objective of the current study was to explore risk-based newborn hearing screening within a developing country by conducting early hearing detection in high-risk neonates within an academic hospital complex in Gauteng, South Africa. Specific objectives included describing the case history factors and audiological function in a group of high-risk neonates; determining the relationship between the case history factors and audiological function; establishing the true- positive (TP) and true-negative (TN) results with different combinations of screening measures; establishing the percentage of TP and TN screening results in the total sample; and exploring the factors associated with follow-up return rate for hearing screening and diagnostic audiological assessment.

Participants: A total of 325 participants, including both males and females comprised the initial study sample. However, due to the longitudinal, repeated measures design of the study, some participants did not attend the repeat hearing screening and/or the diagnostic audiological assessment. All participants' data was analysed for the descriptive analysis aspects of the study. However, the total number of participants differed for inferential statistical analysis as not all participants attended the follow-up appointments.

Design: A descriptive, longitudinal, repeated measures, within-subjects design was employed for the current study. All participants underwent an initial hearing screening, and were booked for a repeat hearing screening (six weeks post discharge). Some participants underwent a re-screening two to three weeks after the repeat hearing screening when transient middle ear pathology was suspected. All participants who *passed* the repeat hearing screening or re-screening were booked for a diagnostic assessment at six months corrected age; whereas those who *referred* were booked soon after the screening.

Methods and materials: Hospital files were reviewed to extract case history information. Participants underwent hearing screenings that comprised of transient otoacoustic emissions (TEOAEs), distortion product otoacoustic emissions (DPOAEs), automated auditory brainstem response (AABR), and high frequency tympanometry when indicated. Diagnostic auditory brainstem response testing was conducted on infants who *referred* at the repeat hearing screening or re-screening. Visual reinforcement audiometry was conducted for infants at six month corrected age. When possible, diagnostic OAE testing was also conducted.

Data Analysis: Descriptive and inferential statistics were used to analyse data from the current study. Inferential statistics included the chi-squared (X^2) test, Fisher's exact test or Wilcoxon rank sum test for associations between variables; the McNemar's test for paired data; the z-test or paired t-test (or one-way repeated measures ANOVA for more than two groups) for comparisons.

Results: Preterm birth (95.7%), exposure to ototoxic medication (87.7%), neonatal jaundice (NNJ) (80.6%) and birthweight below 1500 g (66.7%) were the most frequently occurring case history factors in the study sample. Three hundred and twenty five participants underwent an initial hearing screening, of which 216 returned for a repeat hearing screening. With regard to audiological function, a higher number of participants *passed* the initial hearing screening (n= 192) and repeat hearing screening (n=133), compared to those who *referred* (n=133, n= 27). A total of 93 participants attended the diagnostic audiological assessment. Ninety one presented with hearing within normal limits and two had inconclusive findings as they did not return for the follow-up appointment as recommended. The proportion of true hearing loss based on diagnostic audiological findings was 0%. The relationship between case history variables and auditory function could not be investigated using diagnostic audiological findings, as none of the participants with conclusive diagnostic findings presented with hearing impairment. In addition, the combinations of screening measures yielding TP results could not be investigated. Although the percentage of TN findings was highest at the repeat hearing screening using any combination of screening measures, the TEOAE/AABR yielded the highest percentage specificity. The percentage of TN screening results in the total sample was 60.4% and 89.0% for the initial and repeat hearing screening respectively. The factors associated with follow-up default were mostly unknown for both the repeat hearing screening and behavioural audiological assessment, as caregivers of participants could not be reached telephonically. Results indicated a significant, but weak association between the hospital (research site) and whether or not infants returned for the repeat screening. The mean maternal age for those who returned for behavioural assessment was significantly higher than the mean maternal age of those who did not return.

Conclusion: The current study highlights the important role that audiologists play in the design, piloting and implementation of NHS programmes, with careful consideration of context.Risk-based hearing screening can be conducted in a hospital setting, particularly if appropriately aligned with medical follow-up clinics. However, more research is required into the risk factors associated with hearing loss as current study findings differ from

literature. The inclusion of AABR is valuable within the screening protocol. The feasibility of a risk-based surveillance programme needs to be carefully deliberated, particularly due to high follow-up default. The development of a national database is essential for EHDI programmes in South Africa to allow for tracking of infants.

CHAPTER 1: INTRODUCTION

This chapter introduces the reader to the study by commencing with a brief theoretical overview or background followed by the rationale underpinning the study. The structure of the thesis is also provided through a brief overview of the contents of each chapter.

1.1 Introduction

The current study explored risk-based hearing screening within a developing country through provision of early hearing detection services in high-risk neonates within an academic hospital complex in South Africa. This study was framed within the conceptual framework of early childhood intervention (ECI), as this framework encompasses all aspects of intervention; from prevention to identification of developmental concerns by means of assessment, service delivery, program evaluation, and policy formulation (Meisels & Shonkoff, 2000). ECI refers to the identification and management of children from birth to three years of age, who display or are at risk for communication delay (Rossetti, 2001). As not all children are born healthy and free of disabilities or other biological complications (Meisels & Shonkoff, 2000), the need for early intervention is vital in assisting these individuals to thrive under these circumstances.

One of the most common congenital abnormalities in newborns that places them at risk for communication delay is hearing impairment, as it is reported to be more prevalent than other neonatal conditions routinely screened for at birth (Hatzopoulos, Qirjazi, & Martini, 2007). Variability in prevalence rates of hearing impairment have been documented between neonates from the neonatal intensive care unit (NICU) and well-baby nurseries, with a higher reported incidence and prevalence rate in the NICU population and/or in infants with risk factors for hearing impairment (Mahulja-Stamenkovic et al., 2005; Yoon, Price, Gallagher, Fleisher, & Messner, 2003). Although not specified among global prevalence and incidence rates; in South Africa, it is estimated that nationally, the prevalence of hearing impairment is higher in the public health care sector in comparison to the private health care sector (Swanepoel & Storbeck, 2009). These estimated differences in prevalence rates within the South African health care sector highlight a greater need for the development and implementation of services geared toward early detection and intervention for hearing

impairment in the public health care sector in South Africa, with primarily more focus on newborns and infants who are considered to be at risk.

Early detection of, and intervention for hearing impairment has been associated with positive communication outcomes (Fulcher, Purcell, Baker, & Munro, 2012; Kennedy et al., 2006; Sininger, Grimes, & Christensen, 2010), particularly in developed countries where early hearing detection and intervention (EHDI) programmes are well established. Early detection of hearing loss is conducted through newborn hearing screening (NHS), followed by diagnostic audiological evaluation when indicated. Identification of hearing loss through NHS has been investigated for over a century, and has progressed from the use of behavioural methods to the use of more robust, objective measures such as otoacoustic emissions (OAE) and auditory brainstem response (ABR) testing (Mencher & DeVoe, 2001). These objective measures are currently recommended in position statements and employed in NHS programmes worldwide. Similarly, risk-based hearing screening, commonly referred to as targeted newborn hearing screening (TNHS) was implemented first, with the introduction of the high risk register (HRR) which is used to identify newborns and infants presenting with risk criteria for permanent congenital and early-onset hearing loss (Mencher & DeVoe, 2001). The use of this approach to NHS gradually progressed toward the introduction of universal newborn hearing screening (UNHS) which entails the screening of all newborns (Joint Committee on Infant Hearing- JCIH, 2000; JCIH, 2007).

UNHS has been identified as the recommended screening method for EHDI (JCIH, 2007; Olusanya et al., 2007) in light of the limitations associated with TNHS. It is reported and acknowledged that 25 to 50 % of infants with hearing loss may not be identified using TNHS only, and that the use of the HRR as a sole screening method has documented limited effectiveness. However, the HRR is a necessary and valuable tool for the identification of infants who may require monitoring and follow-up hearing screening (Johnson, 2002b); especially in contexts where UNHS is not yet feasible nor fully implemented, as is the current situation in South Africa. The current researcher is therefore of the belief that there is benefit in revisiting the use of TNHS in the public health care sector in developing countries (where UNHS has not been implemented); where the high burden of infectious diseases and environmental risk factors are priority, manpower shortages exist, and clinical assessment and management costs serve as potential barriers or challenges towards the implementation of UNHS. Irrespective of whether UNHS is eventually established within the public health care

sector in South Africa, the identification and update of contextually relevant high risk factors for hearing loss is important to ensure that these neonates are appropriately monitored and enrolled in a surveillance programme with appropriate caregiver counselling.

1.2 Rationale for the study

UNHS is commonly practiced in developed countries, with well-established, standardized programmes, and dedicated screeners outside of the profession of Speech Pathology and Audiology. While these developed countries with well-established NHS services are concerned with diagnostic follow-up and intervention, South Africa appears to be in the infancy stages of implementation of NHS programmes. The 2007 position statement by the Health Professions Council of South Africa (HPCSA) provides guidelines and principles for EHDI that are primarily based on guidelines from these developed contexts, with slight contextual adaptations in terms of the time frames for screening and diagnosis. Whilst these guidelines are geared toward UNHS and serve as the gold standard that audiologists in South Africa should constantly aim towards achieving, they may not necessarily be currently applicable within all health care sectors within the South African context.

Published literature from South Africa has indicated limited and poor implementation of NHS programmes, with lack of a standardised approach in terms of screening methods and measures adopted. NHS services in the private health care sector in South Africa have been largely described as unstructured and disorganised (Meyer & Swanepoel, 2011). More specifically, very few public sector hospitals in South Africa have been providing some form of NHS (Theunissen & Swanepoel, 2008). This evidence highlights the need for a more structured, manageable interim approach to NHS, such as TNHS.

Effective implementation of a TNHS programme is first and foremost dependent on established and contextually relevant high risk factors for hearing loss. The current high risk factors for hearing loss stipulated in the HPCSA (2007) position statement has been based on evidence from developed contexts, and adapted to include two prevalent conditions within the South African context. Adaptations to the currently stipulated high risk factors are necessary in order to ensure evidence based best practice. These adaptations can only be investigated through thorough planning and implementation of TNHS programmes in hospital settings which can serve as a rich site for research.

The planning and implementation of TNHS programmes also requires careful consideration of the choice of screening measures, and how these measures are to be employed within a screening protocol. Review of literature has indicated clear differences in screening measures in different contexts, as well as amongst the populations being screened. In the United Kingdom, for example, well babies are reported to receive transient evoked otoacoustic emission screening (TEOAE) followed by automated auditory brainstem response (AABR) if indicated by poor TEOAE results, whereas newborns requiring NICU care routinely receive both TEOAE and AABR screening (Sim, Mathew, Foley, & Robinson, 2009). This screening practice differs from some birthing facilities in the United States of America, where AABR is the common screening measure of choice followed by distortion product otoacoustic emissions (DPOAE) and TEOAE. The HPCSA (2007) position statement recommends the use of AABR (although more costly than OAE) for screening in the NICU; and OAE for follow-up immunization visits. Whilst recommendations exist, these are primarily based on research conducted in developed contexts, with no research having been performed regarding the use of various screening measures in high-risk neonates within the South Africa context. Hence, there is still an evident lack of focus on screening methods and their effectiveness in published literature from South Africa (Moodley & Storbeck, 2015). It was hoped that the current study would assist in guiding evidence-based best practice, as it aimed to explore the best combination of screening measures that can be used to effectively conduct TNHS. This would assist in determining the best combination for purposes of reducing false-positive (FP) and false-negative (FN) results which would in turn provide information regarding the most cost-effective, accurate combination, whilst reducing the number of follow-up visits.

One of the most common problems noted in NHS programmes is the high rate of infants that are lost to follow-up at various stages of the programme (Papacharalampous, Nikolopoulos, Davilis, Xenellis, & Korres, 2011). This is particularly true in developing countries where facilities for the effective tracking of mothers are lacking (Choo & Meinzen-Derr, 2010; Olusanya & Akinyemi, 2009). South Africa currently does not have a national database for the effective tracking of newborns and infants enrolled in NHS programmes. This is coupled by a lack of prioritisation of data management (Moodley & Storbeck, 2015) and a paucity of research related to the reasons associated with follow-up default. It is therefore important to investigate the follow-up return rate and reasons affecting follow-up return rate as it is one of

the indicators of success of a NHS programme. It was envisaged that by determining the factors that influence follow-up return rate; the current study would assist in informing clinicians about issues that need to be addressed to ensure the establishment of successful EHDI programmes.

With the current focus on the rolling out of the EHDI position statement in public sector hospitals, it was hoped that the current study would serve as a guide in informing whether risk-based or TNHS can be successfully performed at secondary and tertiary levels of health care within the South African context. It was further envisaged that the current study would inform mid-level worker (health care provider with less training than a professional) training programmes when introduced within the public health care sector, and contribute towards context specific research in the field of EHDI in South Africa.

Research and conceptual papers related to EHDI in South Africa have fortunately acknowledged the impracticalities in attempting to implement developed world models of NHS in developing countries (Moodley & Storbeck, 2015; Swanepoel, Delport, & Swart, 2004; Swanepoel, Hugo, & Louw, 2005). The adoption of EHDI models from developed contexts highlight the possible influence that Eurocentrism and colonialism has had on research in Africa. Eurocentrism has led to third world countries perceiving development in terms of a replication or imitation of Europe (Chukwuokolo, 2009). According to Chukwuokolo (2009), Eurocentric ideas are still prevalent in Africa as Africans view the world from European perspectives in all social, political, developmental ,technological and scientific domains. This view is further supported by Costello and Zumla (2000) who believe that research models supported by funding agencies remain semicolonial in nature. This semicolonial approach to research results in research priorities that are foreign in nature, with a low emphasis on sustainability and generalisability of findings and a low influence on local policymakers.

Thus, whilst research findings from developed contexts may be of value, findings from these higher-income countries may be costly and more difficult to implement into practice in lower-income countries as they may be culturally inappropriate and often focus on non-communicable diseases prevalent in developed contexts. There is therefore a tendency to neglect the specific, local needs of lower-income or developing countries (Chetwood, Ladep, & Taylor-Robinson, 2015). Hence, contextual research is imperative in guiding clinical

practice. The current study therefore aimed to explore a TNHS approach to early detection of hearing loss in a developing country context.

1.3 Organisation of the thesis

Chapter one provided a brief overview of literature, followed by the rationale for the study. Chapter two introduces the reader to ECI as this is the theoretical framework of the current study. Various approaches to ECI are discussed and this is followed by an introduction to EHDI principles and an overview of the status of EHDI in South Africa.

Chapter three raises the importance of early detection of hearing impairment. Prevalence and incidence rates of hearing impairment are considered and comparisons are drawn between developed and developing contexts, as well as between the well-baby and high-risk neonate and infant populations. The etiologies associated with hearing impairment and auditory neuropathy are discussed, with an overview of strategies that may assist in addressing preventable causes of hearing loss in developing contexts.

Chapter four provides background to the South African health care context in which the study was conducted. A description of health care facilities and the structure of the health care in terms of levels of service delivery are provided followed by a discussion of the progress towards health goals, and the proposed restructuring or reengineering of health care in South Africa.

Chapter five focuses on the early detection aspect of EHDI which is the primary focus of the study. NHS approaches are defined along with a review and comparison of electrophysiological measures and NHS protocols. Aspects such as cost-effectiveness, follow-up, and ethical considerations are also discussed along with challenges toward the implementation of NHS in South Africa being highlighted.

Chapter six is more specifically centred on risk-based/ TNHS which was the NHS approach explored in the current study. Rationale for the implementation of TNHS is provided followed by a discussion of risk factors for hearing impairment and the audiological screening and assessment protocols for high –risk neonates and infants.

Chapter seven details the methodology adopted in the study. The study design, data collection procedures and protocol, and methods for data analysis are presented, with rationale provided where necessary. A detailed description of the research context is provided and ethical

principles that were adhered to are also defined. This chapter also describes how reliability and validity of results was ensured.

Chapter eight provides the results from both the pilot study and main study. Results are discussed in accordance with the primary and/or secondary objectives of the study. Similarly, chapter nine provides a discussion of the results detailed in chapter eight, in a manner consistent with the presentation of the results.

Chapter 10 summarises the key findings from the study and presents the conclusions drawn from the study. Limitations of the study are also highlighted and possible recommendations for clinical implementation, education, policy formulation and future research are put forward.

CHAPTER 2: EARLY DETECTION AND INTERVENTION

This chapter provides an overview of ECI, with a particular focus on the approaches and/or frameworks to ECI and how these relate to the current study. Furthermore, this chapter introduces the reader to the principles of, and rationale for EHDI by providing an overview of relevant outcome studies. Lastly, the chapter provides a contextual overview of the current status of EHDI and EHDI research in South Africa.

2.1 Early Childhood Intervention (ECI)

2.1.1 ECI Programmes.

Early childhood is defined as the period from prenatal development to eight years of age and is considered an important period that impacts on later development and success in life (The Consultative Group on Early Childhood Care and Development, 2012).

ECI programmes are aimed at supporting children who are considered to be at risk for developmental delay or who have already been identified as having a developmental delay or disability (WHO, 2012a). These programmes include specialised services such as medical and rehabilitation services; family-centred support (including training and counselling); social and psychological services; special education as well as service planning and coordination. These specialised services are guided by specific rationale and may be provided at different sites that include health care clinics, hospitals, early intervention centres, rehabilitation centres, community centres, homes and schools (WHO, 2012a).

There are a number of rationale guiding the implementation of ECI programmes as outlined by the WHO (2012) discussion paper on early childhood development and disability. The first justification (as stated by the Convention on the Rights of the Child and Convention on the Rights of Persons with Disabilities) is that all children with disabilities have the right to develop to their maximum potential (WHO, 2012a). Secondly, if childhood development is fostered, and appropriate care and support provided, these children are more likely to function more optimally in adulthood which may reduce economic expenditure (WHO, 2012a). Thirdly, there is also a scientific reasoning behind ECI which is based on the critical period of development. The first three years of a child's life is considered the critical period and serves as the foundation for future development. Lastly, implementation of these ECI programmes can assist in ensuring more effective educational initiatives.

2.1.2 Approaches to and Frameworks of ECI

Two different approaches to ECI will be considered in this chapter. Firstly, the World Health Organisation (WHO, 2012a) emphasises that a comprehensive approach is required to support the development of children with developmental delay or disability. This approach includes early identification; assessment and early intervention planning; provision of services; as well as surveillance. A life-cycle approach has therefore been proposed as a useful framework in identifying priority and sustainable interventions if a developmental delay or disability is detected early. This approach also highlights the importance of a continuum of quality care as children transition from birth to primary school. Furthermore, the life-cycle approach draws on involvement and shared roles and responsibilities from a wide range of sectors (health and education) (WHO, 2012a). These shared roles and responsibilities ensure the provision of holistic support without duplication of services.

Secondly, Guralnick (2001) proposed a developmental systems framework for early intervention. This framework is family and community centred, and supports all risk groups. It suggests that children and families should enter the system through referral and a screening process. It also suggests that existing screening programmes and HRRs or other screening tools need to be identified. These screening programmes then need to either be built on, or new programmes need to be created. In this model, Gulranick (2001) also recommends that concerns around universal versus targeted screening, timing, risk criteria and cost-effectiveness be considered when developing screening programmes. Children who do not meet the screening criteria or who are not considered at risk following screening even if parents express concern, should be enrolled in monitoring programmes. Such monitoring or surveillance programmes may include high- risk infant follow-up programmes as children who *pass* initial screenings may present with problems as they develop. The primary function of surveillance programmes is to ensure that the possibility of a child not being identified is minimized and that developmental problems are monitored in a cost-effective manner (Guralnick, 2001). Points of access need to be established for children with identified concerns or risks in order to begin the process of assessment and intervention. Children and families should be referred to these community-based sites or organizations and an interdisciplinary assessment should be conducted prior to referral for early intervention (depending on the established eligibility criteria for early intervention). Guralnick (2001)

recommends that these assessments and early intervention programmes should encompass evaluation and intervention for family stressors.

The above mentioned ECI approaches clearly indicate that early identification of developmental delays or associated health conditions is necessary prior to early intervention. Early identification of some of these health conditions associated with developmental delays or disabilities may be detected through screening during the prenatal period, whilst other impairments may only be detected during or after birth. The WHO (2012a) reports that these early identification processes may include detection of sensory impairments such as hearing loss through targeted, early identification procedures that involve screening through campaigns or in health care and educational settings.

The current study focuses on early identification of newborn and infant hearing loss. The fact that the current study aimed at exploring risk-based or targeted hearing screening, and incorporated aspects of follow-up, diagnostic evaluation, as well as audiological surveillance or monitoring of newborns and infants, makes it be in alignment with specific aspects of Guralnick's (2001) developmental systems approach to early intervention. Moreover, the fact that the target population for the current study was that of newborns and infants with identified medical "risk factors", who were under interdisciplinary care, further supports the framing of the current study under the developmental systems approach. Whilst the developmental systems approach focuses on ECI in the broader context of developmental delay and/or disability, the current study focuses on hearing loss which, if unidentified or detected late can result in developmental delay. Within the field of audiology, the target population for ECI usually comprises newborns, infants or children who have been diagnosed with hearing loss. However, in order to identify children requiring ECI, early identification of hearing loss is vital. ECI in audiology is thus a process from early identification and diagnosis of hearing loss to intervention, and is commonly referred to as EHDI.

2.2 Early Hearing Detection and Intervention (EHDI)

EHDI refers to the early detection of and intervention for newborns and infants with hearing loss through an integrated, interdisciplinary, national NHS programme (JCIH, 2000). The term EHDI further refers to appropriate diagnostic evaluation after screening, followed by a family-centred approach to intervention.

According to the HPCSA (2007) and the Joint Committee on Infant Hearing (JCIH, 2007), EHDI programmes are aimed at identifying and diagnosing hearing loss in newborns and infants; as well as at providing intervention to these individuals as soon as possible. Similar to the general objectives of ECI, the goal of EHDI is to provide individuals diagnosed with hearing loss with optimal opportunity to maximise their growth and development in linguistic, language, literacy, communicative, cognitive, and social-emotional domains (HPCSA, 2007; JCIH, 2007). The objectives of EHDI are guided by a number of principles which are coupled with guidelines that dictate implementation.

2.2.1 Principles and Guidelines of EHDI

The principles of EHDI (as illustrated in Table 1) are aimed at ensuring that all children diagnosed with hearing loss have access to the necessary resources required to reach their maximum potential (JCIH, 2007). These principles were initially defined in an EHDI position statement by the JCIH in the year 2000, and were subsequently revised in 2007. It is this EHDI position statement, along with the statement on newborn and infant hearing loss by the American Academy of Pediatrics (AAP), that guided the formulation of the current HPCSA (2007) EHDI position statement for the South African context (HPCSA, 2007). Although the EHDI guidelines are aimed at optimizing early detection of hearing loss, these guidelines do not differentiate screening and diagnostic assessment timeframes between well - babies and babies in NICU or high-risk babies who may have a longer hospital stay. Prolonged hospital stay is an important consideration as it may influence the age of identification of hearing loss and subsequent enrolment into an early intervention programme. This lack of differentiation between well-babies and high-risk babies was noted and highlighted in a population-based NHS programme in Italy. In this Italian programme, Pisacane et al. (2013) acknowledge that delays in identification in NICU infants in their context were most likely associated with the ill health of these infants which is an immediate priority over hearing screening; a reality that can arguably be applicable to most contexts.

Table 1: Principles of EHDI as stipulated by the JCIH (2007) and HPCSA (2007)

Principles	JCIH (2007)	HPCSA (2007)
Access to hearing screening for all infants.	An objective, physiological measure should be used to assess hearing by no later than one month of age	An objective, physiological measure should be used to conduct hearing screening in the NICU, well-baby nursery or during immunization visits at Primary Health Care (PHC) Clinics.
Access to appropriate audiological and medical evaluation for all infants who *refer* upon initial and subsequent rescreening.	This should occur by no later than three months of age	This should occur by three months of age, and no later than four months for infants enrolled within the PHC based screening programmes.
Provision of intervention to all infants with confirmed, permanent hearing loss.	Intervention should be provided as soon as possible following diagnosis, by no later than six months of age.	Intervention should be provided as soon as possible following diagnosis, by six months of age, and no later than eight months for infants enrolled within PHC screening programmes.
Family-centred approach to EHDI programmes	Families should have access to all information, options for intervention and counselling, to ensure informed choice. Infant and family rights, privacy, shared decision-making and parental consent should be ensured.	Infant and family rights should be guaranteed through ethical practice in terms of informed choice and consent, and protection of hearing screening evaluation and intervention results.
Immediate access to high-quality technology for the child and family.	This includes access to hearing aids, cochlear implants and other assistive devices, when appropriate.	Prompt access to assistive devices.
Access to monitoring of hearing and continued assessment of communication development	This should be provided to all infants, with or without risk factors for hearing loss.	This should be provided to all infants who *pass* the initial screening bilaterally, but demonstrate risk factors for progressive, late-onset, bilateral hearing loss, auditory disorders and/or speech-language delay.
Access to appropriate intervention programmes for infants with hearing loss and their families	These programmes should be interdisciplinary, and should be built on strengths, informed choice , traditions and cultural beliefs of the families	These programmes should be interdisciplinary, and should be built on informed choice, recognise and respect traditions and cultural beliefs of the families.

(HPCSA, 2007; JCIH, 2007)

The 2007 JCIH position statement has recently been expanded with a supplement consisting of principles and guidelines specific to early intervention for varying degrees of confirmed, unilateral and bilateral congenital and acquired hearing loss (JCIH et al., 2013). These early intervention principles and guidelines are aimed at facilitating best practice for the implementation of early intervention for hearing loss. They are also aimed at assisting EHDI systems in enhancing the development of these infants or children and their families (JCIH, et al., 2013).

These recently defined early intervention principles and guidelines stipulate access to the following services for all children with confirmed hearing loss and their families (JCIH, et al., 2013, pp. e1326-e1338):

- Timeous enrolment into early intervention programmes that are supported by systems to allow for tracking of these children and families. Timeous access is defined as referral within two days after audiological confirmation of hearing loss and implementation of intervention within 45 days after the referral.
- Service coordinators who assist families with access to necessary services and service providers within a week after confirmation of hearing loss.
- Contact with early intervention providers who have the professional qualifications, skills and knowledge to enhance development and well-being. This may include teaching of sign language and/or services to develop spoken language conducted by trained professionals.
- Specialists and professionally qualified personnel who have knowledge and skills to support and facilitate optimal development in children with hearing loss and additional disability.
- Culturally and linguistically appropriate services to non-English speakers, whilst ensuring the same quality and quantity of information that is provided to English native speakers.
- Surveillance and monitoring of these children every six months until 36 months of age which includes standardized, norm-referenced assessments for varying modes of communication, assessment of social-emotional, cognitive as well as fine and gross motor skills. This is particularly important as the goal of earlier identification is to ensure prevention of delay rather than remediation of delay.

- Where appropriate, monitoring and follow-up of slight, progressive or fluctuating hearing loss and auditory neuropathy.
- Collaboration with families, ensuring active participation in the development of EHDI at national and local levels.
- Contact with other families of children with hearing loss to serve as a support system.
- Involvement of adults with hearing loss as active participants in the development and implementation of EHDI services at national and local levels.
- Support and guidance from adults with congenital or acquired hearing loss
- Assurance that the early intervention services are sufficient to support good quality of life and are sufficient to provide the necessary strategies for the development of language (whether spoken, signed or multimodal).

2.2.2 Primary, secondary and tertiary prevention in the context of EHDI

The JCIH (2007), HPCSA (2007) and JCIH et al. (2013) EHDI principles and guidelines detailed above are such that they may also be viewed within primary, secondary and tertiary prevention initiatives. Firstly, primary prevention refers to the elimination of exposure to certain conditions that result in a specific health outcome, and this is consistent with EHDI. Alvarez (2008) states that primary prevention may be considered in the context of prevention of newborn or infant hearing loss by addressing maternal exposure to environmental factors, other diseases or health conditions that may increase the risk of the unborn child developing a hearing loss.

Secondly, within the secondary prevention initiatives, EHDI may be seen to serve the role of reducing the morbidity associated with a health outcome. In this instance, early identification of hearing loss (with the initial NHS before hospital discharge) may be considered as a secondary prevention initiative, particularly since early detection is reported to reduce difficulties in various domains of development (Alvarez, 2008).

Lastly, within the tertiary prevention programs, tertiary prevention refers to strategies that decrease the difficulties associated with disability from a health outcome. In terms of EHDI, this may relate to early intervention services (such as fitting of amplification, aural habilitation, culturally and linguistically appropriate communication intervention) provided to newborns and infants with confirmed hearing loss as well as their families (Alvarez, 2008).

For EHDI programmes to yield successful and positive outcomes, it is important that all three levels of prevention be carefully included in the roll out plans in South Africa.

2.3 Outcomes of early detection of hearing loss

Positive outcomes of EHDI have been demonstrated in a number of studies. EHDI has commonly been associated with improved outcomes in terms of speech-language development. This is due to the recognition that unidentified hearing loss at birth or late detection of hearing loss may have adverse effects on individuals' speech-language, academic and social-emotional development (JCIH, 2007). Sininger, Grimes and Christensen (2010) investigated the auditory-based communication outcomes of children (with bilateral, congenital sensorineural hearing loss and no other risk factors, cognitive or disabling conditions) fitted with amplification before six months and after six months of age. Findings indicated that the age at which amplification was fitted was a strong predictor of the speech perception abilities in this group of children. Although this study was focused on the fitting of amplification, age at intervention was closely related to the age of identification of hearing loss.

Improved language outcomes due to EHDI have also been demonstrated in a study by Kennedy et al. (2006) where children with bilateral permanent hearing loss were investigated. In their study, children who were identified early through the UNHS programme by nine months of age had significantly higher mean receptive language scores when compared to those whose hearing impairment was diagnosed later (Kennedy, et al., 2006). This study along with others in a review by Pimperton and Kennedy (2012) have demonstrated that access to UNHS and early identification of permanent childhood hearing impairment are associated with benefits to language development; solid evidence that early identification is linked to positive language outcomes. Although the review by Pimperton and Kennedy (2012) advocates for UNHS, it should be acknowledged that the studies included within this review compared UNHS to previously used techniques such as distraction screening rather than programmes such as risk-based or TNHS programmes.

The positive relationship between early identification and language outcome is further supported by findings from a study comparing early (before or at 12 months) versus late identified (after 12 months) children with hearing loss. Results indicated that the earlier identified group performed significantly better than the later identified group on receptive

vocabulary, and receptive and expressive language measures for all severities of hearing loss (Fulcher, et al., 2012). Due to this study having been a mixed prospective and retrospective design, Fulcher and colleagues (2012) acknowledge that it is possible that their findings between the groups may have been influenced by differences in technology and different amplification criteria used in the early versus later identified children.

2.4 Outcomes of early versus late intervention following diagnosis of hearing loss in infants / children

A strong argument in support of EHDI is that late detection of hearing loss in children may result in these children never catching up with their normally hearing peers in academic, social and emotional domains of development (Olusanya, 2008). Although not specific to academic outcome, a longitudinal study was conducted in Nebraska comparing the phonology and morphology of four children with late-identified, bilateral, mild to moderate sensorineural hearing loss (and subsequent late intervention) to that of 10 children with normal hearing. Prior to intervention, the children with hearing loss presented with significantly delayed phonological skills than their aged- matched peers with normal hearing. Although three of the four children with hearing loss displayed improved longitudinal outcome following intervention, results indicated the presence of some persistent delays in the areas of phonology, morphology as well as speech intelligibility (Moeller et al., 2010).

Similar results were reported from a larger retrospective study in Ohio where baseline measures of children enrolled in an early intervention programme before six months of age displayed better language skills than children enrolled at or after six months of age (Meinzen-Derr, Wiley, & Choo, 2011). However, unlike findings from the study by Moeller et al. (2010), children enrolled before six months of age in this study maintained age-appropriate skills over time, whereas those enrolled later (at or after six months) demonstrated significant improvement in receptive and expressive language skills over time. These findings were consistent across different degrees of hearing loss, and highlight the potential for a "catch-up" period for language skills (Meinzen-Derr, et al., 2011). However, these findings did not specify the possible presence of additional, concomitant factors or difficulties among the participants which may further influence language outcomes.

2.5 Additional factors influencing the outcomes of EHDI

There are a number of authors who have reported additional factors influencing the outcomes in newborns, infants or children diagnosed with hearing difficulties. Contrary to research indicating improved outcomes as a consequence of earlier identification, other authors have found that language outcome is affected by the severity of hearing loss rather than the age of diagnosis. Wake, Poulakis, Hughes, Carey- Sargeant and Rickards (2005) conducted a cohort study on 88 children diagnosed with hearing loss by means of a risk-based screening programme in Australia between 1991 and 1993. These children were between seven and eight years of age, had varying degrees of hearing loss ranging from mild to profound, were fitted with hearing aids at a mean age of 1.9 years, and were enrolled within an early intervention service by a mean age of 2.0 years. Assessment of their speech and language abilities revealed no statistically significant relationship between age at diagnosis and speech, language or reading measures for all but one standardized assessment. The severity of the hearing loss on the other hand, was found to be linearly related to the scores obtained from all speech and language measures. These findings may differ from previous studies as data analysis was focused on the relationship between variables influencing outcome rather than a group comparison (Pimperton & Kennedy, 2012). The authors (Wake, et al., 2005) postulated that having a sample that consisted of older children may have impacted on outcomes, with the argument that the longer the presence of a severe disability, the greater its associated impact on outcome.

Further evidence of the influence of the severity of hearing loss on outcome is present in a similar cohort study that was conducted on a younger study sample of 65 preschool learners in Canada. These learners presented with mild to profound degrees of hearing loss identified either through UNHS, TNHS or by traditional referral practices. Similar findings were reported whereby better speech-language outcome was significantly associated with the severity of the hearing loss (Fitzpatrick, Durieux-Smith, Eriks-Brophy, Olds, & Gaines, 2007). In addition, no statistically significant difference was found on any of the speech-language measures when comparing the outcome of screened (identified through UNHS or TNHS) and unscreened groups (referred by traditional practice) (Fitzpatrick, et al., 2007). Despite the small sample size, both these studies highlight the need to consider the influence of variables other than early diagnosis on outcome. These variables include factors such as parental involvement, as well as quality of intervention services (including educational

services) in order to avoid the assumption that early diagnosis itself equates to long term benefit (Fitzpatrick, et al., 2007; Wake, et al., 2005). Hence, the argument by Yoshinaga-Itano (2004) is a valid one as it states that establishing a relationship between improved language outcome and screening is complex and difficult to conclude due to multiple factors either impeding, or facilitating the early intervention process.

In order to estimate the outcome of early identification and early intervention for hearing loss, it is therefore essential to account for multiple factors that have been suggested as contributing to the differences in outcomes of children with hearing loss (Ching et al., 2013). Ching et al. (2013) investigated speech-language outcomes in a population-based study with children (with varying degrees of hearing loss) who were fitted with hearing aids or cochlear implants and who underwent auditory intervention before three years of age. These authors further explored child, family and intervention related factors that influenced outcome in these children. In this study, age of amplification was not found to be a significant predictor of outcome, yet the age at which the cochlear implant was first switched on was. This study put forward four additional predictors of better speech-language outcomes. These predictors included female gender, absence of additional disabilities, less severe degrees of hearing loss and higher maternal education (Ching et al., 2013). The findings related to severity of hearing loss and parental education are in agreement with those from an earlier, significantly smaller, heterogeneous cohort study by Fitzpatrick, Crawford, Ni and Dureix-Smith (2011). Unlike in the study by Ching et al. (2013), these authors compared the communicative skills in four to five year old children with varying degrees of hearing loss (who received either a hearing aid or cochlear implant and auditory verbal therapy or who were enrolled in auditory-oral programs) to a group of age-matched peers with normal hearing. Children with hearing loss (whether hearing aid or cochlear implant users) were found to obtain significantly lower scores on speech and language measures in comparison to the control group. Whilst the type of amplification and age of diagnosis had no predictive value for outcome, parental level of education and severity of hearing loss were primary predictor variables in the study sample. (Fitzpatrick, Crawford, Ni, & Durieux-Smith, 2011). According to Blaiser (2012), these findings suggest that even with advances in early detection of hearing loss and in hearing amplification technology, infants with hearing loss may still be faced with challenges during early language learning.

Many studies to date have exclusively been conducted in developed contexts and have primarily explored outcome in terms of speech and language skills as a benchmark of success. Other patient-relevant factors such as social aspects, educational development, quality of life or professional situations have not been investigated (Wolff et al., 2013). This highlights the need to consider outcomes relevant to the everyday lives of individuals with hearing loss, including educational achievement, employment, quality of life and social and emotional functioning (Pimperton & Kennedy, 2012), particularly as these domains have been mentioned within EHDI position statements. Review and consideration of evidence from developing countries therefore becomes important.

2.6 The status of EHDI and EHDI research in South Africa

Review of published literature related to EHDI services in South Africa between 1995 to 2014 has highlighted progress in terms of outlining the journey toward implementation of paediatric hearing screening services (Moodley & Storbeck, 2015). However, in contrast to developed contexts, there are very few outcome studies from developing countries such as South Africa that support the efficacy of EHDI. This dearth of evidence from developing countries may be due to the lack of integrated, national EHDI programmes which continues to result in the late diagnosis of hearing loss in children.

Evidence that supports the efficacy of EHDI has been documented in a South African pilot study whereby quarterly language assessments were conducted on 10 children who were diagnosed with hearing loss at an average age of 15 months and enrolled in a home-based , family-centred early intervention program (Storbeck & Pittman, 2008). All 10 children were reported to display an overall language increase of 4.66 months per quarter, with a marked difference between children identified before seven months and those that were identified late (Storbeck & Pittman, 2008). The average age of diagnosis in this study is comparatively better than reports from more recent studies in the public health care sector, which suggests a lack of measureable advancement in EHDI outcomes in South Africa.

A larger, more recent retrospective review on audiological management of children (from birth to three years of age) with hearing loss was conducted at three public sector hospitals in Gauteng, South Africa (Khoza-Shangase & Michal, 2014). The average age of diagnosis of hearing loss was 23.65 months which is significantly late in comparison to some of the findings reported in developed contexts as well as to the guidelines stipulated by the HPCSA

(2007) position statement. Although 60 of the 70 children were fitted with amplification, the time lapse between identification and amplification ranged from two weeks to three years with further delays in the enrolment into aural rehabilitation programmes which was reported to be at an average age of two years five months. These findings are consistent with earlier findings in terms of delays in age of diagnosis, fitting of amplification and enrolment into early intervention programmes in the Western Cape and Free State region by Van der Spuy and Pottas (2008) and Butler et al (2013) . Possible explanations for these delays in diagnosis and intervention have been provided by professionals working within the field of early intervention.

Early intervention practitioners within the public health care context reported inadequate referrals by professionals, lack of NHS services, and poor parental knowledge as factors influencing the provision of early intervention services for hearing loss (Khoza-Shangase, Barratt, & Jonosky, 2010). However, Khoza-Shangase and Michal (2014) postulated administrative issues (such as procurement delays), lack of human resources and busy schedules of speech-language therapists and/or audiologists in the state sector as possible contributors to the delay between time of identification of hearing loss and fitting of amplification. Although the early diagnosis and timeous fitting of amplification are precursors to the enrolment in early intervention programmes, the accessibility of these early intervention programmes needs to be considered within the broader context of EHDI.

Early intervention programmes are essential in ensuring optimal outcomes in infants with hearing loss. Yet, there are only a few centre and school based programmes nationally that provide services for children with hearing loss. It is not until 2006 that HI HOPES (Home Intervention–Hearing and language Opportunities Parent Education Services), a family-centred, home based support programme was established (Swanepoel, Storbeck, & Friedland, 2009). This not only highlights the limited early intervention services in South Africa, aside from privately funded intervention, but findings from the studies mentioned are primarily focused on age of diagnosis and intervention, with limited published literature on the outcome of EHDI in the South African context. There is therefore a dearth of published literature related to early intervention following the detection of hearing loss.

Early detection of hearing loss is considered an important, first step toward providing the appropriate support to infants with hearing loss in order for them to achieve the best possible

outcome during the critical period of development (Olusanya, 2011a; WHO, 2010). The HPCSA (2007) position statement guidelines and principles for EHDI are primarily based on guidelines from developed contexts. These guidelines are geared toward UNHS which involves screening of all newborns. Although UNHS has been recommended as the preferred method for the public health sector (HPCSA, 2007), published literature following the release of the HPCSA (2007) position statement indicates that these NHS services remain mostly unstructured and disorganized in the private health care sectors due to them being unendorsed by hospital management (Meyer & Swanepoel, 2011). Despite an estimated high prevalence of newborn and infant hearing loss in the public health care sector (Khoza-Shangase, et al., 2010), NHS services are far and few between within this sector (Theunissen & Swanepoel, 2008). This consequently results in a poor coverage rate and a higher probability of undiagnosed hearing loss in newborns and infants.

In light of the above-mentioned status of NHS services in the South African public and private health care sectors, some researchers believe that 90% of newborns in South Africa will not undergo hearing screening (Theunissen & Swanepoel, 2008), this, despite the HPCSA (2007) position statement which proposed the screening of 98 % of all newborns by the year 2010. Furthermore, the current status of NHS coupled with the manpower related challenges may possibly suggest that UNHS is currently not applicable in the South African context, particularly in the public health care sector. The manpower demand related to a higher prevalence rate of infant hearing loss in the public health care sector in South Africa is not met as majority of registered audiologists work in the private health care sector. Moreover, there is currently no established mid-level worker programme in Audiology to facilitate hearing screening by personnel other than audiologists. There is therefore an evident shortage of manpower in the public sector which may influence the ability of Audiologists in South Africa to effectively implement UNHS. Plans to train mid-level workers for the Audiology profession are afoot and will arguably propel UNHS significantly forward within this context (HPCSA SLH Board, 2014). However, it is important that an interim approach to early detection of hearing loss be explored and established as a means of potentially identifying newborns and infants with hearing loss, who would ordinarily be missed in the absence of a NHS programme.

As an intermediate solution, the use of TNHS programmes which involves screening of newborns with known risk factors for hearing loss may be a more feasible approach to adopt

in order to identify children with hearing loss early. The appropriateness of screening and final choice should comprise of what is ideal and feasible at any one time for each country (Olusanya, Luxon, & Wirz, 2004a). "Successful public health programmes often start small followed by a systematic scaling up of services" (HPCSA, 2007, p. 23). Yet, in South Africa TNHS of infants with risk factors for hearing loss has not been formally and systematically implemented as an interim, small step towards a larger UNHS programme that has been recommended by the HPCSA (2007) position statement. This may be one of the reasons why implementation of UNHS has, and remains significantly challenging within this context.

As with the effective implementation of UNHS, effective implementation of a TNHS is dependent on a number of aspects. Firstly, the programme is dependent on the existence of established high risk factors for hearing loss. High risk factors for hearing loss stipulated by the HPCSA have been based on position statements from developed contexts, and have been adapted to include Human Immunodeficiency Virus (HIV) and Malaria as these conditions affect hearing and are considered unique to the South African context (HPCSA, 2007). Risk factors for permanent congenital and early-onset hearing loss (PCEHL) may vary across communities and may be influenced by considerable variation of situations and time periods in different countries (Olusanya, et al., 2004a). Much research is therefore needed into the review of high risk factors for hearing loss within the South African context.

Secondly, the implementation of a TNHS programme should also specify screening measures to be utilised. The choice of screening measures used within developed countries varies, with specific differences noted between screening measures used for well-babies versus NICU graduates. The HPCSA (2007) position statement recommends the use of AABR (although more costly than OAE) for screening in the NICU and OAE for follow-up immunization visits. Whilst recommendations exist, these are primarily based on research conducted in developed contexts, with no research having been performed regarding the use of various screening measures in the NICU and/or high care wards within the public health care context in South Africa.

Thirdly, a variety of heath care contexts need to be explored as possible platforms for the establishment and provision of NHS services. This is particularly important as the choice of context may influence coverage rates and follow-up return rates which are two of the key determinants to effective and successful NHS programmes. PHC clinics in South Africa have

therefore been proposed as a one of the platforms for conducting NHS in order to ensure optimal coverage and follow-up return rate, and this is being piloted in the Western Cape. This was based on the statistics in 2002 that indicated a significant amount of home births (HPCSA, 2007), and well-babies being discharged soon after birth, making it difficult to co-ordinate screening (Swanepoel, 2009). However, the number of home births has since decreased, with statistics indicating that 94.1% of live births occur at a health facility (South African Government Information, 2011). Hence, more initiatives are required at secondary and tertiary levels of service delivery, particularly in high-risk neonates who may have a prolonged hospital stay and scheduled follow-up appointments with paediatricians at these facilities.

Lastly, it is important to investigate the follow-up return rate and reasons affecting follow-up return rate during implementation of TNHS programmes as it is one of the indicators of the success of a NHS programme. Although follow-up return rate is a constant challenge in both developed and developing contexts (particularly at the initial stages of implementation of NHS programmes) (Olusanya, et al., 2007); poor follow-up return rates hinder the effectiveness of NHS programmes as EHDI services cannot be provided timeously. The above-mentioned aspects can only be explored and informed through the initiation of context specific, hospital and community-based pilot programmes. The initiation of such programmes will allow for the evaluation of NHS protocols and screening technologies used. Epidemiological data will also be available for countries such as South Africa where this is generally unavailable. Swanepoel (2010) argues that the initiation of NHS programmes will indirectly increase awareness about the importance of newborn and infant hearing loss among health care providers working within these contexts.

Chapter summary

This chapter highlighted the importance of ECI, particularly in newborns and infants diagnosed with hearing loss. The principles and guidelines for EHDI were discussed and there is strong evidence supporting them as highlighted by published studies that have predominantly focused on speech-language outcomes. Early diagnosis of hearing loss is an important precursor to early intervention. However other factors that influence speech-language outcome of early intervention need to be taken into consideration. Outcome studies have been widely published in developed contexts, with very little evidence reported from developing contexts such as South Africa. This lack of evidence in South Africa may be

attributed to the current absence of a well-established, national NHS programme. It is also evident from current literature that EHDI programmes are not well established in South Africa due to a number of challenges, of which the most commonly reported challenge is that related to manpower shortages. This chapter proposes TNHS as an interim step towards achieving UNHS and discusses aspects that need to be considered for the effective implementation of this NHS programme. The current study aimed to explore these aspects, such as risk factors, screening measures and follow-up return rate within a risk-based hearing screening that was initiated in a hospital context. The next chapter aims to highlight the need and importance of NHS through discussion of aspects related to newborn and infant hearing loss.

CHAPTER 3: NEWBORN AND INFANT HEARING IMPAIRMENT

This chapter aims to highlight the importance of early detection of hearing impairment in newborns and infants through, firstly, the presentation of prevalence and incidence rates of hearing loss in both developed and developing contexts. Secondly, this chapter aims to define and provide clarity to terms related to disability and impairment that are often used to describe hearing difficulties. The difference between the terms etiology and risk factor is also discussed. The etiologies of infant hearing loss are discussed thereafter, with the last section providing a brief section on the prevention of some of the infectious and environmental causes of hearing loss. Content covered in this chapter operationalizes the main aim of the current study while establishing rationale for the study.

Hearing impairment is reported to be one of the most common congenital abnormalities in newborns (Prpic, Mahulja-Stamenkovic, Bilic, & Haller, 2007). Hearing loss in this population is also considered an epidemic due to its global prevalence and is classified as being a silent condition for various reasons. Newborn and infant hearing loss is considered a silent epidemic, particularly in countries where early identification services are not well-established. Swanepoel (2010) claims that the reasons why hearing loss is considered a silent epidemic include the fact that it is not detected by routine clinical examination, and is not considered a priority since it is not deemed a life threatening condition. This is despite the globally reported high prevalence and incidence of hearing impairment in the newborn and infant population.

3.1. Incidence and prevalence of hearing impairment

3.1.1 Global incidence and prevalence of hearing impairment in infants

Globally, hearing impairment is twice as prevalent as other neonatal conditions screened for at birth (Hatzopoulos, et al., 2007), and it is estimated that six in every 1000 infants present with permanent hearing loss at birth or within the neonatal period (Olusanya & Newton, 2007). More recent data from a range of studies in different countries indicated that approximately 0.5 to 5 in every 1000 neonates and infants present with congenital or early childhood onset, severe to profound sensorineural hearing impairment (WHO, 2010).

Within the global framework, prevalence rates of hearing impairment have been reported to be higher in developing contexts.

3.1.2 Prevalence and incidence rates of hearing loss in developed vs. developing contexts

Developing contexts refer to low and middle-income countries whereas developed contexts refer to advanced countries, classified as high-income (The World Bank, 2006). Developing countries are reported to be worst affected by this worldwide prevalence (Olusanya & Newton, 2007) as two-thirds of individuals with hearing loss reside in developing countries that contain 80 percent of the world's population (Tucci, Merson, & Wilson, 2010). A review of population based studies in 2011 estimated that 16 million children have a hearing impairment ≥35 decibel hearing level (dBHL). From this estimate, the prevalence was highest (ranging from 1.8-2.2%) in South Asia, sub-Saharan Africa and in the Asia Pacific regions, and was the lowest (0.4%) in high-income countries (Stevens et al., 2011) . Although these results are not specific to newborns and infants, differences in prevalence rates between developed and developing contexts are clearly evident. These differences may be attributed to the higher prevalence of environmental risk factors to hearing impairment in developing countries (Olusanya, et al., 2007). Such risk factors include infectious diseases; other factors such as the use of ototoxic drugs; limited access to prenatal, perinatal and postnatal health care (Tucci, et al., 2010); and pre and post-natal infections such as rubella, measles and meningitis (Stevens, et al., 2011). Whilst the prevalence of these risk factors have been hypothesised as possible contributors to the higher prevalence rate of hearing loss in developing countries, the causes of hearing impairment have not been well documented. This is despite the estimated high incidence of hearing loss in developing contexts.

The incidence of bilateral hearing loss is estimated to be not less than six per 1000 live births (Olusanya, Ruben, & Parving, 2006). This is in contrast to the lower incidence of bilateral, sensorineural hearing loss with a rate of two to four per 1000 live births in developed contexts (Tucci, et al., 2010) where NHS programmes are mostly well-established.

In South Africa, it is estimated nationally, that the prevalence of hearing loss is four to six in every 1000 live births in the public health care sector. This is higher than the statistics documented for the private health care sector, where a prevalence of three in every 1000 has been estimated (Swanepoel & Storbeck, 2009). This higher occurrence in numbers in the

public health care sector highlights a greater need for audiological services in this sector in South Africa. In comparison, NHS pilot programmes in Nigeria suggest a much higher prevalence of 28 per 1000 live births. This prevalence rate is inclusive of all degrees of sensorineural hearing loss and is perhaps thus far, the highest rate reported globally (Olusanya, 2011a; WHO, 2010). It is evident from these reports that prevalence rates differ within developing contexts and this too may highlight possible differences in audiological protocols and risk factors. Similarly, differences in prevalence rates have been documented between well-babies and high-risk neonates within the newborn and infant population.

3.1.3 Prevalence and incidence rates in well-babies vs. high-risk neonates

Literature has shown that babies with recognized risk factors for hearing loss present with a much higher rate of hearing loss than those without risk factors (WHO, 2010). The incidence of hearing loss is therefore reported to be higher in infants with at-risk factors when compared to the general population (Kumar et al., 2014; Mahulja-Stamenkovic, et al., 2005), with the prevalence rate of severe, bilateral sensorineural hearing loss being more than doubled in neonates from the NICU when compared to well-babies (Yoon, et al., 2003).

Permanent, bilateral hearing loss has been reported to be present in 13.3 per 1000 infants discharged from the NICU (Connolly, Carron, & Roark, 2005). A population-based NHS study in an economically deprived region of Italy investigated sensorineural hearing loss ≥ 40dBHL in both NICU and well-infant nurseries. In this study, the incidence rate of sensorineural hearing loss was 9 per 1000 NICU infants in comparison to only 0.67 per 1000 infants from well-infant nurseries (Pisacane et al., 2013). McGurgan and Patil (2014) reported a prevalence of 7.7 per 1000 in a population of high-risk infants in Ireland.

When reviewing these documented differences in prevalence and incidence rates between well babies and NICU graduates, one should consider factors that might contribute to these variations. Berninger and Westling (2011) state that these factors may include whether unilateral hearing loss was included or excluded, differences amongst developed and developing countries, as well as the criteria used to classify hearing impairment in terms of intensity and frequency range.

3.2. Terminology and classification of hearing impairment

3.2.1 International Classification of Functioning, Disability and Health

According to the classification of functioning and disability, the term impairment is defined as problems in body structure or function that differ from the general population and may be the result of an underlying pathology but is not dependent on an etiology. Impairments may be temporary, permanent, progressive, regressive, static, continuous, intermittent or fluctuating and the degree of the impairment may vary from mild to severe. The term disability is considered a broader, umbrella term for impairments and any resulting constraints and limitations to activity and participation (WHO, 2007). Disability therefore results from impairment and may represent a loss or abnormality that results in disturbances in function at the level of the person.

There are two models that are used to understand disability and functioning, namely the medical model and the social model. The medical model views disability as linked to the individual only, directly caused by a health condition or disease that requires individual medical treatment by relevant professionals. The social model on the other hand views disability in terms of the individual's integration into society and disability is therefore viewed as a result of a multitude of conditions, many of which are created by the social context or environment (WHO, 2007). Although EHDI encompasses both these models within the guiding principles, the current study falls within the medical model as it aims to identify hearing problems in newborns and infants using a risk-based hearing screening protocol, whereby risk refers to the medical conditions resulting in the newborns and infants being susceptible to hearing problems.

Many studies on newborns and infants refer to problems in hearing as a "hearing impairment" or "hearing loss" with the terms "deafness" or "hard of hearing" being used less frequently. "Hearing impairment" and "hearing loss" are often used interchangeably and appear to describe a range of severities of hearing difficulty; although one could argue that hearing impairment may be an all-encompassing term while hearing loss should rather refer to only acquired hearing loss. The terms "deafness" and "hard of hearing" appear to have variations in definition. The WHO defines "hard of hearing" as hearing loss ranging from mild to severe, with "deafness" defined as a profound hearing loss (WHO, 2014). The JCIH has used these terms interchangeably, referring to both as inclusive of all types, degrees, and

lateralities of hearing loss as well as to both congenital and acquired hearing loss (JCIH, et al., 2013). For the purposes of the current study, the terms "hearing impairment" and "hearing loss" will be used interchangeably to denote the various degrees, types and laterality of hearing difficulties in newborns and infants.

3.2.2 Audiological Classification

Infant hearing loss is commonly classified in literature according to four factors: type, degree, laterality and etiology (congenital or acquired). Firstly, type of hearing loss refers to nature of the hearing loss; it is related to the site of the disorder within the auditory system(Stach, 2010) and includes conductive, sensorineural and mixed hearing loss (Butler, 2012). Conductive hearing loss results from interference of the transmission of sound in the external and/or middle ear and is more commonly acquired following middle ear pathologies (Butler, 2012; Paludetti et al., 2012). Sensorineural hearing loss on the other hand may result from congenital or acquired causes and may be either cochlear or retrocochlear in origin (Butler, 2012; Paludetti, et al., 2012). In neonates and infants, auditory neuropathy or dyssynchrony can also occur. Auditory neuropathy involves disruption or distortion of the processing of auditory information due to desynchronised activity of the auditory nerve (Butler, 2012; Hall & Swanepoel, 2010; Nikolopoulos, 2014). Mixed hearing loss involves the combination of conductive and sensorineural hearing loss and is not a commonly reported finding in literature on newborn and infant hearing loss.

Secondly, degree of hearing loss refers to the severity of the hearing loss and is related to the extent that the disorder is impacting on normal function. The degree of hearing loss consists of a range from mild to profound hearing loss. Mild hearing loss results in difficulty hearing faint or distant speech whereas profound hearing loss results in the individual possibly being able to hear loud sounds but hearing not being the primary communication channel (Stach, 2010). Disabling hearing loss in the age group 0-14 years has been defined as permanent, unaided hearing thresholds of 30 decibels (dB) or greater in the better hearing ear. Mild hearing loss is defined as 26 to 40dB, moderate as 41 to 60dB, severe as 61 to 80dB and profound as 81dB or greater (WHO, 1991). According to WHO (2012b), these classifications of degree of hearing loss are based on the average hearing thresholds between 0.5, 1, 2 and 4 kilo hertz (kHz). Thirdly, laterality refers to the number of ears involved whereby unilateral

refers to the involvement of one ear only and bilateral pertains to the involvement of both ears.

Many of the existing newborn and infant hearing screening programmes are aimed at identifying permanent sensory or conductive hearing loss of an average of 30-40dBHL in the speech frequency region (500-4000 Hertz -Hz). However, there is growing understanding that mild hearing loss (20-30 dBHL) should also be identified as this too may have negative consequences on later childhood development (WHO, 2010). Similarly, there is growing evidence of the consequences of unilateral hearing loss. Combined, mild and unilateral hearing impairments affect twice as many children as those identified with targeted congenital hearing impairment (Watkin & Baldwin, 2012). The consequence of these hearing impairments is supported by earlier findings in literature reviews conducted by various authors. A literature review by Tharpe (2008) on mild and unilateral hearing loss in children, concluded that children with mild hearing loss and unilateral hearing loss are both at risk for psychoeducational and psychosocial deficits. Similarly, Lieu (2004) concluded that children with unilateral hearing loss appear to require more educational assistance during their schooling. Contrary to these findings, a study conducted in Australia by Wake et al (2006) found that children with mild sensorineural hearing loss were similar to their normally hearing peers and did not perform significantly poorer on receptive and expressive language and reading tasks.

Lastly, etiology refers to the cause of the hearing loss. It is related to the time of onset and can either consist of congenital or acquired causes (Stach, 2010). Congenital hearing loss occurs at birth or soon after birth and may be the result of complications during the prenatal, perinatal or postnatal periods. Acquired hearing loss on the other hand may occur at any age of which the common childhood causes or etiologies are reported to be infectious diseases and chronic otitis media (WHO, 2014). Some of these infectious diseases are also listed as risk factors for hearing loss. It is therefore important to differentiate between etiologies and risk factors associated with hearing loss.

3.3. Etiologies associated with hearing impairment in infants

3.3.1 Etiologies vs. risk factors

There are differences between the terms "etiology" and "risk factor" and attempting to equate these terms should be avoided. An etiology is defined as a cause of a condition and is related to a cause and effect relationship whereby the disease-causing agent must always be present if the condition or effect is to occur (Rifkin & Bouwer, 2007). In instances where a direct cause and effect relationship cannot be established between the disease and agent, but a statistical association between them is present, the agent that is suspected to be associated with the disease is termed a risk factor (Rifkin & Bouwer, 2007). " In other words, a risk factor is a biological condition, substance, or behaviour that has an association with but has not been proven to cause an event or disease." (Rifkin & Bouwer, 2007, p. 17) This definition suggests that a risk factor increases the chances or probability of the occurrence of a condition and that not all individuals with a risk factor may necessarily present with the condition. It should therefore be acknowledged that not all babies presenting with risk factors in the current study may necessarily present with hearing loss.

3.3.2 Etiologies of hearing impairment in infants

Half of the detected cases of congenital or early-onset hearing loss in infants are reported to be due to genetic causes (WHO, 2010). Results from a study in Belgium exploring the etiological and audiological findings in a UNHS programme revealed that of the 116 children diagnosed with unilateral or bilateral, severe sensorineural hearing loss, the etiology was identified in slightly more than half of the sample (55.2%). The main cause of hearing loss in this study was genetic in nature (60.4%), followed by perinatal problems (20.8%) and cytomegalovirus (18.8%) (Declau, Boudewyns, Van den Ende, Peeters, & van den Heyning, 2008). In another study, similar findings were reported; although in that study less than half of the sample presented with a genetic cause of hearing loss, with it being the second most common cause. Of the 505 babies with bilateral or unilateral hearing loss, 100 presented with a genetic cause, followed by congenital cytomegalovirus in 33 neonates and a non-genetic congenital anomaly in 31 neonates (Lammens, Verhaert, Devriendt, Debruyne, & Desloovere, 2013).

Other causes of congenital hearing loss include idiopathic causes, maternal ototoxic drug use during pregnancy, infectious diseases, and cytomegalovirus which is one of the leading

causes (Butler, 2012). Hearing loss from congenital cytomegalovirus reportedly occurs in 30 to 40% of infants that are symptomatic at birth (Grosse, Ross, & Dollard, 2008), and may present as late-onset or progressive in nature, making it difficult to detect at birth through UNHS (Korver et al., 2009). Korver et. al, (2009) investigated the contribution of congenital cytomegalovirus as a cause for permanent congenital hearing loss in three to five year old children who underwent hearing screening during their first year of life. The prevalence of congenital cytomegalovirus was found to be 8% with 23% of these children presenting with profound, permanent congenital hearing loss.

Etiologies of congenital and early-onset hearing loss are most likely to vary between countries (WHO, 2010), as these may be influenced by burden of disease and the types of risk factors associated with hearing loss. In developing contexts such as sub-Saharan Africa, meningitis is considered one of the possible, major contributors to acquired childhood hearing loss (Swanepoel, 2010). Although not a direct cause, infections such as Human Immunodeficiency Virus (HIV) and malaria indirectly contribute to the burden of childhood hearing loss (Swanepoel, 2010). A local study by Khoza-Shangase and Turnbull (2009) found that otitis media was the most prevalent, possible cause of hearing loss in a sample of paediatric patients attending an HIV / Acquired Immunodeficiency Syndrome (AIDS) clinic. These reported preventable contributors to hearing loss are also noted as risk factors within the HPCSA (2007) position statement on EHDI programmes in South Africa. A number of studies from developing contexts, particularly sub-Saharan Africa have primarily focused on risk factors associated with hearing impairment rather than etiologies or causes of hearing impairment in newborns and infants.

Literature has also primarily focused on causes and risk factors associated with permanent, congenital, early-onset sensorineural hearing loss, with very few studies being focused on acquired, conductive hearing loss caused by otitis media with effusion. This bias in research focus may be due to the primary aim of NHS being identification of bilateral, congenital sensorineural hearing loss and not temporary or transient hearing losses resulting from otitis media with effusion (Boudewyns et al., 2011). Otitis media with effusion is defined as the inflammation and collection of liquid in the middle ear space without noticeable signs and symptoms (Gates et al., 2002) and is one of the major contributors to *refer* findings during NHS (Boudewyns, et al., 2011). Records of 152 children who presented with *refer* findings within a UNHS programme were analysed. In this study, otitis media with effusion was found

to contribute to hearing loss in 84 infants of which nine presented with spontaneous resolution of the otitis media with effusion. (Boudewyns, et al., 2011). Similarly, otitis media with effusion was also found to be present in 148 of 505 records of babies presenting with hearing loss within a NHS programme in Belgium (Lammens, et al., 2013). Although otitis media with effusion was not reported as a cause, results from a South African UNHS community-based NHS also yielded a higher prevalence of conductive hearing loss as opposed to sensorineural hearing loss (Friderichs, Swanepoel, & Hall, 2012). In addition to the presence of otitis media in newborns and infants, there is growing evidence regarding the increase in reported cases of auditory neuropathy.

3.3.3 Etiologies and risk factors associated with auditory neuropathy

The occurrence of auditory neuropathy has been investigated in well- babies and infants at risk for hearing impairment. In well- babies, the occurrence of auditory neuropathy has been estimated to vary between 0.06 and 0.3 per 1000 in a review of literature by Korver and colleagues (Korver, van Zanten, Meuwese-Jongejeugd, van Straaten, & Oudesluys-Murphy, 2012). However, these authors emphasise that these estimates should be interpreted with caution as there is very little evidence available in this population. Furthermore, these authors highlight the possibility of these rates being underestimated due to the fact that some cases may be missed as a result of the use of OAE screening alone in the well-baby population.

The prevalence of auditory neuropathy is between 0.23 to 2% in infants who are at risk for hearing impairment. This is possibly due to the proposed contributing factors such as prematurity, hyperbilirubinemia, hypoxia, neural ischemia, central nervous system immaturity and low birth weight (LBW). Nikolopoulos (2014) reports that auditory neuropathy is considered to account for approximately 8% of newly diagnosed cases of hearing loss in children per year, and is reported to be even higher in children with permanent hearing loss.

Talaat and colleagues (2009) also investigated the prevalence of auditory neuropathy in infants and young children (aged 6-32 months) diagnosed with severe to profound hearing loss. In this study, auditory neuropathy was detected in 15 of the 112 children by a present cochlear microphonic and absent ABR. Neonatal hyperbilirubinemia and neonatal asphyxia were postulated as possible causes for six and two cases respectively. However, the remainder of the identified cases in this study were noted to have irrelevant case history

findings (Talaat, Kabel, Samy, & Elbadry, 2009). In another larger retrospective study in Poland, findings indicated that 18 of the 352 infants diagnosed with sensorineural hearing loss presented with auditory neuropathy (Bielecki, Horbulewicz, & Wolan, 2012). In this retrospective study, perinatal causes were noted. These causes included prematurity and LBW, ototoxic medication, mechanical ventilation longer than five days, and hyperbilirubinemia. Locally, a smaller study conducted in South Africa found that admittance to the NICU for more than five days was a prevalent risk associated with auditory neuropathy (Swanepoel, Johl & Pienaar, 2013). Swanepoel and colleagues further concluded that the risks for auditory neuropathy in their study were mostly associated with preventable, perinatal risk factors related to maternal and child health care. These findings suggest the need to explore the strategies that can be used to target and reduce preventable causes of newborn and infant hearing impairment in developing contexts.

3.4. Prevention of newborn and infant hearing loss in developing countries

Addressing preventable causes of infant hearing loss such as infectious diseases, environmental causes as well as poor prenatal and perinatal services are important in reducing the burden of hearing loss, particularly in developing contexts (Olusanya, 2009b). Infectious diseases such as meningitis, measles and rubella are still reported as key contributors to hearing loss in children in developing contexts (Swanepoel, 2010). Researchers refer to these prevention strategies as either primary or secondary in nature.

Primary prevention strategies such as immunizations and vaccinations for infectious diseases are reported to have the potential to assist in decreasing infectious diseases contributing to hearing loss, with consequent reduction in the rates of hearing loss (Butler, 2010). Butler (2010) asserts that the implementation of widespread immunizations has eliminated the risk of congenital rubella, but that these services are not routinely available in developing contexts such as sub-Saharan Africa. However, this author further claims that a recent drive for new meningitis vaccines across sub-Saharan Africa may result in fewer anticipated cases of hearing loss.

Secondary prevention strategies such as newborn and infant hearing screening are reported to be the only means to ensure that infants with congenital and early-onset hearing loss are identified early enough (Korver et al., 2010). In comparison to developed contexts, early detection of hearing loss is mainly passive with very few developing countries having

established and systematic NHS programmes in place. Swanepoel (2010) suggests that these differences may be due to differences in health care between developed and developing contexts.

Chapter summary

This chapter highlighted a higher prevalence of hearing loss in developing contexts as well as in high-risk neonates which further justifies the need for TNHS as an interim step to UNHS. Terminology used to describe and classify hearing impairment was introduced and differences between the terms etiology and risk factor were highlighted. These differences in terminology suggest that not all newborns or infants with risk factors may present with hearing loss. A review of the reported contributors to newborn, infant and childhood hearing loss seems to suggest that these may include a combination of established causes and or prenatal and perinatal risk factors for hearing loss. These contributors also seem to be dependent on the population being studied, the burden of disease and prevention strategies employed in the respective health care contexts. The next chapter aims to provide insight and background into one such health care context, namely the South African health care context which is the setting in which the current study is framed.

CHAPTER 4: THE SOUTH AFRICAN HEALTH CARE CONTEXT

Review of the South African health care context is deemed relevant in contextualising the current study as it was conducted within the public health care sector in South Africa. This chapter aims to provide some background regarding service delivery frameworks, access to health care, maternal and child health care as well as health priorities within the South African context. In doing so, the researcher aims to provide the reader with a contextual background, as well as the contextual challenges in which EHDI needs to be viewed and considered. This chapter also provides information regarding the recent shifts in PHC as well as the future plans for the implementation of national health insurance (NHI) in South Africa.

South Africa's history has had a pronounced effect on the health profile of individuals, health policy and services of the present day. The roots of the flawed South African health care system and the impact of the epidemic of communicable and non-communicable diseases stem from the periods of colonial suppression and apartheid deprivation, and are also found in policies from the post-apartheid period (Coovadia, Jewkes, Barron, Sanders, & McIntyre, 2009).

The current South African health care context is governed by national health policy that is developed by the National department of health (DoH)(Schellack, Meyer, Gous, & Winters, 2011). There are nine provincial health departments that are responsible for developing provincial policy within the structure of the national health policy and public health service delivery. There are both public and private healthcare sectors within the South African health care system, with a recent shift in emphasis to PHC (Schellack, et al., 2011). South Africa has a health profile that consists of four concurrent epidemics with a growing burden of non-communicable diseases (Schellack, et al., 2011). This context is one that services a significantly large population. The mid-year population in South Africa was estimated at 52.98 million in 2013 with approximately 51% of this population being female and 29.2% being under the age of 15 years of age. The largest share of the population resides in Gauteng which is the smallest province in the country (Statistics South Africa, 2006; Statistics South Africa, 2013b). The significantly large population is often coupled by a public health sector that remains under-resourced with inequalities in health expenditure between public and private sectors. Resource distribution and usage as well as standard of care delivered also

varies by province (Schellack, et al., 2011), posing possible challenges toward the standardization of EHDI services.

4.1. Health Facilities in South Africa

4.1.1 Distribution of health care facilities

The distribution of health care facilities in South Africa differs between provinces. In 2004, statistics indicated that the Eastern Cape had the most public hospitals followed by Kwazulu-Natal and then the Western Cape. Gauteng was reported to have 33 public hospitals including specialised hospitals (Statistics South Africa, 2006). More recent information from 2011/2012 indicates that there are 3886 public health facilities and 216 private health facilities in the country, with majority of the public health facilities being clinics. In comparison to other provinces, Gauteng and the Western Cape have more private than primary health care facilities. Despite these differences, these two provinces have the highest total population attending clinics in comparison to other provinces. In Gauteng, the highest population within the public sector is at a tertiary hospital followed by a central hospital (DoH, 2012a). In addition to this unequal distribution of health facilities and population, access to health care remains a challenge within the South African health care context.

4.1.2 Access to health care

The public health care sector serves the majority (84%) of the population whilst the private health care sector serves only 16% of the population (Naidoo, 2012). South Africa is classified as an upper middle income country in terms economy, but is consistently worse in terms of health care outcomes when compared to some lower income countries (Econex, 2013; Schellack, et al., 2011). This may be influenced by the disproportionate distribution of health care professionals in the public and private health care sectors with only 30% working in the public sector that serves majority of the population. This unequal distribution has resulted in a significantly higher ratio of patients to health professionals in the public sector (DoH, 2011; van Rensburg, 2014), and has also led to the reality that many South Africans are unable to access health care services when needed.

Although health care access for all South Africans is a constitutional right, there remain inequities with regard to access. These inequities are mainly due to differences and unequal allocation of resources (Coovadia, et al., 2009; Gilson & McIntyre, 2007). A household

survey conducted in South Africa indicated that the poorest groups of individuals mainly access PHC facilities for outpatient care. Not having to pay for services in the public healthcare sector informs the choice of many of the individuals accessing this sector. Inpatient care is mainly sought at public sector hospitals rather than private facilities for all but the richest groups of individuals. With regard to accessibility to services, the majority of individuals use public transport or walk to outpatient services with the average travel time being twice as long for the poorest individuals. Unaffordability of transport costs to health care facilities contributes to the lack of immediate care. (Harris et al., 2011). In addition to the travelling distance and the inability to cover transport costs to access health facilities, Schellack et al. (2011) highlight further limitations to health care access. These limitations include limited facility working hours, insufficient staff and poor quality of service within the current health system in South Africa.

4.2. Service Delivery Frameworks

The current health system in South Africa is complex, and is two-tiered with a public and private health care sector. There are a variety of levels of care within the public health care sector that are arranged according to a hierarchy of services. Access to higher levels of care are only available once individuals are assessed and referred from lower levels of care (Cullinan, 2006). This hierarchy is based on the PHC approach adopted by government in 1994 (Cullinan, 2006).

The primary health care approach is a public health strategy that is based on the principles of fairness in health service delivery; access to affordable and appropriate services; enablement of individuals and sustainability of service provision (Keleher, 2001; Van Weel & De Maesseneer, 2010). Dookie and Singh (2012) outline the differences between primary care and PHC, terms that are often used interchangeably but differ conceptually. Primary care refers to the actual services provided by general practitioners, nursing staff and allied health professionals at the first point of entry to the health system (Dookie & Singh, 2012). PHC on the other hand is linked to the social model of health and is based on the premise that when basic health needs are met first, better health gains are obtained (Keleher, 2001).

4.2.1 Levels of Service Delivery

4.2.1.1 Primary Level

PHC clinics are the first point of entry for individuals and are usually staffed by nurses and community health workers (Cullinan, 2006; Schellack, et al., 2011). This level consists of a range of PHC services which are classified as preventative, promotional, curative and rehabilitative services. Examples of these services offered at both clinics and community health centres include mother and child care, immunisations, family planning, and care for those with chronic illnesses. Services are usually run by nursing staff, with consultative support and periodic visits by doctors and other specialised healthcare professionals. The shift of healthcare to the primary level has resulted in an increase in patient loads that has been met with the challenge of a shortage of nursing staff (Cullinan, 2006). These challenges following the shift to PHC need to be considered in relation to how they impact on the quality of health care provided.

The quality of care offered to children attending PHC clinics has been explored within Johannesburg, Gauteng. From the 16 clinics reviewed, there was a lack of integrated maternal and child health services and the quality of child health services for sick children was notably poor. Immunizations were provided at 14 clinics and rehabilitation services were only present at five of the clinics. Caregivers waited between six and 383 minutes before their sick child was attended to. Only three clinics made use of the Integrated Management of Childhood Illnesses (IMCI) approach even though 12 clinics had an IMCI trained professional. For the well child visits, age-appropriate milestones and developmental assessments were only conducted on small percentages of children and vision and hearing screening were rarely performed. These findings by Thandrayen and Saloojee (2010) indicate insufficient health care received by children attending these clinics and a lack of uniformity in services offered. These findings were influenced by characteristics related to staffing, enthusiasm and management style, and serve as important considerations when deciding on a suitable service delivery model for EHDI.

4.2.1.2 District level

District level services form the first referral level within the health system with a range of in-patient and out-patient services. These services are provided by generalist staff such as

general practitioners and consist of basic diagnostic and therapeutic services. Family Medicine and Primary health care, Medicine, Obstetrics, Psychiatry, Rehabilitation, Surgery, Paediatrics and Geriatrics form part of the disciplines at this level, but services may differ based on the needs of the population in specific catchment areas (Cullinan, 2006).

4.2.1.3 Regional level

A hospital providing one specialist service is classified as a regional or level two hospital. Care is provided by both specialists and general practitioners. Services are provided in the disciplines of surgery, medicine, orthopaedics, paediatrics, obstetrics and gynaecology, psychiatry, diagnostic radiology and anaesthetics. There is a lack of norms and standards for this level of care despite these hospitals being reported as the most overburdened due to shortfalls at the district level (Cullinan, 2006).

4.2.1.4. Tertiary level

Tertiary level consists of level three care and is the highest level of care in the health system. It comprises of provincial tertiary hospitals, specialised hospitals and central hospitals that provide specialist and sub-specialist care. Provincial tertiary hospitals receive referrals from regional hospitals for sub-speciality care and differ from central and specialised hospitals. Central hospitals provide multi-speciality clinical services that are of high cost but low volume whereas specialised hospitals provide focus on a specific speciality for conditions that are of high incidence and require long-term in-patient care such as psychiatry and tuberculosis (Cullinan, 2006). The current study was conducted at a regional and tertiary hospital within the South African, public health care context. It is therefore relevant to consider the proposed EHDI services within these primary, regional and tertiary levels of service delivery.

4.2.2 Proposed EHDI services within each level of service delivery

The Gauteng Provincial Speech Therapy and Audiology levels of service delivery workgroup in collaboration with the HPCSA board for Speech, Language and Hearing Professions has developed guidelines for planning speech therapy and audiology services at each of the above mentioned levels of service delivery. Table 2 outlines the proposed guidelines for audiological services by audiologists and audiology technicians at each level.

Table 2: Proposed audiological services at each level of service delivery

Level	Context	Proposed audiological services to be provided by audiologists and audiology technicians
Primary	PHC Clinics	*Audiologists:* • Development, monitoring and evaluation of ototoxicity, EHDI, ear and hearing care screening and intervention programmes • Management of referrals *Audiology technicians:* • Promotion and prevention activities • Identification of individuals at risk and with established risk for hearing and balance difficulties • EHDI, ototoxicity and middle ear status screening • Cerumen management • Intervention for and surveillance of individuals with hearing difficulties • Provision of follow-up care post- hearing aid fitting and facilitation of support services for individuals with hearing impairment • Facilitation of (re-) integration of individuals with hearing impairment into community, work and/or school *Audiologists and audiology technicians:* • Liaison with community structures, organisations and PHC providers to be ensured by audiologists and audiology technicians
	Community Health Centres	*Audiologists:* • In addition to the listed services at primary health care clinics: • Implementation and management of aural rehabilitation programmes • Earmould modifications and basic hearing aid trouble shooting *Audiology technicians:* • As per the above listed services at PHC clinics

		Audiologists and audiology technicians: • As per the above listed services at PHC clinics
District Level (Level 1)	District hospitals	*Audiologists:* • Development, monitoring and evaluation of intervention plans and programmes • Management of referrals • Cerumen management • Identification of neonates, paediatric and adults at risk and with established risk for hearing difficulties through EHDI and ototoxicity screening and monitoring programmes at in-patient and out-patient clinics • Diagnostic assessment of hearing • Management of hearing difficulties including aural rehabilitation post cochlear implantation and post bone anchored hearing aid fitting • Ensure appropriate referrals for advanced diagnostic assessment to other levels of care • Collaboration with other team members including district health teams • Recommend school or vocational placement *Audiology technicians:* • As per the above listed services at primary level
Regional level (Level 2)	Regional hospitals	*Audiologists:* • In addition to the listed services at primary and district levels: Screening for vestibular disorders • Diagnostic hearing assessments which include visual reinforcement audiometry, immittance as well as electrophysiological measures such as OAEs , ABR and auditory steady state response (ASSR) • Hearing Aid Assessments and objective hearing aid verification • Hearing aid fitting • Recommendations & referrals to appropriate levels where necessary for surgical intervention including cochlear implants *Audiology technicians:*

		• As per the above listed services at primary level
Tertiary level (Level 3)	Provincial tertiary hospitals	*Audiologists:* • In addition to the listed services at primary, district and regional levels: • Recommendations for surgical intervention including cochlear implants • Provision of consultative clinics for cochlear implants, bone anchored hearing aids, vestibular disorders, electrophysiology, complex disorders, auditory neuropathy spectrum disorder *Audiology technicians:* • As per the above listed services at primary level

(Gauteng Provincial Speech Therapy & Audiology Levels of Servive Delivery Workgroup & HPCSA Board for Speech-Language & Hearing Professions, 2014)

The above-mentioned guidelines need to be considered in light of the status of EHDI services in South Africa, health priorities and millennium development goals that are considered priorities in the South African context.

4.3. Progress toward Millennium Development Goals

The Millennium Developmental Goals (MDGs) act as a universal yardstick for various governments to monitor progress on health performance (Blumberg, Frean, & Moonasar, 2014). These goals include eradication of extreme poverty and hunger, universal primary education, gender equality, reduction of child mortality, improvement of maternal health and combatting HIV, AIDS, malaria and other diseases such as tuberculosis (Mayosi et al., 2012). Goals four to six are directly linked to health and the functioning of the South African health care system (Pillay & Barron, 2014), and are detailed in Table 3.

Table 3: Millennium Developmental Goals four to six

Millennium Developmental Goal (MDG) Number	Description of MDG
MDG 4	Reduce mortality of children under five years of age
MDG 5	Improve maternal health
MDG 6	Combat HIV, AIDS, malaria and other diseases

Sourced from: (Chopra et al., 2009)

South Africa has made progress towards achieving some of the MDGs detailed in Table 3. There has been a considerable decrease in the number of malaria cases detected as well as resulting deaths. In addition, there has been a drop in the incidence of pneumonia and diarrhoea which have been contributors to childhood mortality in children under the age of five years. With regard to HIV/AIDS and tuberculosis, there has been a decrease in the rates of mother to child transmission, more HIV-infected individuals are receiving treatment and there has been a reported decrease in the number of tuberculosis cases (Pillay & Barron, 2014). Despite these improvements, there is still a need to address maternal health and infant mortality in South Africa.

4.4. Maternal and infant mortality

Maternal and child mortality rates are on a decline globally. Although South Africa continues to experience high maternal and child mortality rates, the under-five child mortality rate and

the maternal mortality ratio has begun to decrease (Bamford, 2013). Data from 2011 has revealed a decrease in maternal mortality with an even greater reduction of HIV positive mothers. Burton (2013) claims that this may be the result of the improvements in antiretroviral treatment, particularly with regard to access to treatment for pregnant women that has been prioritised. Despite this, maternal health should be seen in the broader context as MDG 5 makes reference to universal access to reproductive health (Burton, 2013). South Africa is reportedly performing well in this regard with over 97% of women attending antenatal care and more than 90% delivering at a health care facility with trained health care workers (Bamford, 2013; South African Government, 2010).

Despite these reported improvements in maternal care, South Africa has been considered as having made insufficient progress toward achieving MDG 4 and MDG 5 by 2015 (Bamford, 2013). In addition, neonatal deaths are reported to account for 33- 40% of the deaths in children under the age of 5 years (Baleta, 2011; Bamford, 2013; Velaphi & Rhoda, 2012). Neonatal mortality has been reported to result from preventable causes such as health worker related factors, inadequate facilities and poor access to required equipment. Aspects such as responsible use of oxygen, availability of neonatal beds and the appropriate number of staff to care for these neonates have been proposed as measures that may assist in decreasing neonatal mortality rates (Lloyd & de Witt, 2013). These proposed measures need to be considered as maternal, infant and child mortality remain one of the burdens of disease within the South African health profile.

4.5. Health priorities and burden of disease in South Africa

South Africa faces a quadruple burden of disease that consists of maternal, infant and child mortality; HIV/AIDS and tuberculosis; non-communicable diseases and injury and violence (DoH, 2011; Naidoo, 2012).

From this quadruple burden of disease, HIV/AIDS has been one of the main contributors to maternal mortality in South Africa. Similarly, infant and child mortality rates have been associated with the burden of HIV/AIDS as well as other preventable causes. The HIV prevalence is proportionately higher than the global average with the prevalence of tuberculosis being the highest in the world. Collectively, rates of co-infection with these two conditions are also one of the highest in the world. This has resulted in reduction of life expectancy, and has significantly contributed to both maternal and child mortality rates. Non-

communicable diseases include high blood pressure, diabetes, chronic lung diseases, cancer and mental illnesses (DoH, 2011).

The health priorities in South Africa have been focused on addressing four key areas, some of which link directly to the MDGs. These include increasing life expectancy; combating HIV and AIDS; decreasing the burden of diseases from Tuberculosis and improving health systems effectiveness (DoH, 2010). Government (DoH, 2010) also proposed a 10 point plan for 2009-2014 that consisted of priorities including improvement of the quality of health services; improvement of infrastructure and the management of the health care system; increased focus on tuberculosis and other communicable diseases; and the implementation of the NHI.

4.6. National Health Insurance (NHI)

The current two-tiered health system has been critiqued for being unsustainable and not embracing fairness, with a shortage of financial and human resources. Although there has been increased access to public health care, these services have deteriorated and are poor (DoH, 2011; Naidoo, 2012) . The South African government has therefore embarked on an NHI policy that will be phased in over a 14 year period. The objectives of the NHI are to improve access to quality health services to all South Africans (whether employed or unemployed); to pool funds so that fairness will be achieved; to obtain and secure services on behalf of the population and control key financial resources and to improve and strengthen the under-resourced public health care sector (DoH, 2011; Matsoso & Fryatt, 2013). Naidoo (2012) states that the improved access to quality health services will mainly be focused on the re-engineering of PHC services.

4.6.1 Re-engineering of PHC

PHC services will be re-engineered to focus mainly on community-based outreach and home-based services which will be geared towards promotion, prevention and quality curative and rehabilitative services (DoH, 2011). According to the recent NHI white paper, these services will be delivered through four streams, namely, district clinical specialist teams; integrated school health services; municipal ward-based primary health care outreach teams and contracting of private health care practitioners at a non-specialist level (DoH, 2015).

The first stream of district clinical specialist teams will consist of an obstetrician & gynaecologist; paediatrician; family physician; anaesthetist; midwife and primary health care nurse, all with very senior appointments (DoH, 2011; Naidoo, 2012). These teams will be tasked to support the delivery of priority health-care programmes at a district level and to address the high maternal and child mortality rates (DoH, 2011; Feucht, 2013; Naidoo, 2012)

The second stream will include school health services that will be provided through mobile clinics to all school-aged children from pre-Grade R to Grade 12. This team will be led by a professional nurse. Services will also include health promotion, prevention and curative services in respect to the health needs within these age groups, and will focus on screening for health-related barriers such as visual, hearing, cognitive and developmental impairment (DoH, 2011; DoH, 2015; Naidoo, 2012).

The third stream will comprise municipal ward-based PHC outreach teams. These outreach teams will provide services within specified municipal –based demarcations and each team will be headed by a health professional, namely a nurse linked to a PHC facility. The role of these teams will be to facilitate community involvement in the identification of health problems placing individuals at risk for disease and in need of preventative, curative and/or rehabilitative services; as well as provision of health promotion education (DoH, 2011; DoH, 2015; Naidoo, 2012). The community health care workers will be responsible for assessing the health status of individuals in households and making appropriate referrals to a PHC facility.

The fourth stream which involves contracting of private health care practitioners will be implemented to assist in reducing burden of disease and improving access to health care. In addition to general practitioner services, speech therapy and audiology services as well as other allied health services will be prioritised with the aim of addressing early childhood development and physical barriers to learning (DoH, 2015). In addition to these services, the NHI policy includes the re-designation of hospitals.

4.6.2 Re- designation of hospitals

Hospitals will be re-designated into district, regional, tertiary, central and specialised hospitals. District hospitals will be the smallest hospitals limited to four areas of specialist care supported by district-based clinical specialist support teams. Regional hospitals will obtain referral from district hospitals and will offer a range of specialist services with eight of

these being generalist specialist services. Some of these regional services may also be provided at tertiary and central hospitals, and will serve as a platform for training and research. Tertiary and central hospitals will both form the platform for research and training of health workers, with tertiary hospitals offering super specialist and sub specialist care and central hospitals offering highly specialised tertiary and quaternary services. Specialised hospitals will provide acute, sub-acute or chronic care with the two most common specialities being tuberculosis and psychiatry (DoH, 2011; DoH, 2015). In addition to the re-designation of hospitals, there are also mid-level worker initiatives that have been proposed to assist in addressing the human resource shortages and access to health care services.

4.7. Mid-level worker initiatives

Mid-level worker initiatives have been proposed in addition to the re-configuration of primary health care teams. The overall purpose of mid-level workers is to take over some of the tasks of professionals, so that their time can be freed up to fulfil other, higher -level functions (Doherty, Conco, Couper, & Fonn, 2013). The use of mid-level workers plays an important role within PHC as it improves access and coverage to health care and ensures service delivery (Lehmann, 2008). The use of mid-level teams has demonstrated success in addressing human resource shortages and access to health care internationally (Doherty, et al., 2013; Lehmann, 2008). However, this process has been slow in South Africa, with the number of graduates being too low to offset the shortage of professionals (Coovadia, et al., 2009). According to Lehmann (2008), nursing and pharmacy have been the first professions to introduce mid-level workers but other professions are lagging behind.

It is not until recently that a task team has been assigned by the HPCSA to develop guidelines for mid-level workers within the audiology profession. The use of mid-level teams is an important consideration for EHDI, whereby these teams could be trained to conduct NHS. This will not only assist with NHS coverage rates, but will also address the commonly reported manpower shortages that pose as a challenge to the successful implementation of NHS programmes. Mid-level worker initiatives will further assist in freeing up audiologists to fulfil other, high-level functions within their scope of practice.

Chapter summary

This chapter provided information on the structure of the current South African health care system as well as the proposed restructuring of the health care system to address key

challenges. These key challenges include the quadruple burden of disease, difficulties with access to health care, as well as human resource shortages. Despite these key challenges, EHDI has been proposed at all levels of service delivery, with NHS being conducted by audiology technicians at lower levels of care. It is important to consider the future role of audiologists within the PHC re-engineering process as well as the possible use of mid-level workers to conduct NHS. The next chapter explores NHS practices globally with a discussion of manpower and other challenges that influence the implementation of NHS within the South African health care context.

CHAPTER 5: EARLY DETECTION OF HEARING LOSS THROUGH NEWBORN HEARING SCREENING

This chapter discusses NHS as one of the important steps to any EHDI programme. The advantages and disadvantages of UNHS and TNHS are presented, with advancement of the argument that TNHS may be a beneficial interim step toward UNHS. Audiological measures used within NHS programmes are discussed and the various uses of these measures are evaluated within the global context. Other aspects related to NHS programmes are discussed, namely, follow-up return rate, as well as environmental, cost and ethical considerations. This chapter also highlights the challenges to the implementation of NHS in South Africa.

5.1. Newborn Hearing Screening in EHDI

Early detection of hearing loss is the initial stage to any EHDI programme, and is conducted by means of NHS. Identification of hearing loss through NHS has been investigated for over a century (Mencher & DeVoe, 2001). NHS has demonstrated benefits towards earlier identification of all degrees of hearing loss (Canale et al., 2006; Fitzpatrick, Whittingham, & Durieux-Smith, 2014; Nikolopoulos, 2015). Two main types of NHS methods exist, namely UNHS and TNHS or risk-based hearing screening. Risk-based hearing screening or TNHS was implemented much earlier with the introduction of the HRR throughout the 1950s and 1960s. The HRR identifies risk criteria for hearing loss in neonates and infants (Mencher & DeVoe, 2001). Identification of infants at risk for PCEHL based on established risk factors on the HRR was recommended by the JCIH in 1973.This continued until the introduction of UNHS by the JCIH in the year 2000 (JCIH, 2000). Although UNHS is recommended, there is still debate around the use of TNHS, particularly in some developing contexts. It is therefore important to review findings in the literature that support and/or negate the use of UNHS versus TNHS.

5.1.1 Universal versus. targeted/risk-based hearing screening

UNHS involves screening of all newborns, and has been identified as the recommended screening method for EHDI, particularly in developed countries (Olusanya, et al., 2007); whereas TNHS involves screening of newborns at risk for PCEHL based on established risk factors (Olusanya, et al., 2004a). Due to a considerable proportion of infants without risk factors for hearing loss, UNHS has replaced TNHS in most developed contexts (Patel, Feldman, Canadian Paediatric Society, Community Paediatrics Committee, 2011). In South

Africa, the 2007 HPCSA Position Statement also recommends the use of UNHS as the preferred method for the public health care sector (HPCSA, 2007). This is probably based on the premise that implementation of UNHS decreases the age of diagnosis. Durieux-Smith, Fitzpatrick and Whittingham (2008) retrospectively investigated the age of diagnosis of permanent hearing loss between children identified through TNHS, UNHS and through medical referral. Of the 709 children in the study, 128 (of which 124 presented with risk factors) had been identified through NHS programmes (UNHS or TNHS) and 581 had been referred by a physician. Children who were screened through either of the NHS programmes were diagnosed significantly earlier (mean age of diagnosis at 6.3 months) than children with risk factors who were referred (mean age of diagnosis at 34.5 months). The children with risk factors were in turn diagnosed earlier than those referred without risk factors (mean age of diagnosis at 51.8 months). However, only twenty one of the 128 children who underwent NHS met the JCIH (2000) recommendations of diagnosis by three months of age and intervention by six months of age. The authors proposed that this may be due to other medical problems taking precedence over the management of hearing loss in those admitted to NICU (Durieux-Smith, et al., 2008). Results from the study further indicated that from the cohort of children with permanent hearing loss, 58% did not have risk factors whereas 42% did, which highlights the advantage of UNHS over TNHS. The implementation of UNHS has also been associated with a significant decrease in the age of diagnosis of unilateral sensorineural hearing loss in Missouri (Ghogomu, Umansky, & Lieu, 2014). While the overall benefits of UNHS have been made clear, there are limitations which are noteworthy. The first of these limitations is that less severe congenital hearing loss (less than 30-40dB) is often not detected in most UNHS programmes. The second limitation is related to the two-step screening protocol in which low-risk infants with auditory neuropathy may not be detected by the sole use of OAEs (Patel, et al., 2011). Limitations related to TNHS have also been documented.

One common disadvantage that has been highlighted about TNHS is that it may result in missed cases of hearing loss. Literature suggests that 25 to 50 percent of infants with hearing loss may not be identified if TNHS is the only programme adopted, and that the use of TNHS results in babies without risk factors for hearing loss remaining at risk for late identification (Durieux-Smith & Whittingham, 2000; Hyde, 2005; Kountakis, Skoulas, Phillips, & Chang, 2002). The percentage of babies missed may be due to the absence of hearing loss in babies

with risk factors and the presence of hearing loss in babies without risk factors. However, one needs to consider the context in which TNHS is conducted. A recently published review on Cuba's NHS programme indicated that a two-step TNHS programme has proven to be a valid and resource-efficient method for EHDI for the past 25 years (Abalo et al., 2009). Earlier studies on UNHS performed in developing countries such as Brazil revealed that of the newborns referred for diagnostic testing, seven out of 10 were found to have risk factors for hearing loss (Chapchap & Segre, 2001). Although this study was conducted on a small sample of infants diagnosed with hearing loss, more than half of the sample presented with risk factors. The presence of risk factors in infants diagnosed with hearing loss was also found in a study conducted in Slovakia. Results from this study indicated that more newborns with risk factors were diagnosed with hearing loss in comparison to those without risk factors (Jakubikova, Kabatova, & Zavodna, 2003). These findings along with those by Abalo et al. (2009) and Chapchap and Segre (2001) indicate that TNHS may be a beneficial, interim screening method in developing countries where the recommendation of UNHS appears rather overwhelming or is not yet feasible. In addition to the type of NHS programme, the choice of electrophysiological measures employed within either of the NHS programmes needs to be considered.

5.1.2 Electrophysiological measures employed in NHS programmes

A variety of electrophysiological screening measures may be employed within a NHS programme. These include OAEs, AABR and a combination of OAE and AABR (Berninger & Westling, 2011). OAEs are acoustic signals generated from the outer hair cells within the cochlea reflecting the mechanical processes that provide an indication of the integrity of the cochlea (Kemp, 2002). Emissions are categorised by the presence or absence of an evoking stimulus with evoked OAEs (TEOAEs and DPOAEs) being of greater clinical significance (Baiduc, Poling, Hong, & Dhar, 2013).TEOAEs are low intensity sounds originating from active amplification of outer hair cells of the cochlea, whereas DPOAEs are generated by two continuous pure tones presented simultaneously to the ear (Hall, 2000). The AABR is a modification of the conventional ABR (Suppiej et al., 2007) which consists of an electrical response to auditory stimuli and assesses the peripheral auditory pathway from the ear to the brainstem (Olusanya, Somefun, & Swanepoel, 2008). Whilst OAEs are simple, fast, cheaper and non-invasive measures; they provide limited assessment of the auditory system and are negatively impacted by vernix and middle ear fluid (Choo & Meinzen-Derr, 2010). In

contrast, the AABR provides more information regarding the auditory system and provides better detection of auditory neuropathy in infants; a condition which is missed entirely by OAEs. However, the AABR requires more knowledge and expertise to conduct in comparison to OAE testing; it is typically more costly and requires a longer test time to conduct (Choo & Meinzen-Derr, 2010); all factors which may influence the implementation of a comprehensive screening programme in different contexts.

The various EHDI position statements recommend the use of different screening measures for different screening contexts. The JCIH, for example, recommends either screening measure (OAE or AABR) for infants admitted to well-infant nurseries with AABR being the recommended choice for infants admitted to the NICU (JCIH, 2007). The HPCSA (2007) position statement on the other hand recommends use of AABR for infants admitted to the NICU and OAE for screening during immunization visits at PHC clinics within the South African context. However, the ideal hearing screening measure is yet to be defined (Guastini et al., 2010), with various protocols currently being used in different contexts. Countries such as China use DPOAE measures within the different stages of the screening protocol whilst a majority of birthing facilities worldwide use TEOAE and/or AABR (WHO, 2010).

There has been developing interest in experimenting with two technology screening protocols within NHS programmes, with TEOAE and /or AABR being the most commonly investigated or used screening measures (Benito-Orejas, Ramirez, Morais, Almaraz, & Fernandez-Calvo, 2008; Berg, Prieve, Serpanos, & Wheaton, 2011; JCIH, 2007). This is evident in published literature which has indicated several protocols using these screening measures (Table 5).

"TEOAE is perhaps the commonest screening test in NHS programmes worldwide because it is easier and quicker to perform with less expensive consumables" (Olusanya & Bamigboye, 2010, p. 1303). TEOAEs have been more commonly explored within a screening protocol, either as a single screening measure, or in combination with AABR. The use of TEOAEs was investigated within a NHS protocol in Western Sicily with the aim of developing a low-cost protocol with a good "screen sensitivity". Newborns that *passed* the initial screening with no risk factors were discharged whereas those who either *passed* with a risk factor, or *referred* with or without a risk factor underwent a second screening followed by an audiological assessment (where indicated). A 99.6% final specificity was indicated by this protocol. The

authors concluded that FP results were observed in the group of neonates who *referred* without the presence of a risk factor, and that repeated TEOAE screening (at least four times) in this group reduces the number of more expensive, secondary level evaluations (Martines, Porrello, Ferrara, Martines, & Martines, 2007). These findings are further supported by studies that have employed a two-stage TEOAE screening protocol or a multiple (at least three) stage TEOAE screening protocol followed by clinical ABR (if indicated) (Berninger & Westling, 2011; Hergils, 2007). Berninger and Westling (2011) found that the specificity of TEAOE measurements (conducted three to six days after birth) increased with repeated screening and reduced the need for diagnostic ABR. Findings from the two-stage TEOAE protocol employed by Hergils (2007) indicated higher *pass* rates (when screened two days or later after birth). However, the inclusion of AABR screening before referral for diagnostic assessment could have further enhanced the hearing screening outcome. A number of authors (McGurgan & Patil, 2014; Olusanya, Somefun, et al., 2008)argue for the use of OAE and AABR as the use of OAEs in isolation may miss the proportion of babies with auditory neuropathy or auditory dysfunction. A test-battery approach or cross-check principle to screening may therefore be more appropriate in order to ensure a higher percentage of true-positive (TP) and true-negative (TN) results. Hence, the inclusion of tympanometry is also important within NHS programmes as it may assist with differential diagnosis.

5.1.3 Inclusion of high frequency tympanometry in newborn hearing screening programmes

Tympanometry is included within a battery of diagnostic tests to assist in distinguishing between sensorineural and conductive types of hearing loss (Olusanya, Somefun, et al., 2008). The use of high frequency tympanometry using a 1000 Hz probe tone is recommended over the use of the conventional 226 Hz probe tone due to the anatomical and acoustical differences between the adult and neonatal middle ear (Baldwin, Sutton, Gravel, & Low, 2008). Although many of the above mentioned studies did not include the use of high frequency tympanometry, a 1000 Hz high frequency probe tone has been reported to assist with clarifying TP results in NHS programmes by identifying middle ear effusion in infants (Swanepoel, Werner, Hugo, Louw, Owen, & Swanepoel, 2007). Other studies have suggested a positive relationship between high frequency tympanometry and OAE results.

Shahnaz, Miranda and Polka (2008) found that high frequency tympanometry (1000 Hz) is also a good predictor of the presence of TEOAE. Tympanograms obtained with *pass* results

for TEOAE and AABR had a single peak, were bell shaped and well defined. In comparison, *refer* results for TEOAE were accompanied by flat or widened, multipeaked tympanograms (Shahnaz, et al., 2008). Similar findings were reported in a recent study by do Carmo, Almeida, and Lewis (2012) which investigated the use of the 226 Hertz and 1000 Hertz probe tone tympanometry in infants with risk factors for hearing loss. Results indicated that flat tympanograms were more frequent in the presence of absent TEOAEs. These authors concluded that high frequency tympanometry using a 1000 Hertz probe tone is the most appropriate for infants below six months of age as it has a higher sensitivity for the detection of middle ear effusion, which is often a reason for *refer* findings in OAE testing. Another common factor influencing OAE *refer* results is ambient noise levels within the screening environment.

5.1.4 Ambient noise levels in the screening environment

Ambient noise levels may influence OAE screening outcomes. The presence of high ambient noise levels may result in higher *refer* rates which not only influences the efficiency of the NHS programme but has cost implications for the programme. A two-stage NHS programme was employed within a hospital and community-based setting in Nigeria (Olusanya, 2010). The NHS programme comprised of TEOAEs on two different models of equipment followed by AABR if a TEOAE *refer* result was obtained. Average noise levels were similar across both settings with differences within the hospital setting. Higher ambient noise levels were noted in the special care baby unit in comparison to the well- baby nursery. There was no significant correlation between TEOAE *refer* findings and ambient noise levels. However measured ambient noise levels were higher in this study when compared to those reported by developed countries. Noise levels were only measured at the start of the screening programmes resulting in a possible lack of data regarding fluctuating noise levels (Olusanya, 2010). Despite no correlation being established, the main finding of the study suggests that not all TEOAE screening equipment designed in developed countries can be successfully used in contexts with high ambient noise levels.

The sensitivity and specificity of electrophysiological measures in relation to the ambient noise levels within the screening environment is also important to establish. A study was conducted in Malaysia using TEOAEs in four different test environments (in an isolation room in the ward during peak and non-peak hours and at the maternal bedside during peak and non-peak hours). Results indicated that *refer* findings were highest during peak hours

when screening was conducted at the maternal bedside (Salina, Abdullah, Mukari, & Azmi, 2010). In addition, screening time increased as ambient noise levels increased and specificity was also altered with different noise levels. The specificity of TEOAEs was 100% when the mean noise levels were 50.1 decibel A-weighted (dBA) but this reduced slightly to 96.8% with a mean noise level of 61.4 dBA and was significantly reduced when the mean noise level was 71.2 dBA (Salina, et al., 2010). These findings have significant implications for the choice of environment in which NHS is conducted and emphasizes the need to evaluate the ambient noise levels in screening environments when initiating NHS programmes.

Although not specific to the correlation between ambient noise levels and hearing screening outcome, noise levels were measured in three NICUs in Johannesburg, South Africa, two of which were in the private health care sector and one in the public health care sector. Noise levels were highest in the public health care sector where there were more incubators and nurses per shift in comparison to the private sector (Neille, George, & Khoza-Shangase, 2014). These are all important considerations when implementing a NHS programme.

5.2. Newborn and Infant Hearing Screening Practices Worldwide

5.2.1 Implementation of NHS programmes globally

The implementation of NHS programmes has evolved over the years, particularly in developed countries. High income countries (previously not conducting UNHS) such as Hong Kong and Canada have taken steps toward UNHS. Hong Kong has implemented a UNHS programme at eight birthing hospitals using a two-stage screening protocol (Yu et al., 2010). The Canadian Association of Speech-Language Pathologists and Audiologists (CASLPA) have developed a position paper in support of UNHS (CASLPA, 2010). However, the 2011 position statement by the Canadian Paediatric Society (CPS) has indicated that many Canadian infants are still not offered UNHS. Some provinces conduct TNHS for infants in the NICU whilst other provinces that have been afforded funding have not yet implemented UNHS (CPS, 2011).

South Africa (an upper middle income country) (The World Bank, 2015) has taken similar steps toward the initiation of NHS programmes through the position statement by the HPCSA (2007). Despite these HPCSA recommendations, published data following the release of the position statement indicates that where programmes are in place, they remain mostly unstructured due to them being unendorsed by hospital management and/ or the South

African DoH. This is accompanied by challenges within the public health care sector related to a lack of resources in terms of staff and equipment, discharge of well babies soon after birth (approximately six hours after birth) as well as a high default rate (D.E. Ballot, personal communication, October 3, 2012). On the other hand, published literature from Nigeria (a lower middle income country) (The World Bank, 2015) has indicated the implementation of pilot studies related to UNHS (conducted by non-specialists) in hospital-based settings (Olusanya, Wirz, & Luxon, 2008). The reviewed literature highlights that there is no consistent approach to NHS worldwide (Table 4) for which the reasons are not always financial (WHO, 2010) but rather dependent on what is considered feasible for each context at particular time periods.

Table 4: Examples of Approaches to Newborn and Infant Hearing Screening Practices in Different Countries Worldwide

Continent/ Region	Country	World Bank Classification	Approach to Newborn and Infant Hearing Screening	Limitations/ Challenges	Source
Europe			Regional- based EHDI programmes in approximately 30% of countries. Local EHDI initiatives in 20% of countries.	The JCIH (2007) benchmark of audiological evaluation by three months of age is only achieved in half of the countries, and only four of these countries provide early intervention by six months of age	(WHO, 2010)
	United Kingdom *England*	High Income	UNHS guided by comprehensive, national standards. In-hospital screening before discharge. Screening at homes (in some areas) by a health visitor nurse UNHS- 113 local programmes that are part of the National Health Service provision Majority of programmes are hospital-based (for well-babies and all NICU babies). Outpatient screening if conducted at clinics for babies who did not undergo complete		(WHO, 2010) (Wood, Sutton, & Davis, 2015)

			screening before discharge Community-based model for screening of well-babies at 10 days of age is the least conducted programme		
	Germany	High Income	UNHS- screening of well-babies by the 3rd day of life, screening of severely ill babies when practical but before the end of the 3rd month of life		(WHO, 2010)
North America	United States of America	High Income	EHDI programmes established per state and consist of UNHS	Loss to follow-up at all stages of the EHDI process. Most states are still working toward the JCIH(2007) recommendations in terms of benchmarks	(White, Forsman, Eichwald, & Munoz, 2010; WHO, 2010)
Australia	Queensland	High Income	UNHS part of the Healthy Hearing programme that is a state government funded and offers free hearing screening at 62 hospitals in Queensland.		(Beswick, Driscoll, Kei, & Glennon, 2012)
South-East Asia			No serious organised effort in many countries in this region	The presence of other pressing health priorities, poor audiological resources such as human resources, poor availability of rehabilitative services	(WHO, 2010)

	India	Lower Middle Income	Combination of institutional-based screening (hospital-based screening) and community-based screening at immunization visits by a trained health care worker. NHS at medical colleges, speech and hearing centres and private clinics, with UNHS more common amongst speech and hearing centres than medical colleges	The need for patients or caregivers to make repeated visits at different centres. Shortage of centres where ABR testing is conducted. Shortage of audiological personnel and as a result a heavy burden is placed on health care workers	(WHO, 2010) (Kumar & Mohapatra, 2011)
	Bangladesh	Lower Middle Income	No national policy for newborn and infant hearing screening. Institutions do conduct some form of hearing screening (not specified) as well as provide hearing aid fittings and cochlear implants.		(WHO, 2010)
Asia	China	Upper Middle Income	Hospital-based UNHS TNHS in rural and remote areas Questionnaires and simple tests for monitoring purposes within a community screening approach	Lack of human resources particularly audiologists. Follow-up return rate Lack of national databases to track infants. Difficulties associated with implementation of screening in rural/remote areas	(WHO, 2010)

Sub-Saharan Africa	Nigeria	Lower Middle Income	Routine screening at immunization clinics by community health workers	Poor tracking of infants and poor follow-up return rate influencing screening completion and completion of diagnostic evaluation	(WHO, 2010)
North Africa	Egypt	Lower Middle Income	No national program for EHDI but steps have been taken to promote a national NHS programme	Limited resources available to provide diagnostic services in hospitals	(Kamal, 2013)

Although UNHS is a widely accepted approach to NHS, there are some critiques of this approach. One such critique is based on the high FP rates of the screening measures and protocols used within this approach (Tatli et al., 2007). The FP, FN rates, sensitivity and specificity of the screening measures are closely linked to the validity of the screening procedures used. Knowledge of the aspects related to sensitivity and specificity of screening measures is key to ensuring that identification of infants with hearing loss is achieved at an acceptable and manageable cost (JCIH, 2007). This is particularly important in South Africa where NHS programmes are not standardised and are still in the pilot phases in some public health sector contexts.

5.2.2 NHS programmes in South Africa: Public and private health care contexts

NHS programmes in South Africa have not been standardised nationally, with differences existing between provinces as well as between the public and private health care sectors. Further inconsistencies with regard to NHS and paediatric audiological protocols and practices have also been reported in recent unpublished and published studies (Farr, 2015; Kanji & Opperman, 2015). Overall, results from NHS studies in South Africa have revealed poor coverage rates and limited implementation of UNHS due to a number of documented, context-specific challenges.

There have been a limited number of UNHS programmes that have been implemented within the private health care sector. Furthermore, the efficiency of UNHS programmes has decreased over time owing to associated cost implications. A UNHS programme was conducted over a four year period at a private health care hospital in South Africa. Of the 13,799 births during this screening period, only 6421 neonates were screened. This study reported a 75% coverage rate within the first 22 months when hearing screening was included within the hospital birthing package. The efficiency of the UNHS was found to have decreased during the following 26 months when parents were responsible for payment of this service, resulting in a 20% coverage rate only (Swanepoel, Ebrahim, Joseph, & Friedland, 2007). This study was conducted in the private health care sector where resources are usually well developed. If coverage is this poor where resource restrictions are not as profound as in the public sector; one needs to question the ethics as well as feasibility of recommending UNHS at this stage.

A recent, national survey conducted in the private health care sector in South Africa, which serves 15% of the entire population, indicated that only 14% of obstetric units offer true UNHS (Meyer & Swanepoel, 2011). A significant percentage (47%) of the private health care units included in the survey reported not performing NHS. Although TNHS may yield a greater coverage rate, more units (18%) reported conducting screening on request instead of employing an interim TNHS approach (3%) (Meyer & Swanepoel, 2011). The lack of UNHS programmes has also been documented within the public health care sector (Theunissen & Swanepoel, 2008).

An earlier national survey amongst public sector hospitals in eight of the nine provinces indicated that of the participating hospitals, 74% do not conduct NHS at all. It was therefore estimated that 7.5% of public hospitals (nationally) in South Africa provide some form of NHS, and less than one percent provide UNHS (Theunissen & Swanepoel, 2008). PHC clinics have been proposed as a platform for UNHS with the rationale that PHC level provides an opportunity to reach the entire population resulting in increased coverage of screened infants and improved follow-up return rates (HPCSA, 2007; Swanepoel, Hugo, & Louw, 2006). The rationale for a higher coverage rate has also been argued through findings from a study by Khoza-Shangase and Harbinson (2015). These authors propose the inclusion of Midwife Obstetric Units three- day assessment as a NHS platform in order to ensure that a higher number of neonates are reached.

A pilot study was previously conducted at two immunization clinics in South Africa. The risk factors documented in the newborns highlighted a significantly increased risk for hearing loss. Whilst this pilot study indicated the potential implementation of hearing screening at immunization clinics with a good screening coverage rate and co-operative nursing staff in majority of cases; FPs for sensorineural hearing loss were present in more than 50% of initial OAE referrals. Swanepoel, Hugo and Louw (2006) further reported a high level of external noise in the clinic environment with the main barrier to successful implementation of hearing screening being poor follow-up return rates.

More recently, the first systematic community-based NHS programme initiated at eight PHC clinics in the Western Cape was evaluated against the guidelines in the HPCSA (2007) position statement. Hearing screening was implemented using a two-stage DPOAE protocol conducted by trained nursing staff at Maternal and Child Healthcare clinics over a 19 month

period. Although follow-up return rates varied amongst clinics, they were considered to be good. Overall, poor coverage rates (32.4%) were reported across clinics which do not meet the benchmarks specified by the HPCSA (2007) position statement (Friderichs, et al., 2012). The authors concede that findings may have been further influenced by the high turnover of clinic staff as some sites as well as the use of already burdened nursing staff at the clinics who struggled to incorporate screening amongst their routine priority tasks. These challenges are in addition to findings reported from another study by Petrocchi-Bartal and Khoza-Shangase (2014). Findings from this study conducted at PHC immunization clinics in Gauteng and North West provinces revealed the absence of formalised newborn or infant hearing screening due lack of equipment, as well as budgetary and human resource challenges. These challenges need to be carefully considered in each province prior to the implementation of such NHS programmes nationally, particularly in light of the re-engineering of PHC as proposed by the South African DoH.

Despite current initiatives to pilot NHS services at the PHC level, the current PHC package for South Africa is only focused on the prevention of hearing impairment resulting from otitis media (DoH, 2012b). The primary health care package includes norms and standards related to medical staff competencies that are focused on the use of subjective measures for infants younger than 12 months. These subjective measures consist of the 'Voice test' and the 'Swart Questionnaire' for babies younger than 12 months (DoH, 2000; DoH, 2012b). These subjective measures further lack objectivity as they are based on parental reports and subjective observation of responses. The documented protocol for assessing infants lacks sensitivity and specificity as it merely acts as a screening method to identify those infants that may need to be referred for objective audiological assessment. The protocol does not provide any information about the auditory function of infants younger than 12 months of age; highlighting its lack of emphasis on EHDI. The lack of emphasis on EHDI is also evident by the inadequate implementation of NHS programmes as highlighted by national surveys conducted in the private and public health care sectors. The challenges to successful implementation of NHS programmes have primarily been related to the specific health care settings in which these programmes have been piloted. However, it is important to also consider the challenges faced by audiologists within the broader health context of South Africa.

5.2.3 Challenges to the implementation of NHS programmes in South Africa

5.2.3.1 Health priorities

One of the broader challenges influencing the lack of prioritisation of EHDI is the current focus on other health priorities by the South African government. The poor implementation of appropriate EHDI programs may therefore be due to the overwhelming burden of infectious diseases such as HIV, where priorities are aimed at saving lives rather than at addressing quality of life in individuals with non-threatening conditions such as hearing loss (Swanepoel, 2006). South Africa is still currently committed to working toward the achievement of the health related MDGs which are focused on the reduction of mortality and morbidity rates amongst mothers and children. These health related goals specified by the DoH (DoH, 2012d) include the eradication of extreme hunger and poverty; the promotion of gender equality; reduction of child mortality; improvement in maternal health; and combatting of HIV/AIDS, malaria and other major diseases. These health related priorities are in addition to the context specific challenges faced by audiologists in both the private and public health sectors.

Challenges associated with the implementation of NHS programmes in the private health care sector have been reported to include the fact that NHS does not form part of the maternity birthing package or institutional policy. NHS programmes in the private sector are also not supported by medical aid schemes and other health care professionals, and poor follow-up return rate remains a challenge (Meyer & Swanepoel, 2011). This is in contrast to NHS programmes in other countries worldwide which are financed by parents, health insurance, the government and/or hospitals (WHO, 2010). The challenges reported by audiologists in the South African public health care sector differed with the most frequently reported reasons for the absence of NHS programmes being staff shortages and a lack of equipment (Theunissen & Swanepoel, 2008).

5.2.3.2 Equipment

A lack of equipment was noted in a survey conducted by Theunissen and Swanepoel (2008). Fifteen of the 44 public hospitals in this survey reported having at least one piece of equipment for NHS (OAE and/or AABR). With regard to diagnostic measures, none of the district hospitals had diagnostic OAE or ABR equipment. Secondary and tertiary level

hospitals were found to be better equipped in terms of both screening and diagnostic equipment, with the majority of tertiary hospitals (70%) being equipped with both screening and diagnostic measures and 22% of secondary level hospitals having either one or both of these measures (Theunissen & Swanepoel, 2008). Findings from this study highlight the need for NHS programmes at tertiary level hospitals that are the best equipped to conduct these services. The ethics surrounding the introduction of NHS services and programmes in settings that are unable to provide, or do not have fully established diagnostic services and habilitation for intervention purposes needs to be considered (WHO, 2010). These ethical considerations are particularly important at PHC level settings within South Africa. Although screening at immunization visits at this level of health care may ensure a good coverage rate as it provides a platform for an accessible infant hearing screening service to the entire population (Swanepoel, et al., 2006); there are no diagnostic and habilitation services and infants would therefore need to be referred to an appropriate tertiary or secondary level hospital. Whilst there is a need for streamlining of audiological services, the need for caregivers to make repeated visits to different health care facilities may negatively affect follow-up return rates. Apart from the challenge of availability of resources in terms of equipment, Theunissen and Swanepoel (2008) assert that the availability of trained staff will also impact on the ability of the public health care sector to implement and manage EHDI programmes.

5.2.3.3 Manpower shortages

The manpower demand related to a higher prevalence rate of infant hearing loss in the public health care sector in South Africa is not met as majority of registered audiologists work in a private health care sector (Swanepoel, 2006). There is currently no mid-level worker programme in Audiology to facilitate hearing screening by personnel other than audiologists. The most recent statistics by the South African National Treasury have indicated a growth in the number of speech-language pathologists and audiologists in the public health care sector between 2002 and 2010, with 396 speech therapists and audiologists reported in 2010 (DoH, 2012c). There is therefore an evident shortage of manpower in the public sector which may influence the ability of Audiologists in South Africa to effectively implement UNHS. Recent HPCSA statistics indicate registration of 1439 speech-language therapists and audiologists and 256 audiologists (HPCSA, 2012). Recent statistics regarding the number of speech-language therapists and audiologists working in the private and public health care sectors

were not available upon enquiry. When exploring the effects of manpower shortages and resolutions to this challenge, one needs to take into consideration the other roles and responsibilities affiliated with the speech pathology and audiology profession. For example, speech pathologists and/or audiologists are responsible for assessment and management of outpatients in individual sessions, outpatient clinics as well as other inpatient services on a daily basis, possibly leaving limited time for a single professional to perform UNHS.

It is clear that manpower plays an important role in the successful implementation of UNHS. Practical considerations within a NHS programme therefore include the personnel who are able to conduct hearing screenings in newborn nurseries and paediatric units. In some contexts, these personnel are trained audiologists and this allows for the greatest level of expertise and may thus result in the most effective screening (Choo & Meinzen-Derr, 2010). However, many birthing facilities make use of trained volunteers, patient care assistants, clerical staff or nursing staff working in the respective units (Choo & Meinzen-Derr, 2010; Ferro, Tanner, Erler, Erickson, & Dhar, 2007). The chosen personnel appear to yield different results which need to be carefully considered when setting up programmes. Referral rates are reportedly lower in programmes using dedicated technicians and/or medical doctors rather than volunteers and students (Hille, van Straaten, & Verkerk, 2007) and this is probably linked to the level of experience and its impact on the screening outcome.

Reports from countries such as Australia, Brazil, China, Germany, India and United States of America indicate that screening is performed by a variety of personnel other than audiologists. These include nurses, midwives, audiological technicians and physicians (Olusanya, 2011a; WHO, 2010). Moodley and Storbeck (2012) propose various roles of the neonatal nurse in EHDI within the South African context. These authors suggest that due to the involvement of nursing staff in the lives of infants and their families, they would be well suited for various roles within the EHDI process. The first role being their involvement in referral of infants for hearing screening prior to discharge due to their knowledge of risk factors and illnesses. Secondly, the nurse is proposed as an educator, providing information to parents about the importance of screening, follow-up and diagnostic assessment and intervention options. Lastly, involvement as a screener and organiser for follow-up appointments was recommended (Moodley & Storbeck, 2012). However, these proposed roles need to be carefully considered in light of the current workload faced by nursing staff. Although reports available from the South African Nursing Council (SANC) indicate a

growth in nursing figures over the years, there still may be a shortage of individuals practicing in the nursing profession, with a current patient to nurse ration of 428:1 (SANC, 2011). This may therefore be easier recommended then done within the South African context, as nurses' workload remains extremely high and is influenced significantly by the burden of disease to which hearing loss might not be a priority. These considerations are supported by findings reported by Friderichs et al (2012) from the community- based hearing screening programme initiated in Western Cape, South Africa.

To date, there are currently no formally recognised training programmes for speech-language and hearing (SLH) support personnel within the South African context (South African Speech-Language-Hearing Association- SASLHA, 2010). Hence, at present, only individuals whose training has included hearing screening are permitted to conduct NHS. These individuals currently include speech-language therapists and audiologists (SASLHA, 2010).These personnel challenges highlight the need to explore TNHS as a more feasible, interim step toward NHS in South Africa. The use of TNHS within the NICU may be a good starting point for hospital based settings whereas screening at immunization visits may be a useful platform for well-babies due to difficulties in co-ordinating screening as a result of early or same day discharge (da Mata Lupoli, Garcia, Anastasio, & Fontana, 2013; Swanepoel, 2009). Early or same day discharge may dictate the need to conduct hearing screening prior to 48 hours of life in the presence of vernix in the outer auditory canal. This has significant implications on the choice and outcome of OAE measures employed within NHS protocols.

5.3 NHS protocols

Screening protocols and measures used within NHS programmes worldwide differ, with some countries and/or regions within a country using TEOAEs and AABR and others using DPOAE screening as well. For example, screening protocols in India consist of three stages with TEOAE at the first and second stages of screening, followed by AABR at the third stage. In comparison, hospitals in the United States employ a two stage screening protocol with TEOAE and AABR screening at both stages (WHO, 2010). Questionnaire based tools administered to caregivers and behavioural measures, possibly including noisemakers have been recommended by WHO (2010) as alternative measures in contexts where the use of physiological measures is not yet practical. However, the HPCSA (2007) position statement does not endorse the use of alternative measures such as noisemakers. Instead, the use of

physiological measures for NHS has been recommended in South Africa. Although more costly, AABR has been recommended for NHS in the NICU, and OAE screening has been recommended for NHS at immunization clinics (Swanepoel, et al., 2006). However the type of OAE is not specified, and there is currently a lack of published literature related to the use of different combinations of screening measures within NHS protocols in the South African context.

One of the ethical standards for NHS is that an appropriate, reliable, valid and safe test should be available and suitable to the target population being screened (WHO, 2010). Ultimately, the choice of screening measures and the approach to screening should be guided by evidence from well-conducted pilot studies in each country (Olusanya, 2011a; WHO, 2010). A low FP rate is essential in the success of a NHS programme and the reduction of FP results is therefore a key goal in developing a more reliable NHS programme (Korres et al., 2006). The current study aimed to determine the TN and TP results from a TNHS programme in a tertiary hospital. This will not only assist in determining the best combination of screening measures, but may also assist in determining the most cost-effective combination of screening measures. Table 5 provides comparison and outcomes of various screening protocols adopted within documented UNHS programmes worldwide.

5.3.1 Comparison and outcome of various screening protocols using TEOAE, DPOAE and AABR in UNHS

Table 5: Comparison and Outcome of Various Screening Protocols Using TEAOE, AABR and/or ABR within a UNHS programme

Country	Electrophysiological Screening and/or Diagnostic Measures	Details of Screening Protocol	Results, Conclusion and/or Recommendations	Reference
Italy	TEOAE, AABR and conventional ABR	Five Level screening protocol **First level:** TEOAE before discharge **Second Level:** Repeat TEOAE screening after two weeks for neonates who referred at the initial screening **Third level:** AABR at 45-90 days of life for newborns who *passed* first level but had risk factors and newborns who *referred* at the second level. **Fourth level:** Conventional ABR for infants who *referred* at the third level **Fifth Level:** Tympanometry, ABR and vocal audiometry for infants who did not *pass* the conventional ABR.	FP rates decreased with each step within the screening program. ABR plays a significant role in reducing the FP rates. Accuracy of NHS may be improved with the use of better screening protocols and conventional ABR is the most accurate measure when assessing function of the auditory system in NHS programmes.	(Guastini, et al., 2010)

Italy	TEOAE, diagnostic ABR	Two-stage TEOAE followed by diagnostic ABR for those newborns who *referred* with TEOAE and those at high risk for hearing loss Two-stage OAE for well-babies (the first being 48-72 hours after birth and the second between 3-4 weeks of age if a *refer* result is obtained) followed by diagnostic ABR if a *refer* is obtained at the second screening. OAE screening prior to discharge for NICU infants followed by diagnostic ABR at 3-4 months of age if a *refer* result is obtained.	100% sensitivity and 99.3% specificity in detecting congenital hearing loss. A two-stage TEOAE followed by diagnostic ABR appears to be feasible, minimally invasive and accurate protocol. The screening protocol for NICU infants excluded AABR which resulted in delayed diagnosis of auditory neuropathy in some infants	(De Capua et al., 2007) (Pisacane, et al., 2013)
Nigeria	TEOAE, AABR and diagnostic ABR	Two stage screening protocol followed by diagnostic ABR for all infants *referred* after the second stage screening in a hospital-based and community-based UNHS programme. **Stage 1:** TEOAE **Stage 2:** AABR for all infants who *referred* from Stage 1.	Referral rates from the first-stage TEOAE screening were higher than the recommended benchmark of 4% by the JCIH The introduction of AABR in the second stage reduced the referral rate Although the use of AABR in the first stage would have resulted in lower referral rates, it	(Olusanya, Emokpae, Renner, & Wirz, 2009)

			would have been impractical within the community-based screening.	
Nigeria	TEOAE, AABR	Two-stage screening protocol **Stage 1:** TEOAE **Stage 2:** AABR for newborns from the well-baby nursery that *referred* at the stage 1 screening and all newborns admitted to the special care baby unit.	High percentage of true-negative results followed by FP results, TP and then FN results The FN and FP results were more evident in the newborns in well-infant nurseries, delivered vaginally or whose mothers received antenatal care. A careful evaluation of the trade-offs resulting from various TEAOE/AABR options needs to be investigated, and the effects on efficiency using a one-stage or two-stage screening protocol with the same technology needs to be carefully considered.	(Olusanya & Bamigboye, 2010)
Brazil	TEOAE, AABR	Three different screening protocols **Protocol 1:** two-stage TEOAE **Protocol 2:** two-stage AABR **Protocol 3:** TEOAE followed by a retest with AABR for all newborns who *referred* with TEOAE.	Protocol 1 resulted in four times more the referral for audiological diagnosis in comparison to Protocol 2. The FP rate and specificity was better for Protocol 2, followed by Protocol 1 and lastly Protocol 3.	(de Freitas, de Freitas Alvarenga, Bevilacqua, Martinez, & Costa, 2009)
Spain	TEOAE, AABR	Two different, two-stage screening protocols **Protocol 1:** two-stage TEOAE **Protocol 2:** two-stage AABR	A lower referral rate was obtained with AABR. A lower FP rate was achieved with TEOAE during the first stage of screening as opposed to AABR, but a lower FP rate was achieved with AABR at the second stage of screening.	(Benito-Orejas, et al., 2008)

			A higher predictive value for hearing loss was achieved with a two-stage AABR protocol.	
Spain	TEOAE only for screening ABR for diagnostic assessment	Two phases at different time periods **Phase 1:** TEOAE 48 hours after birth **Phase 2:** TEOAE after 1 month for babies who obtained a *refer* result in phase 1 and after 2 months for babies who *passed* but presented with a risk factor for hearing loss Diagnostic assessment using ABR for babies who *refer* in the 2nd phase	Coverage rate was above 95% Referral rate for diagnostic assessment was low (3.8%)	(Borkoski Barreiro et al., 2013)
Poland	TEOAE, DPOAE, ABR	**First stage:** Screening TEOAE **Second stage:** Diagnostic ABR and diagnostic DPOAE for neonates that obtained a *refer* result in the first stage as well as for neonates with risk factors for hearing loss	FP rate of 82.73% from the first stage- possibly attributed to having performed screening on the 2nd or 3rd day of life in the presence of amniotic fluid in the middle ear or debris in the external ear canal. The inclusion of AABR in the first stage may assist in improving quality of results and decreasing FP results.	(Lachowska, Surowiec, Morawski, Pierchala, & Niemczyk, 2014)
Taiwan	TEOAE, AABR	Three different screening protocols used at different time periods **Protocol 1:** One-stage TEAOE **Protocol 2:** TEOAE and AABR **Protocol 3:** One-stage AABR	Referral rates were lower for Protocol 3 as opposed to Protocol 1 & 2. No statistically significant difference was found with regard to the accurate identification rate of congenital hearing loss.	(Lin, Shu, Lee, Lin, & Lin, 2007)

			The total cost was lower for Protocol 3 than Protocol 1 & 2. Intangible costs such as parental anxiety and transportation fees were lower for Protocol 3 due to a lower referral rate.	
Sweden	TEOAE Diagnostic click-evoked ABR	Multiple TEOAE recordings (typically 3 sessions) **Stage 1:** TEOAE screening before discharge **Stage 2:** TEOAE screening as outpatient **Stage 3:** TEOAE screening if *refer* results were obtained **Stage 4:** Click-evoked ABR	TEOAE screening had high specificity and sensitivity was observed to be 100% The use of multiple TEOAE recordings reduced the referral for diagnostic ABR TEOAE was best recorded 3-6 days after birth.	(Berninger & Westling, 2011)
Tapei City, China	AABR OAE Diagnostic ABR, ASSR	**Stage 1:** AABR screening at 24-26 hours after birth **Stage 2:** AABR screening at 36-60 hours of age or before discharge if *refer* results were obtained **Stage 3:** OAE and AABR at one month of age at a diagnostic hospital if a refer result was obtained on second screen Diagnostic ABR, ASSR and OAE (and behavioural observation audiometry or visual reinforcement audiometry) for infants who referred on Stage 3.	Coverage rate was 99.1% Referral rate was low (1%) revealing that a two-stage pre-discharge AABR screening strategy is effective	(Huang et al., 2013)

Israel (newly established programme)	TEOAE AABR	**Stage 1:** TEAOE screening followed by a repeat TEOAE screening a day later if a *refer* result was obtained (well-babies) TEOAE and AABR for neonates with risk factors **Stage 2:** AABR screening if a *refer* result was obtained after the second TEOAE screen Comprehensive audiological assessment following a *refer* result from stage 2. Audiological measures were not specified.	Coverage rate was 94.5% Referral rate of 5.18%	(Gilbey, Kraus, Ghanayim, Sharabi-Nov, & Bretler, 2013)

Whilst the above mentioned studies in Table 5 have been conducted within a UNHS programme, investigations regarding various screening protocols have also more specifically been conducted in targeted populations (either neonates from a well-infant nursery or high-risk neonates). Suppiej et al. (2007) investigated the use of TEOAE, AABR and ABR in neonates with high-risk factors for hearing loss. Results from this study indicated that although TEOAEs and ABRs were able to predict hearing loss in high risk neonates admitted to the NICU, ABR was the most reliable test as it had the best sensitivity and specificity with AABR being the worst. Similar findings were reported by Martines and colleagues who concluded a TEOAE/ABR combination to be the gold standard for screening NICU babies who are at risk for auditory neuropathy (Martines et al., 2012). Berg, Prieve, Serpanos and Wheaton (2011) compared the use of two screening protocols (AABR followed by OAE when *refer* results were obtained from AABR, and OAE followed by AABR when *refer* results were obtained from OAE) in infants admitted to the well-infant nursery. Results from this study indicated that the conventional protocol of OAE followed by AABR (if a *refer* OAE result was obtained) was more efficient in terms of time. The authors further concluded that the use of OAEs as a screening tool for infants in well-baby nurseries is reasonable.

The choice of screening protocol employed within a NHS programme is influenced by a variety of factors such as costs, logistics, infrastructural considerations, targeted referral rates and follow-up default rates (Olusanya & Bamigboye, 2010). Although the same screening measures may be employed, there are clear differences in their implementation or use within a screening protocol. Differences in screening protocols highlight that the choice of screening protocol may not only be determined by what is feasible within a particular context, but also by the objective of achieving the ideal screening protocol (achieving good sensitivity and specificity, achieving a high initial *pass* rate or achieving a low-cost protocol). This is particularly important for the South African context where the above-mentioned factors may significantly influence the success of a NHS programme.

5.4. Cost-effectiveness of NHS programmes

"When considering the implementation of any health care programme it is important to evaluate whether the benefits of the programme will outweigh the costs. For NHS programmes, costs are incurred for all those screened, but the benefits are experienced by only a small percentage of neonates. The most important variables to include in such an analysis are the actual costs of the screening, the effectiveness of the screening, the

prevalence of hearing loss and the cost consequences associated with preventing, treating or managing hearing loss. Assessment of benefits must then include both the health and economic benefits associated with preventing, treating or managing hearing loss" (WHO, 2010, p10).

Huang et al. (2012) explored the cost-effectiveness of UNHS and TNHS using the above mentioned guidelines stipulated by WHO (2010) in eight different provinces in China. TNHS tended to be more cost-effective in some provinces whilst UNHS tended to be more cost-effective in other provinces. The authors found that the implementation of NHS programmes varied according to the socioeconomic status of provinces and that UNHS tended to be more cost-effective when the programme yielded a good coverage rate, diagnosis rate and intervention rate. TNHS on the other hand tended to be more feasible in provinces where the rates of these indicators were low. In order to improve TNHS in these provinces, it was recommended that pilot surveys be conducted to determine the context-specific risk factors for permanent congenital and early-onset hearing loss (Huang, et al., 2012). In addition to these findings, a systematic review by Colgan et al (2012) indicated that the cost-effectiveness of UNHS for the detection of permanent congenital hearing impairment cannot be concluded due to the lack of evidence of the longer-term costs and outcomes associated with these programmes.

An international comparison of cost-effectiveness by Burke, Shenton, and Taylor (2012) was also conducted between the United Kingdom and India, whereby cost-effectiveness was explored in terms of UNHS and selective screening of newborns with pre-specified risk factors. Comparison was also done for provision of a one-stage versus a two-stage screening protocol (Burke, et al., 2012). Although the UNHS strategy identified more infants with hearing loss, the selective screening strategy yielded a better positive predictive value (Burke, et al., 2012). The UNHS strategy resulted in a significantly larger number of FP findings, resulting in greater costs incurred. The two-stage screening demonstrated to be a more feasible protocol as opposed to the one-stage screening protocol which was found to have incurred more costs. These authors postulate the costs to be dependent on the prevalence of hearing loss in each region, with costs per case being higher in regions with a lower prevalence (as more infants need to be tested in order to detect an additional case) (Burke, et al., 2012). It can be argued that the costs incurred within the South African context may be lower as it is a developing country where the prevalence of hearing loss may be higher.

Cost-effectiveness has primarily been investigated in terms of screening protocols (screening measures used) and programmes (UNHS or TNHS) with little focus on the costs involved in tracking newborns with bilateral hearing impairment. A study conducted in Germany indicated that tracking resulted in more cases being detected, but this was accompanied by higher costs of approximately €1,697 per additional case. The use of tracking systems may therefore assist in attaining adequate follow-up of infants with hearing impairment as the cost-effectiveness of a NHS programme is not only reliant on the accuracy of the programme, but also encompasses the ability of such a programme to ensure adequate follow-up of newborns who obtained *refer* results from the initial or subsequent screening sessions (Langer, Brockow, Nennstiel-Ratzel, & Menn, 2012).

5.5. Follow-up in NHS programmes

With the development and progression of NHS programmes, particularly UNHS, one of the areas of focus has been the challenge of reducing issues linked to poor follow-up return rate following referral from NHS and recommended diagnostic assessment and management (Choo & Meinzen-Derr, 2010). Loss to follow-up within EHDI programmes has both clinical and epidemiological implications. Clinically, poor follow-up return rate undermines the effectiveness of early detection of hearing loss and subsequently, the provision of early intervention (Olusanya, 2009a; Rawool, 2010). Epidemiologically, it leads to inaccurate data regarding prevalence and incidence of hearing loss (Kanji, Khoza-Shangase, & Ballot, 2010; Olusanya, 2009a).

Developed countries with successful UNHS programmes suggest that the challenges related to follow-up return rate can be lessened by addressing the socio-demographic and economic factors that underpin follow-up (Liu, Farrell, MacNeil, Stone, & Barfield, 2008). The American Speech-Language Hearing Association (ASHA) has considered system issues such as follow-up by primary care providers; lack of communication and coordination among health care service providers; access to funding for EHDI programmes; and the type of personnel involved in NHS programmes to influence follow-up return rate (ASHA, 2008). Family issues related to caregiver education and infant factors have also been considered as contributing to loss to follow-up (ASHA, 2008). Provision of appropriate information to families has also been explored as a means of contributing to high-quality follow-up (Laugen, 2013). It has been recommended that information giving should entail providing families with information about what the EHDI process entails as well as reasons for repeated

measures and waiting periods between screening or assessment sessions. Easy access to professionals that parents may liaise with as well as provision of comprehensive, unbiased information to facilitate decision making have also been noted as aspects that professionals need to be aware of during the EHDI follow-up process (Laugen, 2013). Whilst these are some of the services that may assist in ensuring follow-up, professionals also need to consider and evaluate contextual reasons for poor follow-up return rate.

Poor follow-up return rate is perhaps more common in developing contexts where there is no effective facility for tracking of patients and caregivers (Olusanya & Akinyemi, 2009). Investigations of follow-up return rate in a community-based NHS programme in Nigeria revealed that less than half of the infants returned for a second stage screening. These results were not attributed to maternal education or affordability of services as most mothers who did not return had a minimum of secondary education and services were offered free of charge (Olusanya & Akinyemi, 2009). These authors therefore concluded that other factors not examined in this study may have contributed to the poor follow-up return rates. Results differed slightly to those found in a hospital-based UNHS programme conducted in an inner-city maternity hospital in Lagos, Nigeria where the mode of delivery and admission to a special care baby unit were noted as key determinants of parental compliance (Olusanya, 2009a). Results from a South African study in the public health care sector indicated that follow-up return rate was likely to be influenced by the distance caregivers lived from the hospital (Kanji, et al., 2010). Another study conducted in the private health care sector in South Africa revealed that the most common reasons for follow-up default were that caregivers had forgotten about the follow-up appointment whilst others viewed follow-up as unnecessary Thus highlighting the key role of parental involvement in the EHDI process.

5.6. Caregiver/parental consent and involvement in NHS programmes

"The success of any EHDI program hinges on the support and informed choices of the parents involved" (Swanepoel & Almec, 2008, pS46). These informed choices made by parents or caregivers are based on their knowledge and attitude towards newborn and infant hearing loss. This is particularly important in the South African context where cultural beliefs need to be considered. In a face to face survey conducted with 100 mothers (attending a public sector immunization clinic) in South Africa, superstitious cultural beliefs were commonly identified as a cause of infant hearing loss. Despite these findings, mothers were found to be positive towards EHDI with 99% of them having indicated that they would want

their baby's hearing to be screened (Swanepoel & Almec,2008). These informed choices may differ between public and private health care sectors within the South African context.

Contrary to the findings from the above mentioned survey, a survey conducted at two private hospitals revealed that 11 out of 100 caregivers at the one hospital and just under half of the 907 caregivers at the second hospital refused the NHS services offered to them. Reasons for refusal were explored in a sample of these caregivers (n=25). The most common reason was related to cost due to medical insurance not covering for it, followed by their view that NHS was unnecessary. Other reasons included not enough information being provided prior to birth, NHS services not being part of the birthing package and the fact that a hearing screening was not recommended by a paediatrician (Scheepers, Swanepoel, & le Roux, 2014). These findings highlight the need for cost-effective protocols, information counselling by audiologists as well as a collaborative approach to NHS services with other health care professionals, whilst ensuring that ethical standards are maintained.

5.7. Ethical issues in NHS in developing countries

Medical ethics requires that parental or caregiver decisions and informed consent are attained through informed choices which are influenced by their knowledge and attitude. Olusanya, Luxon and Wirz (2004b) define various dimensions to informed choice. These dimensions include the importance of hearing impairment amongst other life threatening health priorities; the role of physicians in NHS programmes and the need for their involvement; and lastly, caregiver or parental views on NHS and the need for comprehensive information giving by professionals. The aspect of comprehensive information giving is required for purposes of informed choice.

Olusanya and colleagues proposed an action model for informed choice whereby categories are defined by good or poor knowledge and attitude toward NHS. These authors indicate that the aim of informed choice is to have all individuals in the quadrant of good knowledge and good attitude by educating and counselling them regarding early identification of hearing impairment (Olusanya, et al., 2004b). This should be done whilst ensuring that communication with parents is handled in a culturally appropriate manner and with sensitivity. Olusanya and colleagues (Olusanya, et al., 2004b; Olusanya, Luxon, & Wirz, 2006) emphasise that parental autonomy should also be respected when NHS services are still declined as professional ethics prohibits coercing individuals.

Apart from informed choice of parents or caregivers, there are other, broader ethical issues which need to be considered in relation to the initiation and implementation of NHS programmes in developing contexts. The first issue is related to whether or not NHS programmes should be introduced if there are no effective intervention programmes in place. Whilst early intervention following diagnosis is essential, one needs to consider that these services develop and grow with time and for these reasons, early detection of hearing impairment should be encouraged even if early intervention services are limited at the time. The second issue is related to the traditional approach of first determining the cost-effectiveness of introducing a NHS programme. However, Olusanya, Luxon, et al (2006) stress that this may be unethical if the alternate choice is to offer no hearing screening. These authors suggest that it may be more appropriate if different approaches to screening are evaluated such as hospital based versus community-based hearing screening or UNHS versus TNHS. Hence the current study aimed to explore TNHS in hospital settings with poor or no established NHS programmes.

Chapter summary

This chapter has carefully highlighted that there are pros and cons associated with UNHS and TNHS. Although UNHS is strongly recommended, there are studies from developing countries that support the use of TNHS as an initial step to NHS. Within each of these approaches to NHS, there are evident differences in the choice of electrophysiological measures used within screening protocols. These variations in NHS programmes are most probably dictated to by contextual challenges and feasibility. Despite these differences in approaches to NHS, follow-up return rate remains a central challenge in both developed and developing contexts, with caregivers playing a key role in the follow-up process. Informed choice is thus vital, whilst ensuring that cultural appropriateness and sensitivity towards caregivers is maintained from an ethical perspective. Broader ethical issues also need to be addressed, such as the provision of some form of NHS programme with an evaluation of which approach to NHS (whether UNHS or TNHS) is best suitable for a particular context. The next chapter focuses on risk-based/ TNHS which the current researcher considers an appropriate step towards UNHS for the South African context.

CHAPTER 6: RISK-BASED HEARING SCREENING AND RISK FACTORS FOR HEARING LOSS

This chapter focuses on risk-based or TNHS as it forms the basis for the current study. It aims to provide rationale for the use of risk-based hearing screening whilst highlighting the aspects that need to be considered when implementing such a programme. This chapter reviews the recommended risk factors and discusses findings from literature that suggest how these risk factors may differ amongst contexts when implementing TNHS. The types of audiological screening measures employed in TNHS programmes are also discussed. This is followed by information related to the audiological surveillance or monitoring of high-risk infants to ensure detection of delayed or late onset hearing loss in this population.

6.1. Targeted/risk-based hearing screening as an alternative to UNHS

According to Abalo et al (2009) and Olusanya et al (2004a), there is no single NHS method that can be considered as being perfect or the most effective in all circumstances or contexts. This is evident in published literature reviews pertaining to the implementation of NHS programmes globally. NHS programmes from 46 countries were reviewed and evaluated against the JCIH (2007) recommendations (Tann, Wilson, Bradley, & Wanless, 2009). From the 26 high income countries included in the study, 18 (69%) were recorded as having implemented UNHS. This is in comparison to the middle income countries where UNHS was indicated for eight (44%) out of the 18 countries and no UNHS programmes were indicated for the low income countries (Tann, et al., 2009). Despite the implementation of these UNHS programmes in specific high and middle income countries, the average screening coverage rate was below the recommended rate of 95%. In addition, the average referral rate was above the JCIH (2007) recommendation of four percent and the average follow-up return rate was lower than the JCIH (2007) recommendation of 90%. It should be noted however that the latest data available for this study was 2006, which was prior to the release of the JCIH (2007) position statement. Differences in approaches to NHS still exist between developed and developing countries which speaks to context playing a major role in the choice of NHS programmes.

"Differences between countries in terms of health care systems and the availability of resources and personnel to implement hearing screening programmes will result in very different approaches to implementation" (WHO, 2010, p 31). The appropriateness of screening and final choice should consist of what is ideal and feasible at any one time for each country (Olusanya, et al., 2004a). In contexts where UNHS (using physiological, objective measures) is not yet feasible and practical, physiological screening should be offered to a target group, specifically those with known risk factors for hearing loss (Olusanya, 2011a; WHO, 2010). This reality speaks very much to the South African context where challenges impede the implementation of UNHS. When comparing contexts; one should also consider the most common causes of hearing impairment in developed and developing contexts as this may assist in guiding the choice of screening method as well as the risk factors for hearing loss. Exploratory studies in Brazil have reportedly found hospital based screening of high risk neonates to be a very successful starting point toward the bigger goal of UNHS (WHO, 2010). The TNHS approach proved to be useful in organising follow-up , maintaining a database of infants screened, as well as training of community health workers (WHO, 2010). Similarly, Rai and Thakur (2013) argue that although results from their study in India revealed a high incidence of hearing impairment suggestive of the need for UNHS; starting with TNHS followed by a gradual implementation of UNHS may be more applicable for their context when considering the infrastructure limitations and the lack of a NHS policy.

Although TNHS has been recommended as an alternative approach in contexts where UNHS is not yet attainable, little evidence exists on the relevant risk factors that can be used to facilitate this method of screening (JCIH, 2007). It is important to identify risk factors for hearing loss as infants with any of these factors in neonatal history has a greater chance of experiencing hearing impairment (Colella-Santos, Hein, De Souza, Do Amaral, & Casali, 2014). There are a number of other rationale for the identification and use of risk factors for hearing loss. Firstly, risk factors assist in identifying children who should undergo audiological assessments in geographical regions where UNHS programmes do not exist, or where limited resources prevent the implementation of such programmes (Núñez-Batalla, Trinidad-Ramos, Sequí-Canet, De Aguilar, & Jáudenes-Casaubón, 2012) . Secondly, risk factors assist in identifying children who require medical and/or audiological monitoring (JCIH, 2000). Lastly, risk factors facilitate the identification of children who are at risk for

auditory neuropathy (JCIH, 2007). The identification of relevant risk factors can further assist in effective, primary prevention of the disabling conditions resulting from them, and earlier identification which allows for timely intervention (Olusanya, 2009b). Context specific risk factors are particularly relevant to ensure appropriate identification of hearing loss in high risk neonates.

6.2. Risk factors for hearing loss

6.2.1 Recommended risk factors for hearing loss

It is estimated that half of congenital and early onset hearing loss is attributable to genetic factors (Olusanya, 2011a). Other recognised causes for hearing loss include infections such as cytomegalovirus, rubella and meningitis; as well as perinatal conditions such as birth asphyxia, LBW and hyperbilirubinemia. However, Olusanya (2011a) argues that the prevalence of these causes or any risk factors cannot be generalised worldwide and the relevant contributions of risk factors to hearing loss are likely to vary from country to country.

The HPCSA has recommended a list of high-risk factors to be used for TNHS. These risk factors have been modified from those stipulated by the JCIH, with the addition of risk factors that are considered contextually relevant to the South African context (HPCSA, 2007). These differences in the current high-risk factors by the HPCSA and JCIH are noted in Table 6.

Table 6: Risk Factors Associated with Hearing loss according to JCIH (1982), JCIH (2007) and HPCSA (2007)

RISK FACTOR	JCIH (1982)	JCIH (2007)	HPCSA (2007)
Caregiver concern regarding speech, language and or developmental delay		✓	✓
Family history of permanent childhood hearing loss	✓	✓	✓
Findings associated with a syndrome known to include sensorineural or permanent conductive hearing loss		✓	✓
Craniofacial anomalies	✓	✓	✓
Postnatal infections associated with sensorineural hearing loss		✓	✓
Head trauma, especially basal skull and temporal bone fractures		✓	✓
Neurodegenerative disorders		✓	✓
Syndromes associated with progressive or late-onset hearing loss		✓	✓
Chemotherapy		✓	
Neonatal intensive care admission			
• more than 5 days		✓	
• 48 hours or greater			✓
Neonatal indicators:			
• extracorporeal membrane oxygenation (ECMO)		✓	✓
• hyperbilirubinemia requiring exchange blood transfusion	✓	✓	✓
• Mechanical/assisted ventilation		✓	✓
• Exposure to ototoxic medication		✓	
• Bacterial Meningitis	✓		
• Severe asphyxia: Activity, Pulse Grimace Appearance Respiration (APGAR) scores of 0-3 & hypotonia persisting to 2 hours of age	✓		
• Birth weight less than 1500 grams	✓		
In-utero infections:			
• Cytomegalovirus	✓	✓	✓
• Herpes	✓	✓	✓
• Rubella	✓	✓	✓
• Syphilis	✓	✓	✓
• Toxoplasmosis		✓	✓
• Human immunodeficiency virus (HIV)			✓
• Malaria			✓

(HPCSA, 2007; JCIH, 1982; JCIH, 2007)

Most of the risk factors listed in Table 6 are related to NICU admittance (Coenraad, Goedegebure, van Goudoever, & Hoeve, 2010) . It is therefore unclear which risk factors independently contribute to sensorineural hearing loss and it is only by comparison within the NICU population that the risk factors specifically associated with sensorineural hearing loss can be evaluated (Coenraad, et al., 2010). Hence, the current study sample consisted of neonates from the NICU and/or high care wards. These risk factors (Table 6) have been specifically stipulated for birth through to 28 days, with some of them also recommended for the use of risk-based surveillance from 29 days through to two years of age. These include (HPCSA, 2007):

- Parental or caregiver concern regarding hearing, speech, language, and or developmental delay.
- Family history of permanent childhood hearing loss.
- Stigmata or other findings associated with a syndrome known to include a sensorineural or conductive hearing loss or Eustachian tube dysfunction.
- Postnatal infections associated with sensorineural hearing loss including bacterial meningitis.
- In-utero infections
- Neonatal indicators—particularly hyperbilirubinemia requiring exchange transfusion, persistent pulmonary hypertension of the newborn associated with mechanical ventilation, and conditions requiring the use of ECMO
- Syndromes associated with progressive hearing loss such as neurofibromatosis, osteoperosis, and Usher's syndrome.
- Neurodegenerative disorders, such as Hunter syndrome, or sensory motor neuropathies, such as Friedreich's ataxia and Charcot-Marie-Tooth syndrome.
- Head trauma
- Recurrent or persistent otitis media with effusion for at least 3 months

Whilst the above listed risk factors are based on the JCIH position statement, in developed contexts such as Queensland, Australia, the recommended risk factors from the JCIH (2000) have been adapted based on medical practice and conditions in their context. For example, instead of admission to NICU, LBW (≤1500g) has been included due to the total number of these babies who would be admitted to the NICU and referred to the risk or targeted surveillance programme. Although LBW is no longer listed as risk factor for hearing loss in

the JCIH (2007) position statement, this population has been found to present with multiple risk factors listed on the HRR (Kanji & Khoza-Shangase, 2012). Secondly, ECMO was replaced by severe asphyxia as ECMO is not routine practice in Queensland. The risk registry used in Queensland has been outlined in Table 7.

Table 7: Risk Factor Registry used in Queensland, Australia for UNHS and Targeted Surveillance Programmes

Family history of permanent childhood hearing loss (excluding grommets, infection or trauma)
Syndromes associated with hearing loss, for example Down syndrome, Foetal Alcohol Syndrome
Prolonged ventilation ≥ 5 days (intermittent positive pressure ventilation- IPPV or continuous positive airway pressure- CPAP)
Confirmed or suspected bacterial meningitis
LBW (≤ 1500 g)
Severe birth asphyxia (convulsions or hypoxic ischemic encephalopathy-HIE or persistent pulmonary hypertension of the newborn-PPHN)
Craniofacial anomalies excluding cleft lip and skin tags
Hyperbilirubinemia levels of ≥450 µmol/l in term infants or ≥340 µmol/l in preterm infants
Proven or suspected congenital infection
Professional concern

(Beswick, Driscoll, Kei, et al., 2012; Beswick, Driscoll, Kei, Khan, & Glennon, 2013)

In addition, findings from a systematic literature review by Beswick, Driscoll, & Kei (2012) indicated that of the recommended JCIH risk factors for risk-based surveillance, only monitoring of children with cytomegalovirus and ECMO is well supported by literature as cohort studies have identified a strong relationship between these risk factors and postnatal hearing loss. In another study in Queensland, Driscoll and colleagues investigated the validity of family history as a risk factor for pediatric hearing loss (Driscoll, Beswick, Doherty, D'Silva, & Cross, 2015). These authors concluded that although it is valid for infants and children with a family history of hearing loss to be screened at birth and monitored through surveillance programmes, unnecessary surveillance costs need to be avoided as there is a low yield of hearing loss when family history is a sole risk factor. These findings highlight the

need for context specific, evidence-based risk factors that need to be explored by each country.

6.2.2 Risk factors in developed contexts

Additional risk factors not listed by the JCIH have been found in some studies. A study conducted at a tertiary level hospital in the Netherlands on risk factors for sensorineural hearing loss in NICU infants found that of the NICU infants diagnosed with hearing loss, dysmorphic features; a low APGAR score at one minute; sepsis; meningitis; cerebral bleeding and cerebral infarction were statistically significant risk factors (Coenraad, et al., 2010). Of these risk factors, sepsis is not a risk factor listed by the JCIH but was found in a to have a strong correlation with sensorineural hearing loss in this study as well as a study by Eras et al (2014) conducted in Turkey. These findings are is in comparison to an earlier study conducted in the Netherlands with a slightly smaller NICU cohort whereby results indicated severe birth asphyxia and assisted ventilation for more than five days as the only independent risk factors for hearing loss (Hille, et al., 2007).

In another study, Ohl, Dornier, Czajka, Chobaut, and Tavernier (2009) explored TNHS in a group of newborns presenting with one or more risk factors defined by the JCIH (2000). Results indicated severe birth asphyxia to be the most statistically significant risk factor associated with sensorineural hearing loss, followed by neurological disorders, syndromes and in-utero infections (cytomegalovirus and herpes). Hyperbilirubinemia was not a prevalent risk factor within the sample. Apart from the type of risk factors found to be associated with hearing loss; associations between the number of risk factors and hearing loss was found, with the presence of two or more risk factors significantly increasing the risk of bilateral hearing loss (Ohl, et al., 2009). It should be noted that the inclusion criteria for this study was based on the risk factors defined by the JCIH (2000), possibly preventing the identification of other risk factors within their context. Another limitation of this study was that it utilized a two stage OAE screening protocol which limited the identification of auditory neuropathy within this high risk population.

More recently published literature in Italy evaluated the main risk factors for sensorineural hearing loss (from birth to 28 days of life) reported by the JCIH (2007) position statement. Using both OAE and ABR measurements, 51 of the 508 infants were diagnosed with sensorineural hearing impairment. Of the risk factors, TORCH (Taxoplasmosis, Syphilis,

Rubella, Cytomegalovirus, Herpes) infections were found to be an independent risk factor for prelingual sensorineural hearing loss. No statistical significance was found between those newborns admitted to NICU and those exposed to other risk factors (Martines, Martines, Mucia, Sciacca, & Salvago, 2013).

Knowledge of these risk factors and epidemiological characteristics of hearing impairment in each region or context allows for effective planning for prevention of hearing impairment and risk-based surveillance programmes for infants at risk (Martines, et al., 2013). The current study aimed to explore TNHS in all neonates discharged from the NICU or high care, to low care and Kangaroo Mother Care (KMC) wards, and included both OAE and AABR measures. Studies reviewed above highlight that differences among the risk factors for sensorineural hearing loss (in the NICU population) exist within developed contexts, and that these risk factors may change over time. Similarly, differences in risk factors have been noted from studies in developing contexts.

6.2.3 Risk factors in developing contexts

In Africa, a study conducted at a tertiary maternity hospital in Nigeria revealed that from the newborns screened (in the special care baby unit and well- baby nursery), emergency caesarean section delivery, vaginal delivery, low APGAR scores at five minutes and hyperbilirubinaemia requiring phototherapy were found to be independent risk factors for sensorineural hearing loss (Olusanya, 2009b). Although associations between risk factors and audiological outcome were noted in this study, these were based on screening results and not diagnostic outcomes due to reported poor follow-up return rates. Further research linked to diagnostic outcomes is therefore needed in low income countries such as Nigeria (Olusanya, 2009b) and the rest of Africa. Resource-poor countries have also reported the presence of different risk factors to hearing loss such as the lack of skilled attendants at delivery, maternal hypertension and malnutrition of infants. Whilst these risk factors are not listed on the HRR, they are considered to be reflective of the cultural and epidemiological profile in these contexts (Olusanya, 2011a; WHO, 2010). Hence, it is deemed important to revisit high risk factors for hearing loss in various contexts.

The risk factors that are most commonly associated with hearing loss in newborns and infants will not only vary from country to country, but may also differ within countries and it is thus vital that the risk factors used within NHS programmes are good predictors of hearing loss in

that particular geographical location (WHO, 2010). This information can be collected from already established NHS programmes. However, in contexts where this is difficult, the screening of neonates who have been in the NICU can be very valuable in order to provide a relatively good proxy measure of these risk factors (WHO, 2010). Whilst the epidemiological profile for permanent congenital hearing loss is likely to display clear differences across various regions worldwide, no systematic attempt has been reported in literature to establish the appropriateness of the JCIH high risk factors for developing countries (Olusanya, 2011b).

Research regarding the current high risk factors for hearing loss is needed in middle income, developing countries such as South Africa. The risk factors listed in the HPCSA (2007) position statement provide some guidance for TNHS within the South African context. However, this list has primarily been based on position statements from developed contexts, and adapted to include HIV and Malaria as these are prevalent conditions within the South African context. A retrospective review of 100 files conducted at a University based paediatric referral clinic indicated that the most prevalent risk factor for sensorineural hearing loss was a family history of hearing loss, with NICU stay for more than five days being the most prevalent risk factor associated with auditory neuropathy. Other risk factors associated with hearing impairment and/or auditory neuropathy (all of which are listed on the HPCSA (2007) position statement) included hyperbilirubinemia, asphyxia, extremely low birth weight (ELBW), syndromes, congenital infections, craniofacial abnormalities and bacterial meningitis (Swanepoel, et al., 2013) . There is currently no other published literature on the high risk factors for hearing loss within the South African context. The current study aimed to explore risk-based hearing screening in a tertiary and secondary level hospital within the South African context with one of the objectives being the review of high risk factors for hearing loss. Unlike some studies (Martines, et al., 2013; Ohl, et al., 2009) that have used the JCIH recommended risk factors as inclusion criteria, the current study recorded all case history information and main medical diagnoses from participant files. Apart from the types of risk factors that predispose newborns and infants to hearing impairment, a number of studies investigating the correlation or relationship between types of risk factors and hearing impairment have also indicated a relationship between the number of risk factors and hearing impairment.

6.2.4. Hearing loss in relation to the number of risk factors

Martines and colleagues found that the probability of sensorineural hearing loss increased from 5.12% in infants with two risk factors to 28.5% in infants with five or more coexisting factors (Martines, et al., 2013). Results from another Polish study indicated that the rate of hearing impairment detected increased with the presence of more risk factors, with the highest rate detected in infants with six risk factors (Wrobel, Greczka, & Szyfter, 2014). These findings are further supported by earlier studies (Bielecki, Horbulewicz, & Wolan, 2011; Martines, et al., 2012; Ohl, et al., 2009; Onoda, de Azevedo, Miyashiro, & dos Santos, 2011) that also reported this relationship between the number of risk factors and hearing loss. Bielecki et al. (2011) reported a higher frequency of sensorineural hearing loss with three or four risk factors with the probability nearly doubling in the presence of five or more risk factors. Literature has clearly indicated correlations between the types of risk factors, the number of risk factors and sensorineural hearing loss. However, in order to accurately identify hearing loss in newborns and infants with risk factors, appropriate audiological screening and diagnostic protocols need to be employed within NHS programmes

6.3. Screening and assessment protocols for high-risk neonates

6.3.1 Audiological protocols within NHS programmes

Hearing screening protocols recommended for newborns and infants admitted to NICU for more than five days differ from those recommended for well-babies. Unlike well-babies, AABR has been included as part of the hearing screening of NICU babies. The rationale that NICU babies are at an increased risk for neural hearing loss (auditory neuropathy or auditory dyssynchrony) which may be missed without the inclusion of this electrophysiological measure (JCIH, 2008). A retrospective study was performed to investigate the prevalence and risk factors of auditory neuropathy in a population at risk for hearing loss. The study made use of OAEs, acoustic reflex measurements and ABR. Results indicated an auditory neuropathy prevalence of 5.1% in children diagnosed with sensorineural hearing loss. Fourteen of the eighteen children diagnosed with auditory neuropathy presented with risk factors which included prematurity, LBW, ototoxic medication and mechanical ventilation for longer than five days. Recommendations made by these authors (Bielecki, et al., 2012) include the use of tympanometry, OAEs and acoustic reflex testing for all infants following the first OAE *refer* results when screening is conducted in the neonatal unit. ABR testing is

also suggested to assist with diagnosis in instances where OAE results are normal but acoustic reflexes are absent.

Many of the studies reviewed have employed both screening and/or diagnostic OAE and ABR measurements when assessing hearing in newborns or infants with risk factors for hearing loss. However, there are variations to the structure of these protocols. Some studies (Bielecki, et al., 2011; Bielecki, et al., 2012) have used TEOAE screening followed by tympanometry, acoustic reflex testing and ABR assessment, whereas other studies (Ohl, et al., 2009) have employed a two-stage OAE screening followed by ABR assessment. Other literature has indicated the use of a two-stage AABR screening followed by diagnostic ABR assessment (Hille, et al., 2007); a two-stage AABR screening followed by diagnostic ABR, diagnostic TEAOEs and tympanometry (Coenraad, et al., 2010); or diagnostic ABR, TEOAE and tympanometry measurements on all infants with prenatal and perinatal risk factors for hearing loss as defined by the JCIH (Martines, et al., 2013). However, the use of these electrophysiological measures needs to be extended to audiological surveillance programmes of newborns and infants presenting with risk factors for hearing loss.

6.3.2 Risk-based surveillance programmes

Not all childhood hearing impairment will be detected during the newborn period (HPCSA, 2007; Walker et al., 2014). Hence, although NHS programmes are important for early detection of hearing impairment, monitoring of hearing during early childhood (particularly in children with known risk factors), post NHS is also important (Beswick, et al., 2013; HPCSA, 2007; Patel, et al., 2011). Initially, the JCIH recommended the monitoring of children who had *passed* the NHS but presented with one or more risk factors for hearing loss. This recommendation was then amended to the monitoring of all infants with and without risk factors for hearing loss (JCIH, 2007) to assist with the detection of delayed-onset or progressive hearing loss.

6.3.3 Audiological assessments in risk-based surveillance programmes

The initial recommendation by the JCIH was to ensure follow-up audiological assessments every six months until three years of age. However, this was felt to place a great burden on audiologists, the system, and families, and may be economically unfeasible in developed contexts (JCIH, 2008; Núñez-Batalla, et al., 2012). Hence, this recommendation for follow-

up assessments was subsequently changed to at least one audiological assessment at 24-30 months for infants considered to be "low risk" (those that have *passed* the NHS but have a risk factor). More frequent assessments have been recommended by the JCIH (2007; 2008) for infants with risk factors that are known to be associated with late onset or progressive hearing loss such as cytomegalovirus or family history of hearing loss.

The age at which these hearing re-evaluations are conducted and the number of these audiological evaluations for infants with risk factors should be decided based on the likelihood of delayed-onset hearing loss with each infant (JCIH, 2007). These recommendations for surveillance have been implemented differently in different countries. The NHS programme in England has implemented targeted surveillance around the age of eight months corrected age for babies who *passed* the NHS but presented with only one or more of five specific risk factors for hearing loss. These risk factors include syndromes (other than Down's Syndrome) associated with hearing loss; NICU with bilateral OAE *refer* results and bilateral AABR *pass* results; craniofacial anomalies; Down's syndrome; and congenital infection (Wood, Davis, & Sutton, 2013). In comparison, in the Queensland Health Hearing Programme, infants with infection are first assessed at three months followed by six monthly visits until two years of age. Children with a family history of hearing loss undergo a first assessment post NHS at six months of age followed by six monthly assessments until two years of age, and a discharge assessment at three years of age. The assessment time frames for infants with any of the other risk factors consist of a single assessment between nine to twelve months of age followed by another assessment at three and half years if ear specific information could not previously be obtained (Beswick, et al., 2013). The types of audiological measures used at these follow-up assessments also vary (depending on the child's age and developmental level) and include tympanometry, visual reinforcement audiometry (VRA), TEOAEs, DPOAEs and play audiometry (Beswick, et al., 2013)

However, due to limited available resources and the health care context in South Africa, recommendations in the HPCSA (2007) position statement differ to that stipulated by the JCIH. The HPCSA (2007) position statement recommends that all infants with risk factors be monitored by their caregivers for communicative development after being informed by trained personnel.

Chapter summary

This chapter has lucidly highlighted that the choice of NHS programme is dependent on what is feasible for each context, with risk-based NHS proving to be a successful starting point in some developing countries. This chapter expanded on risk-based hearing screening through discussion of the various aspects that need to be considered when implementing such an approach to NHS. Literature has highlighted differences in risk factors between developed and developing contexts as well as within each of these contexts. This speaks to possible differences in health care and burden of disease in each of these contexts, and suggests the need for evidence-based and context specific HRR for hearing loss. The use of appropriate audiological screening and diagnostic measures are also important in ensuring accurate diagnosis of hearing loss in newborns and infants with high risk factors for hearing loss. AABR and ABR are required for the diagnosis of auditory neuropathy which is considered prevalent in this high-risk population. The implementation of risk-based surveillance programmes is also deemed important to ensure detection of progressive or late-onset hearing loss associated with some of the stipulated risk factors. The next chapter discusses the methodological aspects that were employed in the current study which aimed to explore risk-based/TNHS in a hospital context in South Africa

CHAPTER 7: METHODOLOGY

This chapter provides a description of the research context, the adopted research design, sampling methods and research process followed. Data analysis methods are described and data collection procedures are presented and discussed in relation to reliability and validity. The chapter ends with a discussion of ethical considerations that were considered and carefully adhered to during the current study.

7.1. Aims of the Study

7.1.1 Primary Objective

The main aim of the current study was to explore risk-based hearing screening within a developing country context through early detection of hearing loss in high-risk neonates, within an academic hospital complex in Gauteng, South Africa.

7.1.2 Secondary Objectives

The specific objectives of this research were to:

- Describe the case history factors in a group of high-risk neonates.
- Describe the audiological function in a group of high risk neonates.
- Determine the relationship between the case history factors and audiological function in high-risk neonates.
- Establish which combinations of audiological screening measures provide both TP and TN results for risk-based screening, at and across time.
- Establish the percentage of TP and TN screening results in the total sample.
- Explore the factors associated with follow-up return rate for hearing screening and diagnostic audiological assessment.

7.2. Research Question

What are the outcomes of a risk-based NHS protocol for early detection of hearing loss at hospitals within an academic complex in in Gauteng, South Africa?

7.3. Research Design

The current study adopted a developmental research strategy (Schiavetti & Metz, 2006), as audiological function was measured across different time periods within a group of high-risk neonates. A descriptive, longitudinal, repeated measures, within-subjects design was employed (Schiavetti & Metz, 2006). This design was deemed appropriate as the research aimed to describe the audiological function and case history factors in a group of high risk neonates as well as determine the relationship between case history factors and audiological findings in the same group of participants over time. The research also used the same hearing screening measures on the same group of participants over time. Descriptive research is used to determine group differences, developmental trends or relationships among variables and is appropriate when there is no manipulation of variables or conditions (Schiavetti & Metz, 2006). Longitudinal research designs involve following participants over time as they age, and noting changes during this time. Although longitudinal research designs are time-consuming, expensive and more susceptible to attrition (with the additional possibility of differences between those that drop out and remain in the study), they can be used to directly observe development (Jackson, 2009; Schiavetti & Metz, 2006). Within- subjects designs involve the comparison of performance within the same group of participants in different conditions and are usually associated with longitudinal, developmental studies (Schiavetti & Metz, 2006).

7.4. Research Contexts

The current study was conducted at two hospitals which are part of an academic complex linked to the University of the Witwatersrand. The first hospital Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) is an accredited, central hospital that serves patients across the Gauteng province as well as neighbouring provinces. The hospital offers a full range of tertiary, secondary and highly specialized services and serves as a referral hospital for a number of hospitals in its referral chain. In-patient and outpatient services are offered to regional and district level hospitals. It is also a main teaching hospital for the faculty of Health Sciences at the University of the Witwatersrand and provides services for undergraduate and post graduate training for health professionals (No Author, 2011).

The second hospital Rahima Moosa Mother and Child Hospital (RMMCH) is a teaching hospital with a neonatal unit, NICU, premature unit and KMC programme. There are

approximately just under 2000 babies admitted to the neonatal units per year, most of whom are premature. There are a number of specialist, follow-up clinics at the hospital, one of them being the neonatal follow-up (NNFU) clinic (Wits Paediatric Fund, 2008).

The study was conducted at both these hospitals within an academic complex as both have an NICU, high care/premature unit and KMC wards. There is also a speech pathology and audiology department at both these sites which allowed for appropriate referral of participants within the research study. NNFU clinics are also offered by both hospitals, and these involve follow-up by neonatologists. At CMJAH, the NNFU clinic further includes assessments by speech-language therapists and audiologists, physiotherapists and occupational therapists. Both hospitals serve patients from across the Gauteng province as well as patients referred from neighbouring provinces which resulted in a more representative sample for the research study.

During the period of initiation of the current study, risk-based hearing screening was being conducted at CMJAH, with the only target population being babies in the KMC ward. NHS was performed by two audiologists or speech-language therapists once weekly (J. Jogianna, personal communication, July 3, 2012). The NHS protocol involved DPOAE screening in hospital, followed by a DPOAE screening and AABR at three months corrected age at the Audiology department following discharge from hospital. NHS at RMMCH was being conducted on a referral basis from paediatricians and neonatologists and was not routinely conducted. Prior to the commencement of the current study, a UNHS feasibility study was conducted by a paediatrician at RMMCH (with screening having been conducted by the audiologists employed at the hospital). Results of this feasibility study indicated that UNHS was not feasible at this site (J. Bezuidenhout, personal communication, August 10, 2012).

7.5. Description of Participants

7.5.1 Sampling

A non-probability, purposive sampling method was utilized as the sample was characteristic and representative of high-risk neonates. Purposive sampling involves the selection of participants based on their characteristics in order for the sample to be representative of its population (de Vos, Strydom, Fouche, & Delport, 2005; Maxwell & Satake, 2006). The AAP classifies high risk infants into four categories, namely, the preterm infant; the infant with special health care needs or dependence on technology; the infant at risk because of family

issues; and the infant with anticipated early death (AAP, 2008). Yee and Ross (2006) report the term 'high-risk infants' to include infants with significant congenital anomalies or disease processes undergoing complex intervention and indicate that the definition is heterogeneous. Although there is no defined profile of high risk neonates within the South African context, an unpublished study in 2007 documented the condition of babies transferred to NICU, high care ward or neonatal admission units at three academic hospitals in Johannesburg for further medical management. This study's findings indicated that over two thirds of all infants included were preterm with a gestational age of between 28-32 weeks and majority (73%), and were of LBW (weighing less than 2500 grams) (Thawala, 2007). Hence, for the purposes of the current study, the sample was considered representative if the majority of participants were preterm with a LBW and/or requiring special health care needs within the high care ward, NICU or other neonatal admission wards such as KMC.

7.5.2 The Sample

The sample consisted of 325 high-risk neonates who were discharged from the NICU and high care wards to wards 184 and 185 at CMJAH and wards 16b and 16c at RMMCH.

7.5.3 Inclusion/Exclusion Criteria

Neonates admitted to the NICU or high care wards (after birth) and transferred to wards 184 and 185 or wards 16b and 16c, for whom consent was obtained from the caregiver were included in the study. Neonates who were previously discharged, returned home and were readmitted to any of the wards were not enrolled in the study at the time of initial, in-hospital hearing screening. These neonates were not enrolled as the aim of the current study was to ensure that initial hearing screening was conducted before initial discharge from hospital. In addition, babies requiring readmission were admitted to other general paediatric wards in the hospital, and not those included in the current research.

7.5.4 Participant Recruitment

Participants were recruited from neonatal wards 184 and 185 at CMJAH and wards 16b and 16c at RMMCH. Babies in these wards were discharged from the NICU or high care wards and were medically stable. It was noted at both research sites that all babies from the KMC wards were routinely booked for NNFU by the nursing staff as per recommendations by the

consultant paediatricians. However, only certain babies from the high care wards were booked for NNFU clinic as some were referred to the local clinics only.

After obtaining the necessary permission to conduct the study, consultant paediatricians and nursing staff from the respective wards were informed about the study. Consultant paediatricians provided the researcher with details of babies from the high care wards that they thought were high-risk, medically stable and were to be followed up at the NNFU clinic. Nursing staff in the KMC wards provided the researcher with a new list of babies who had been transferred to the ward. This was done twice weekly on days of data collection. The researcher discussed the study with groups of caregivers present in the respective wards, explaining the aim, methods and time frame for their babies to be employed in the study. Caregivers who were interested in volunteering for their babies to be enrolled in the study indicated this to the researcher.

7.6. Test Protocol

7.6.1 Research Process

The current study was submitted for ethical review to the University of the Witwatersrand Human Research Ethics Committee (Medical). Once ethical clearance was obtained (protocol number: M1211103) (Appendix A), permission was obtained from relevant authorities at the research sites (Appendix B, Appendix C, Appendix D and Appendix E). Thereafter, a pilot study was conducted following approval from the Medical Ethics Research Committee as well as permission from relevant authorities.

The aims of the pilot study were to:

- Determine the average time required to screen each neonate or infant
- Determine the most suitable time for the initial hearing screening in the wards
- Determine the ambient noise levels in the wards and the NNFU clinic

The first aim of the study assisted in approximating the average time taken to conduct the hearing screening. For the current pilot study, this information was also required to be able to be included in the informed consent sheet provided to caregivers when inviting them to participate in the study. The second aim of the study was to ensure that the hearing screening did not disrupt other nursing duties and/ or ward rounds that caregivers needed to be present

for. Determining the appropriate time for hearing screening also informed the researcher as to possible times at which caregivers would be present in the wards for informed consent purposes. This information is crucial for a screening programme that will be sustainably implemented, one that will adhere to ethical practice of acquiring informed consent from caregivers, and one that would allow for efficient information counselling when caregivers are present. Furthermore, identifying suitable times for screening has implications for highlighting unsuitable times which might render the screening programme unreliable, invalid, and unsustainable – variables that were of particular relevance in the current context. The third aim of the pilot study was to ensure that the ambient noise levels did not exceed those suggested in literature. Measurement of the ambient noise levels in the screening environments also allowed the researcher to make any adaptations to minimize these noise levels which enhanced the reliability and validity of hearing screening results.

The pilot study differed at each of the research sites. CMJAH was the initial site at which the pilot study was conducted and included ten participants who underwent an initial hearing screening. These participants were subsequently booked for a follow-up hearing screening at the NNFU clinic. Ambient noise levels were also measured in the respective wards from which participants were recruited as well as at the NNFU clinic. The researcher also liaised with relevant personnel such as the nursing sisters in charge of the respective wards and clinic, as well as administrative staff responsible for the booking of patients. The average time required to screen each neonate or infant was established by recording the time taken to screen using all three screening measures. These times were available when downloading the data from the screening equipment and were recorded by subtracting the starting time from the time of completion. These recordings were then added and divided by the number of screening sessions in the study.

The pilot study at RMMCH primarily consisted of discussion with consultant paediatricians and/or neonatologists as well as the head of the Speech Pathology and Audiology department. These discussions provided the researcher with sufficient detail regarding the process of admissions to various wards, functions of the wards from which participants would be recruited, as well as access to a suitable area for the repeat hearing screening. In addition, the pilot study at this research site consisted of two site visits which involved measuring of ambient noise levels as well as liaison with administrative and nursing staff in the respective wards and the NNFU clinic.

Phase 1 of the pilot study (initial hearing screening) at CMJAH commenced on 10th May 2013 and was completed on 17th May 2013. Screening was conducted every afternoon (except for the Wednesday) between 12:30 and 16:00. Phase 2 of the pilot study (repeat hearing screening) was conducted between 11th June 2013 and 16th July 2013.

TEOAE screening was conducted (frequency range of 1.5- 4.5 kHz). This was followed by DPOAE screening that was conducted using the most comprehensive protocol on the machine (i.e. 1000, 2000, 3000, 4000, 5000 and 6000 Hz) with a 4/6 frequency *pass* criterion. All frequencies were tested unlike other protocols where testing is automatically discontinued based on the number of frequencies that *pass* or *refer* according to set criteria. AABR screening was conducted at the default level of 35 decibels above normal hearing level (dBnHL) using high forehead, cheek and nape of the neck electrode placements.

Following completion of the initial hearing screening, results were explained to caregivers, and follow-up appointments for NNFU clinic were made for approximately 6 weeks.

Following completion of the pilot study, appropriate amendments to the study design and research tools were made. The main study commenced in May 2013 and ended in October 2015. Following data collection, data was captured and analysed (Figure 1).



Figure 1: Research Processes for the Current Study

7.6.2 Measures/ Materials

- TEOAE, DPOAE and AABR screening using the AccuScreen.
- OTOflex 100 screening tympanometer with a 1000Hz probe tone
- Interacoustics AC-40 diagnostic audiometer
- GSI Audera for diagnostic ABR testing
- Necessary hygiene and infection control solutions
- Necessary nubs and inserts for conducting screening and diagnostic measures
- Recording forms to record case history factors and screening results (Appendix F, Appendix G and Appendix H).

7.6.3 Data Collection Procedures

Data collection methods adopted in the current study included:

- A detailed review of medical charts at the initial hearing screening.
- Pre and post-screening counselling where sharing of information with caregivers regarding the purpose of NHS, the importance of NHS, as well as the screening outcome and recommendations was done.
- TEOAE, DPOAE and AABR screening at two different intervals or time periods, with the first being prior to discharge, and the second, six weeks post discharge (at the NNFU clinic) (Figure 2).

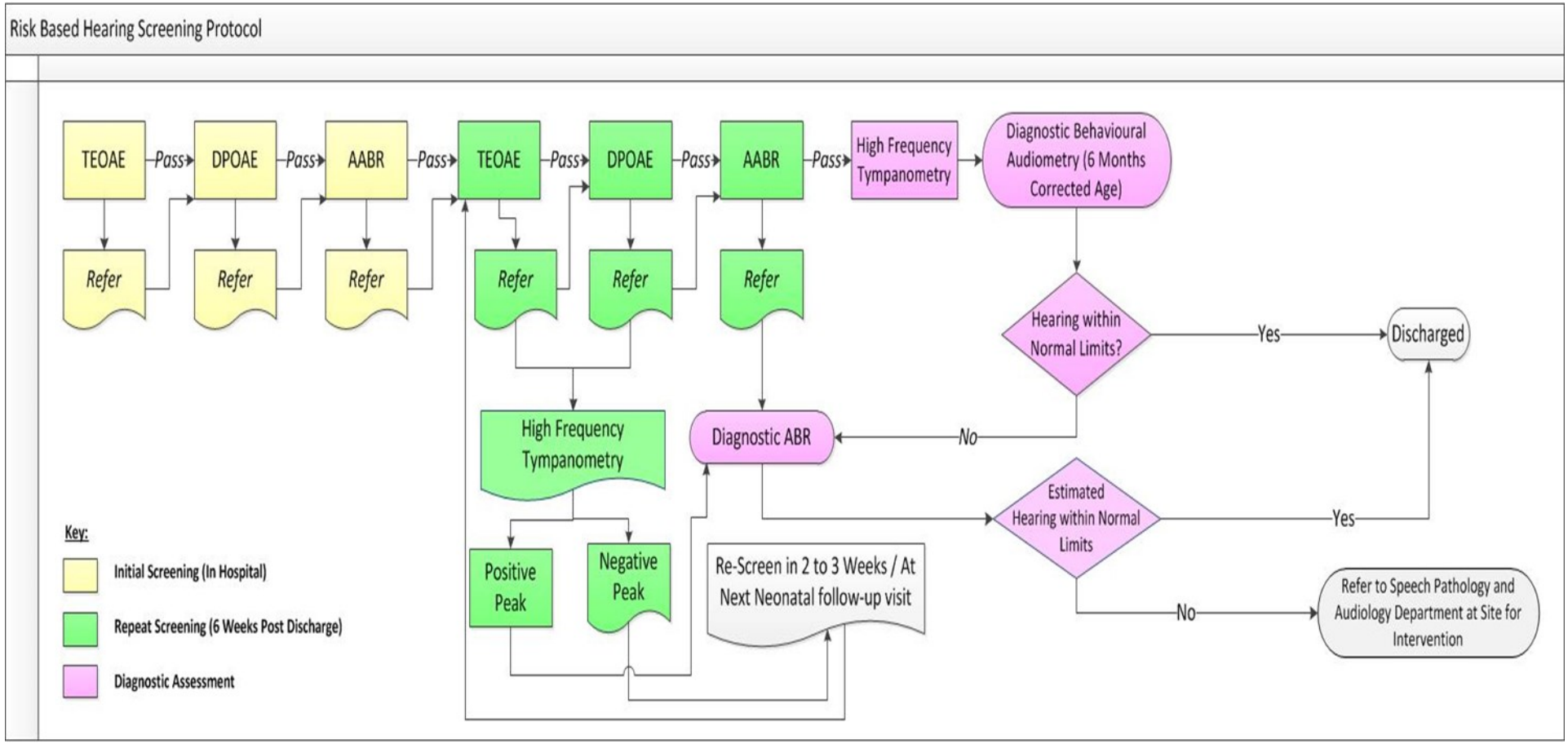

Figure 2: Risk-based hearing screening protocol for the current study

Specifications for each of the screening measures are outlined in Table 8. *Pass/ Refer* criteria were based on manufacturer settings as most automated screening equipment have internal computerized systems for what constitutes a *pass* or *refer* at each frequency (Michigan Association for Deaf, Hearing and Speech Services- MADHS, No Year). Overall, standard *pass/ refer* criteria for DPOAE screening have not been specified by literature. Earlier studies using DPOAE measures have indicated varying overall *pass/ refer* criteria with some literature defining an overall *pass* criteria as a *pass* result at four out of five frequencies screened (Swanepoel, et al.2006), and other literature defining it as a *pass* at two frequency bands (Hatzopoulos, et al., 2007). For the purposes of the current study an overall DPOAE *pass* for each ear was determined by a *pass* result for four or more of the frequencies screened (1-6kHz). The level used for AABR was 35dBnHL which was the lowest possible intensity level on the screening equipment (Table 8).

Table 8: Specifications for screening measures

Screening Measure	Specifications
TEOAE	Stimulus level: 70-84 decibel sound pressure level (dBSPL) (45-60dBHL) Frequency range: 1.5-4.5kHz This screening measure required a total of at least 8 registered, valid peaks in alternating directions (both above and below the median line), in the temporal waveform of the emissions in order or a *pass* result to be obtained
DPOAE	Stimulus levels: L1/L2 60/50 dBSPL Frequencies: 1, 2, 3, 4, 5, 6 kHz *Pass/Refer* criterion: *'Pass'* result at 4/6 frequencies
AABR	Stimulus level: 35dBnHL Stimulus type: broadband, 2-4kHz Electrode placement: nape of neck, high forehead, cheek Impedance test indicators: Good (< 4kΩ) Fair (4 to 12 kΩ) Poor (> 12 kΩ) Impedance balance indicators (difference between high forehead and nape of neck): Good (0 to 2 kΩ) Fair (2 to 4 kΩ) Poor (> 4 kΩ)

- High frequency tympanometry was performed at six weeks post discharge, on the same day as the repeat hearing screening (if a *refer* result was obtained from OAEs with a *pass* from AABR) and at the diagnostic behavioural audiometry session at six months corrected age. This strategy was adopted because evidence exists which indicates that in comparison to newborn infants, six week old infants have a more mature auditory system with a larger ear canal (Mazlan, Kei, Hickson, Gavranich, & Linning, 2010).

- Diagnostic ABR (conducted under natural sleep) was conducted if a *refer* result was obtained from both screening intervals, the repeat hearing screening or from the rescreening for both OAEs and AABR or AABR only. Diagnostic ABR consisted of a two-channel, bilateral neurological click ABR using a stimulus rate of 11.1/s at 80dBnHL (Table 9). If waves I, III and V were visible at normal latencies and had normal amplitudes; a one-channel, bilateral audiological click ABR using a stimulus rate of 33.1/s (Table 10) and a one-channel, bilateral tone burst ABR at 500Hz and/or 1000Hz using a stimulus rate of 39.09/s was conducted. Using click stimuli along with, but prior to tone burst stimuli provides multiple diagnostic results without increasing test time (Hall & Swanepoel, 2010). If there were delayed absolute wave latencies and the amplitudes were reduced, a tone burst ABR was conducted at 500, 1000, 2000 and 4000Hz. (Hall, 2007; Hall & Swanepoel, 2010). Stimulus intensity levels were decreased in 20dB steps and increased in 5-10 dB steps (Table 11). This was conducted as a means of minimizing test time without sacrificing the quality of the data obtained (Hall & Swanepoel, 2010). The criterion for estimated hearing within normal limits was the presence of wave V at a stimulus intensity of 20dBnHL (Can, Verim, Başer, & İnan, 2015). If a clear neurological ABR was not obtained at an increased intensity level (90dBnHL), an ASSR was conducted to establish estimated hearing thresholds (Hall, 2007; Hall & Swanepoel, 2010).

  Neurological click ABR tracings were analysed using normative data by Hall and Mueller (1997) for neonates and for children aged three months to three years.

Table 9: Stimulus and Acquisition Parameters for Neurological click ABR

Parameter	Stimulus/Acquisition Parameter used	Rationale
Transducer	Insert earphones	Assists with reduction of ambient noise during ABR measurement Minimizes ear canal collapse which is a concern with infant ear canals Accurate and consistent sound delivery in small infant ear canals (Hall & Swanepoel, 2010)
Stimulus type	100 us click	Click stimuli are considered necessary for neurodiagnostic ABR (Hall & Swanepoel, 2010)
Stimulus rate	11.1/s	A slower rate is required to enhance the response for neurodiagnostic ABR (Hall, 2007)
Stimulus polarity	Rarefaction	Provides larger amplitudes and shorter latencies in comparison to other polarities (Hall, 2007) Most appropriate for activating the cochlea and auditory pathways (Hall & Swanepoel, 2010)
Stimulus level	80 dBnHL	A high intensity is used for neurodiagnosis (Hall, 2007)

Electrodes	Non inverting: High forehead (Fz) Ground: Low forehead (Fpz) Inverting: Earlobes (A1 & A2)	A high forehead site is preferred over the vertex, and the low forehead is convenient for the common or ground electrode (Hall, 2007). Earlobe placement provides a larger wave I amplitude than mastoid placement and reduces postauricular muscle artefact (Hall & Swanepoel, 2010)
Total sweeps	± 1058	A greater number of sweeps are required when noise is greater, for example in restless, unsedated infants or children (Hall & Swanepoel, 2010)
Filter settings	High band pass filter: 150Hz @ -6dB 12dB/oct RC Low pass filter: 3kHz linear phase >40dB/oct	Low frequency energy may not be important for the accurate interpretation of neurodiagnostic ABR (Hall, 2007)
Sensitivity	50 µV	
Noise rejection level	25 µV	

Table 10: Stimulus and Acquisition Parameters for Audiological click ABR

Parameter	Stimulus/Acquisition Parameter used	Rationale
Transducer	Insert earphones	
Stimulus type	100 us Click	
Stimulus rate	33.1/s	For threshold estimation, higher stimulus rates allow for collection of larger amounts of data within a shorter test time (Hall, 2007)
Stimulus polarity	Rarefaction	
Stimulus level	80 dBnHL with 20 dB decrements and 5-10 dB increments	To minimize test time without compromising the quality of data (Hall & Swanepoel, 2010)
Electrodes	Non inverting: High forehead (Fz) Inverting: Earlobes (A1 & A2)	
Total sweeps	± 1054	
Filter settings	High band pass filter: 30Hz @ -6dB 12dB/oct RC Low pass filter: 1.5kHz linear phase >40dB/oct	Low frequencies contribute to the ABR and are important for the detection of ABR in infants (Hall, 2007)
Sensitivity	50 µV	
Noise rejection level	25 µV	

Table 11: Stimulus and Acquisition Parameters for Audiological Tone Burst ABR

Parameter	Stimulus/Acquisition Parameter used	Rationale
Transducer	Insert earphones	
Stimulus type	Blackman Pip 2-1-2 cycles	Blackman windowing is considered the best for tone burst ABR (Hall & Swanepoel, 2010)
Stimulus rate	39.09/s	
Stimulus polarity	Rarefaction	
Stimulus level	80 dBnHL with 20 dB decrements and 5-10 dB increments	
Electrodes	Non inverting: High forehead (Fz) Inverting: Earlobes (A1 & A2)	
Total sweeps	± 1054	
Filter settings	High band pass filter: 30Hz @ -6dB 12dB/oct RC Low pass filter: 1.5kHz linear phase >40dB/oct	
Sensitivity	50 µV	
Noise rejection level	25 µV	

- Diagnostic, behavioural audiometry at six months corrected age was done for all neonates with a *pass* screening outcome. VRA has been the recommended gold standard for determining NHS test performance from six months corrected age (JCIH, 2000). This was conducted in the current study to ensure the inclusion of risk-based surveillance for late or delayed-onset hearing impairment. Although some well-established programmes in

developed contexts involve audiological monitoring every six months until two years of age (Beswick, et al., 2013) , the protocol in the current study adopted the recommendations made in the clarification to the JCIH 2007 position statement (JCIH, 2008). Due to the burden placed on audiologists for six monthly audiological follow-up assessments, the responsibility for surveillance of all infants was shifted to the primary care provider who is expected to refer to the audiologist if a concern regarding hearing loss arises (JCIH, 2008). This recommendation appeared to be in line with the context of the current study as follow-up screening at the research sites were conducted at NNFU clinics. These clinics include paediatricians who conduct regular follow-up of these high-risk babies until two years of age. Hence, if any hearing loss was to be suspected following the six month audiological assessment, these babies would be referred by paediatricians. Corrected age was used for premature babies to ensure that misdiagnosis and over referral was avoided and to account for any transient delays (Wilson & Cradock, 2004). Literature also suggests that infants born prematurely and who have spent time in the NICU tend to perform better if testing is delayed until six to eight months corrected age (Moore, Thompson, & Folsom, 1992; Widen, 1990). This was also to ensure that appropriate test protocols and normative data were used.

- Adequate follow up return rate was facilitated by reminding caregivers of the scheduled appointments as well as contacting caregivers who had not attended the repeat hearing screening and/or diagnostic evaluation. Reasons for not having attended the follow-up sessions were recorded when contacting the caregiver telephonically. Patients were provided with funding toward transport costs to assist in ensuring an adequate follow-up return rate. Transport money was only provided for the diagnostic evaluation as the initial screening consisted of an in-patient screening and the repeat hearing screening was aligned with the NNFU clinic visit. It is however acknowledged that transport costs may not have been the only contributor to default rates as infant mortality, adoption and moving to a different place of residence may also be some of the contributing factors within the South African context.

7.7 Data Analysis

Following consultation with statisticians, data from the current study were analysed. Descriptive statistics were used to describe the case history factors, audiological function, the percentage of TP and TN screening results, and the factors associated with follow-up return rate. Categorical variables were summarised by frequency and percentage tabulation, and

illustrated by means of bar charts. Continuous variables were summarised by the mean, standard deviation (sd), median and interquartile range (IQR), and their distribution illustrated by means of histograms (Howell, 2002).

The association between specific case history factors (all categorical) and hearing screening outcome (overall and for each screening measure) was determined using the chi-squared (X^2) test or Fisher's exact test. Fisher's exact test was used for 2 x 2 contingency tables or where the requirements for the chi-squared test could not be met (Woodward, 2013).

To establish which combinations of tests had the best specificity (% TN); screening outcomes were compared to diagnostic audiological outcome. The participant was classified as presenting with an overall *refer* if the outcome for any one test was *refer*. Proportions were compared by the z-test for proportions, with critical p-values adjusted (to 0.040) for multiple comparisons. The overall screening outcomes (at the initial hearing screening and repeat hearing screening) for different test combinations were compared using McNemar's test for paired data. Proportions across different test combinations were compared by the z-test for proportions, with critical p-values adjusted (to 0.044) for multiple comparisons (Agresti & Kateri, 2011).

Comparison of the mean time per test (taken as the average over the two ears) for different screening measures (or combinations of measures) was carried out as an additional analysis. This was analysed using the paired t-test or one-way repeated measures ANOVA for more than two groups. The test times were log-transformed to meet the assumptions of the tests (Verbeke & Molenberghs, 2009).

The association between maternal case history factors and whether or not participants returned for follow-up assessments was determined by the chi-squared test for categorical variables and the independent samples t-test for continuous variables. Fisher's exact test was used for 2 x 2 contingency tables or where the requirements for the chi-squared test could not be met. Where the data did not meet the assumptions of these t-tests, a non-parametric alternative, the Wilcoxon rank sum test was used (Woodward, 2013).

The strength of the associations for the chi-squared and Fisher's exact tests was measured by Cramer's V and the phi coefficient respectively. A value of 0.50 and above was interpreted as a strong association whereas values between 0.30 to 0.49 and 0.10 to 0.29 were interpreted as a moderate association and weak association respectively (Woodward, 2013).

The strength of the associations for the independent samples t-test and the Wilcoxon rank sum test was measured by Cohen's d and the r-value respectively. Values of 0.80 and above were interpreted as having a large effect, while values between 0.50 and 0.79 were interpreted as having a moderate effect. Values between 0.20 and 0.49 were interpreted as having a small effect (Woodward, 2013).

The 5% level of significance was used throughout the data analysis ($p < 0.05$).

7.8 Validity and Reliability

Reliability refers to the consistency of a measurement and the degree to which one can depend on the measurement; as well as the general trustworthiness of the data obtained from the measurements used. Validity refers to the accuracy of the measurement and is a necessary precursor to reliability (Schiavetti & Metz, 2006).

In audiology, reliability and validity are defined in relation to the audiological measures used for assessment. Roeser, Valente and Hosford-Dunn (2007) define reliability as the consistency of a measure when repeated at different times, either by the same examiner or a different examiner. Validity on the other hand is defined as the ability of the audiological measure to identify the disorder that it was designed to detect. A measure is therefore considered valid if it identifies the majority of individuals with a specified disorder (high sensitivity) and excludes those without the specified disorder (high specificity) (McPherson & Olusanya, 2008). Roeser et al. (2007) highlight that test reliability can be controlled and maintained by careful consideration and attention to a number of procedures. These procedures include the standardisation of test administration, ensuring proper equipment calibration and controlling of patient related variables (Roeser, et al., 2007). The researcher ensured that these procedures were considered and implemented for the purposes of the current study.

Calibration is key to ensuring accurate results and involves verifying that the specified equipment produces the appropriate signal, that this signal is only present in the transducer and that it is free from unwanted distortion and noise. It is therefore the responsibility of the user to either check the calibration personally or arrange for regular calibration by an outside service (Wilber, 2002). The researcher ensured that annual calibration of equipment was conducted by relevant personnel during data collection. Weekly probe and electrode checks were also conducted by the researcher on the screening device.

The current study employed the use of objective screening measures (OAEs and AABR) within a repeated measures design. The use of these objective measures assists in eliminating the limitations associated with a repeated measures design which include practice effects, sensitisation and carry-over effects (Miles & Banyard, 2007). Standardization of test administration was ensured by using standardized *pass/ refer* criteria for screening TEOAE, DPOAE and AABR measurements. Threats to inter-tester reliability were minimized by ensuring that the same audiologist conducted both screening and diagnostic measures. Validity was also ensured within the test protocol through the appropriate use and timing of measures.

Test performance has been reported to be better when screening is conducted two days or later after birth (Hergils, 2007) as the referral rate is much higher when screening is conducted within 24 hours after birth (da Mata Lupoli, et al., 2013). The researcher therefore ensured that the initial hearing screening was not conducted before 48 hours after birth to minimize the influence of vernix on OAE results (Olusanya & Bamigboye, 2010). The use of 1000Hz probe tone for tympanometry is considered appropriate for infants below six months corrected age (Baldwin, et al., 2008). This assisted in improving the validity of results obtained since the presence of middle ear effusion is known to influence hearing screening results (Boone, Bower, & Martin, 2005).

During both screening and diagnostic measures, careful consideration was paid to patient related factors and the test environment that may influence the reliability of the results obtained. Martin and Clark (2009) highlight that certain requirements such as a tightly fitting probe and a quiet test environment should be met when conducting NHS. The researcher avoided holding the probe during testing to prevent it from touching the ear canal wall and causing interference with the signal (Olusanya, 2010). The researcher also conducted screening with the baby swaddled or in the KMC position to facilitate a calm state, with minimal movement and restlessness which could result in the probe slipping out during screening (Olusanya, 2010). With regard to TEOAE screening, the researcher ensured that the artifact value did not exceed 20%, and that the stimulus stability was 80% or greater as stipulated in the Accuscreen manual. The influence of environmental factors such as ambient noise levels could influence the validity of the screening results (as FP results may be obtained) as well as the time taken to obtain accurate results. Accurate OAE screening results have been demonstrated when background or ambient noise levels do not exceed 65 to 68 dB

A (Olusanya, 2010; Salina, et al., 2010). Sound levels were measured during screening to ensure that ambient noise did not exceed the levels stipulated in literature.

Additional consideration was made to the recording of case history information as it sheds light on the possible factors that may contribute to a hearing disorder (Stach, 2010) . Recording of all necessary case history factors was particularly important for the current study as it aimed to describe the case history factors in a group of high-risk neonates and determine the relationship between the case history factors and audiological function in high-risk neonates. "Patients may understand and assimilate different types of information with various degrees of accuracy and levels of retention" (Yee & Ross, 2006, p. 292). Panacek (2007) states that limited recollection of events by caregivers may result in recall bias, influencing the reliability of information obtained. Hence, reliability of all case history information was ensured by obtaining information related to birth and medical history from medical charts instead of caregiver reports. Demographic information including family history of hearing loss was obtained directly from caregivers. Reliability was further ensured by recording any additional medical history between screenings and/or diagnostic evaluations.

7.9 Ethical Considerations

The ethical practices undertaken in this study were guided by the World Medical Association (WMA) Declaration of Helsinki's statement of ethical principles for medical research involving human subjects (WMA, 2013).

Ethical clearance was obtained from the University of the Witwatersrand Medical Ethics Committee and permission was also obtained from relevant authorities at the research sites where the study was conducted.

Caregivers were provided with information about the study. The information was provided both verbally and in written format (Appendix I and Appendix J) and included an explanation of NHS, what the testing involved as well as a description of the study. Caregivers were asked to volunteer for their babies to be part of the study. Once caregivers of participants agreed to participate in the study, the informed consent form was signed by both the caregiver and researcher (Appendix I and Appendix J). The researcher assured caregivers that they had the right to withdraw their baby from the study at any time without any negative consequences and that confidentiality would be maintained. In instances where the caregiver

was a minor but volunteered to participate in the study, a trusted adult nominated by the minor was also contacted and provided with an information sheet (Human Sciences Research Council- HSRC, 2012). In the current study, this was often the father of the participant who was above the age of 18 years or the grandparent of the participant. The current research was anchored around the ethical principles of confidentiality, anonymity as well as beneficence and non-maleficence.

The researcher conformed to the following ethical principles (Babbie, 2008 ; CIOMS, 2002; WMA, 2012):

Confidentiality and Anonymity: Participant codes were used instead of participant names.
Autonomy: Caregivers of participants were allowed to withdraw from the study at any time; without any negative consequences.
Beneficence and Non-maleficence: Participants who did not *pass* the screening underwent diagnostic evaluation, and those who *passed* the screening measures underwent behavioural audiological assessment at six months corrected age to ensure that effective monitoring of these participants. This also assisted in accounting for possible late onset hearing loss. Participants presenting with tympanograms indicating possible middle ear pathology were rescreened within three weeks of this result, and if still unresolved, were referred to the neonatologist, paediatrician or ENT for management. Arrangements were made with the Speech Pathology and Audiology departments at the respective sites for referral of participants identified with a sensorineural hearing loss following diagnostic evaluation, for appropriate management and intervention.

Chapter Summary

The current study was conducted at two hospitals within an academic hospital complex in Gauteng, South Africa. Participants comprised of high risk neonates who underwent an initial hearing screening, repeat hearing screening and in some instances, a rescreening. Diagnostic assessments were also conducted. The hearing screening was conducted using DPOAE, TEOAE and AABR whilst diagnostic assessments consisted of ABR or VRA depending on the hearing screening outcome. A descriptive, longitudinal, repeated measures, within-subjects design was employed to explore risk-based hearing screening within a developing country context.

CHAPTER 8: RESULTS

This chapter presents the findings from the study, commencing with those from the pilot study and followed by the results from the main study. The main study results are presented in accordance with the respective secondary objectives with a discussion of the findings presented in the next chapter.

A pilot study was conducted in order to determine the most feasible manner in which to proceed with data collection for the main study. Conducting a pilot study was particularly important for the current study as there are multiple factors that influence the implementation of a NHS programme within a public sector hospital. These factors include the hearing screening environment; liaising with relevant personnel; understanding routine care of the newborn or infant in the ward; administrative considerations such as booking of appointments for follow-up appointments and the overall logistics related to the weekly specialist or NNFU clinics.

Although it is more usual to define 'N' for a population and 'n' for a sample, for the purposes of the current study; 'N' represents the total sample whereas 'n' represents some of the sample and/or the final sample.

8.1. Pilot Study Results

8.1.1 Hearing screening outcomes

A total number of 15 babies were discharged or being queried for discharge during the pilot study period. Of these 15 babies, 11 caregivers provided consent, three caregivers did not volunteer to participate and one baby was discharged before the initial hearing screening could be conducted. All 11 participants were booked for a follow-up hearing screening on the same day as their NNFU six weeks after discharge.

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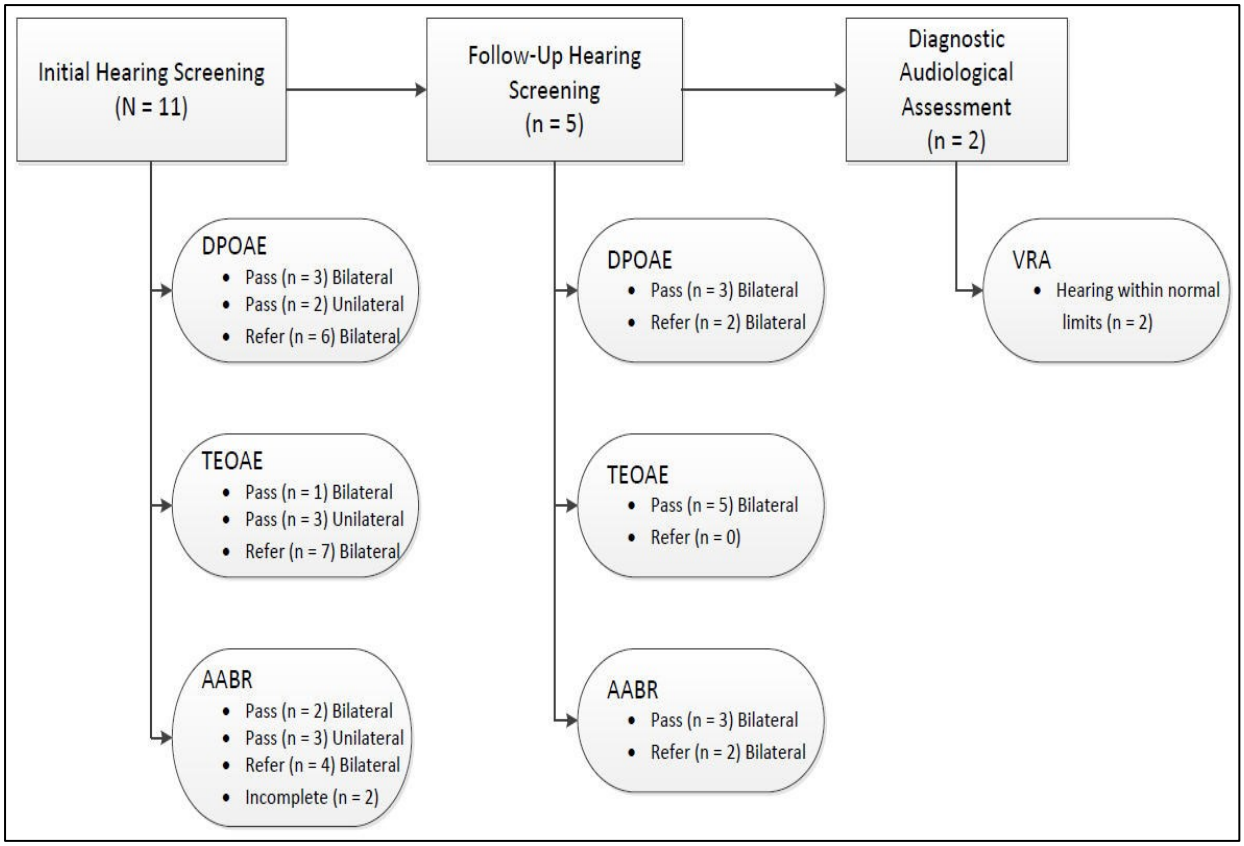


Figure 3: Outcomes of hearing screening protocol employed during pilot study

From the initial hearing screening, six participants presented with an overall, bilateral *refer* result for DPOAE, four presented with a bilateral *refer* for AABR, and seven participants presented with an overall, bilateral *refer* result for TEOAE. Three participants presented with a bilateral *pass* result for DPOAE, one participant presented with a bilateral *pass* result for TEOAE and a bilateral *pass* result for AABR was present in two participants. A unilateral *pass* result for DPOAE was present in two participants, with three participants presenting with a unilateral *pass* result for TEOAE and AABR. AABR could not be completed on two participants as they were restless and difficult to calm.

Of the 11 participants, six attended NNFU clinic with five participants having undergone a repeat hearing screening. The caregiver of the one participant had left the clinic following consultation with the paediatrician. Two of the five participants presented with *pass* results on all screening measures and were subsequently booked for behavioural audiometry at six months corrected age. Both participants attended the six month follow-up and presented with VRA results that were within normal limits (Figure 3). One participant underwent a rescreening due to incomplete results at the repeat screening. *Pass* results were obtained for all screening measures, but there was no attendance at the six month follow-up. Two

participants obtained bilateral *refer* results on both DPOAE and AABR measures and were subsequently booked for a diagnostic ABR. However, both participants did not attend this follow-up appointment.

8.1.2 Description of participants in pilot study

Table 12: Description of participants in pilot study

Participant	Gender	Gestational age (weeks)	Birth weight (grams)	Length of hospital stay (days)
1	Female	32	Unknown	10
2	Female	32	1480	17
3	Female	30	1440	15
4	Male	27	1000	34
5	Female	40	2880	3
6	Female	28	1390	24
7	Female	31	1500	10
8	Female	30	1460	21
9	Male	27	820	26
10	Female	29	1240	29
11	Female	27	730	34

The pilot study comprised 11 participants. All eleven participants were Black African, with nine of the 11 participants being female (Table 12). The average gestational age was 30 weeks, with six participants being classified as very low birth weight (VLBW), one as LBW, and two as ELBW neonates. One *p*articipant had a normal birth weight of 2880 grams and the birth weight was not recorded in the file for one participant. None of the participants had been admitted to the NICU, but all had a prolonged hospital stay. The mean stay in high care was seven days (sd=4.80), with a longer stay in the KMC ward of an average of 14 days (sd= 7.76). Three of the 11 participants underwent phototherapy due to neonatal jaundice (NNJ). With regard to retroviral disease (RVD), two participants were RVD exposed, seven were unexposed, and the RVD exposure of two participants was unknown. Antibiotics considered to be ototoxic were administered to eight of the eleven participants during their hospital stay. These ototoxic drugs were administered intravenously and consisted of Gentamycin, Amikacin, and Vancomycin, with Gentamycin having been the most frequently administered drug in seven of the participants.

8.1.3 Time required per screening measure for each neonate

The average time to complete TEOAE screening was one minute per ear. DPOAE screening time was slightly longer with the average time of two minutes per ear and AABR screening time was similar to DPOAE with an average time of one minute, 55 seconds. The average time taken to complete the hearing screening with all three measures was 18.4 minutes as this included obtaining good probe fit and ensuring that participants were calm when conducting each screening measure.

The researcher observed three factors that influenced the time taken to complete each of the screening measures:

1. The first factor was the state of the newborn or infant,
2. The second factor was the signal to noise ratio for OAE screening and,
3. The third factor was the electroencephalogram (EEG) for the AABR.

An awake but calm, or sleeping newborn or infant with a good signal to noise ratio on OAE screening, and a good EEG resulted in a quicker test time. These findings have important implications for NHS programmes as they indicate both the time requirements as well as possible influencing factors which if managed, would lead to the success of a screening programme; especially in a resource stricken environment.

8.1.4 Most suitable days and times for screening

As far as establishing the most suitable times for screening, current findings revealed that the afternoons were better suited for initial hearing screening as ward rounds were usually over at this time of the day, which made it easier to identify babies who were going to be discharged or babies where discharge was being queried. The fact that this was after ward rounds were completed also meant that the noise levels were significantly minimal as there was no longer academic teaching that occurs within the academic hospital environment during ward rounds. The most suitable time appeared to be between feeding times, which were between 12h00 and 14h00 as well as 15h00 and 17h00 in the afternoon. The conclusion drawn from this finding was that this was the time when the babies were generally comfortable, satisfied and sleeping. These are ideal intrinsic conditions for hearing screening where objective measures are utilised and sleep is the preferred neonatal state of arousal.

When exploring the most suitable days for screening, ward round days and weighing days were found to be appropriate. Babies were reportedly weighed on Tuesday and Friday mornings at CMJAH, unless they weighed less than 1500g in which case they are weighed every day. Based on the initial aims of the pilot study, these were therefore identified as the most suitable days for hearing screening at this research site. It seemed best to screen babies weighing approximately 1460g and above on these days, in order to avoid missing babies should they be discharged on days that the researcher was not at the hospital. Babies at RMMCH were weighed every day. However, Mondays and Thursdays were recommended days by paediatricians for the initial hearing screening from 11 am onward following completion of ward rounds.

Caregivers were usually present at all times in wards 184 and 185 at CMJAH and were always present in ward 16c at RMMCH. Difficulties were sometimes experienced in ward 177 at CMJAH and in ward 16b at RMMCH. The reasons for this were that caregivers of babies in these wards did not stay in the ward due to lack of caregiver accommodation facilities; or that caregivers may have been admitted to another ward for medical care whilst their baby was being cared for by nursing staff in these wards.

8.1.5 Ambient noise levels

Sound level readings ranged between 50 dBA (minimum) to 70dBA (maximum) during the pilot study in wards 184 and 185. The average sound level was 59.6dBA, making screening in these wards possible (sd=5.60). Screening was not conducted in ward 177 as there were only two babies during the pilot study that were discharged or transferred to another ward. Sound level readings ranged between 48dBA to 60dBA in ward 16c (KMC ward) at RMMCH. Ward 16b (the high care ward) was not a suitable environment for hearing screening due to multiple cribs per cubicle, noise generated by alarms on incubators, a high volume of medical and nursing staff conducting routine care and training of medical students during the course of the day. It was therefore decided that babies in cribs would be tested in the last empty cubicle used for storage in 16b, or an empty cubicle in ward 16c.

The average sound level in the screening environment at the NNFU clinic at CMJAH was 57.25dBA. These sound levels were lower at RMMCH and ranged between 40 to 50dBA as the follow-up hearing screening was conducted in the Audiology department due to a lack of available consulting rooms in the NNFU clinic. The Audiology department was a short distance away from the clinic which allowed for fairly easy access to the participants.

8.1.6 Additional findings

There were a number of additional findings that were noted when conducting hearing screening or planning for, and conducting diagnostic audiological assessments for participants from the pilot study. These additional findings had implications for the main study as they were related to administrative and logistical aspects of the study, availability of equipment, and the feasibility of conducting specific, initially proposed audiological measures.

8.1.6.1 Administrative and logistical aspects

8.1.6.1.1 Booking of appointments:

Initially, booking of follow-up appointments at CMJAH was challenging as some caregivers had already been provided with a follow-up appointment by nursing staff. However, these dates did not coincide with a six week time frame and babies were often booked for a much later date. Following discussion with the booking clerks in the NNFU clinic, the clerks agreed to book some of the babies for an earlier date, as there was still scheduling slot availability, with the maximum number of bookings being 30 patients per clinic. Bookings for follow-up appointments at CMJAH were also done by the researcher to ensure that the appropriate time frames of the research protocol were met.

8.1.6.1.2 Availability of a screening room:

Availability of a room for screening at the NNFU clinic at CMJAH was initially difficult, with the Pharmacy stock room having been offered, and then later being allocated to another medical professional. There was only one room available which was at the entrance to the clinic. In order to minimise the influence of ambient noise levels, the researcher ensured that screening was conducted at the furthest corner from the entrance to the room.

8.1.6.2 Availability of diagnostic equipment

The lack of diagnostic equipment and the constant repair of diagnostic equipment for behavioural audiometry and/or electrophysiological testing at both research sites resulted in the researcher having to conduct diagnostic assessments at the University Clinic. This resulted in caregivers of participants having to travel to another site to receive these services.

8.1.6.3 Feasibility of conducting initially proposed audiological measures

Conducting high frequency tympanometry on all infants attending the repeat hearing screening did not prove to be feasible in terms of time. It was therefore decided that this measure would only be conducted if refer results were obtained for both TEOAE and DPOAE screening. The initial protocol also included referral to the paediatrician at the NNFU if middle ear pathology was suspected (i.e. refer on OAE results and an absent peak on high frequency tympanometry). However, caregivers often reported that no management was conducted which possibly aligns with the watch-and-wait approach. According to clinical practice guidelines, many children with fluid build-up in the middle ear improve on their own, especially when fluid is present for less than three months (Minnesota Department of Health, 2014) . It was therefore decided that these infants be booked three weeks later for a rescreen. The screening protocol was amended accordingly as depicted in Figure 2 in the methodology chapter.

With regard to diagnostic assessment, it was initially thought that visual reinforcement audiometry at six months corrected age would be conducted using insert earphones or headphones to obtain ear specific information. However, this did not prove feasible when assessing participants from the pilot study as they were restless and often did not permit the placement of insert earphones or headphones. Freefield testing had to be conducted instead, and where possible, diagnostic OAE testing was conducted to obtain ear specific information. However, diagnostic OAEs could not be conducted consistently on all infants due to the state of the infant at the time of assessment.

Based on the pilot study findings; all necessary changes were made to the measures and design of the study for which the results are presented next.

8.2. Main Study Results

The specific objectives of the main study were to:

- Describe the case history factors in a group of high-risk neonates.
- Describe the audiological function in a group of high risk neonates.
- Determine the relationship between the case history factors and audiological function in high-risk neonates.

- Establish which combinations of audiological screening measures provide both TP and TN results for risk-based screening, at and across time.
- Establish the percentage of TP and TN screening results in the total sample.
- Explore the factors associated with follow-up return rate for hearing screening and diagnostic audiological assessment.

A total of 423 participants were recruited for the current study. Of these 423 participants, 98 were excluded from the total sample; and this left 325 being the final sample size. Ninety four of these 98 participants were excluded as consent to participate in the study was not obtained from the caregivers. Reasons for no consent were varied and examples of these are documented in Figure 4 below. The most common reasons associated with no consent being obtained were caregivers not being present in the ward at the time of screening, followed by discharge prior to screening days or times and caregivers reporting that they were unable to travel back to the hospital for follow-up visits. The remaining four participants were enrolled in the study but excluded from the analysis as the initial hearing screening was incomplete due to participants being restless during TEOAE and/or AABR screening. These four participants were also being discharged at the time of initial hearing screening, which did not permit for screening to be continued at a later stage or on another day during that particular week.

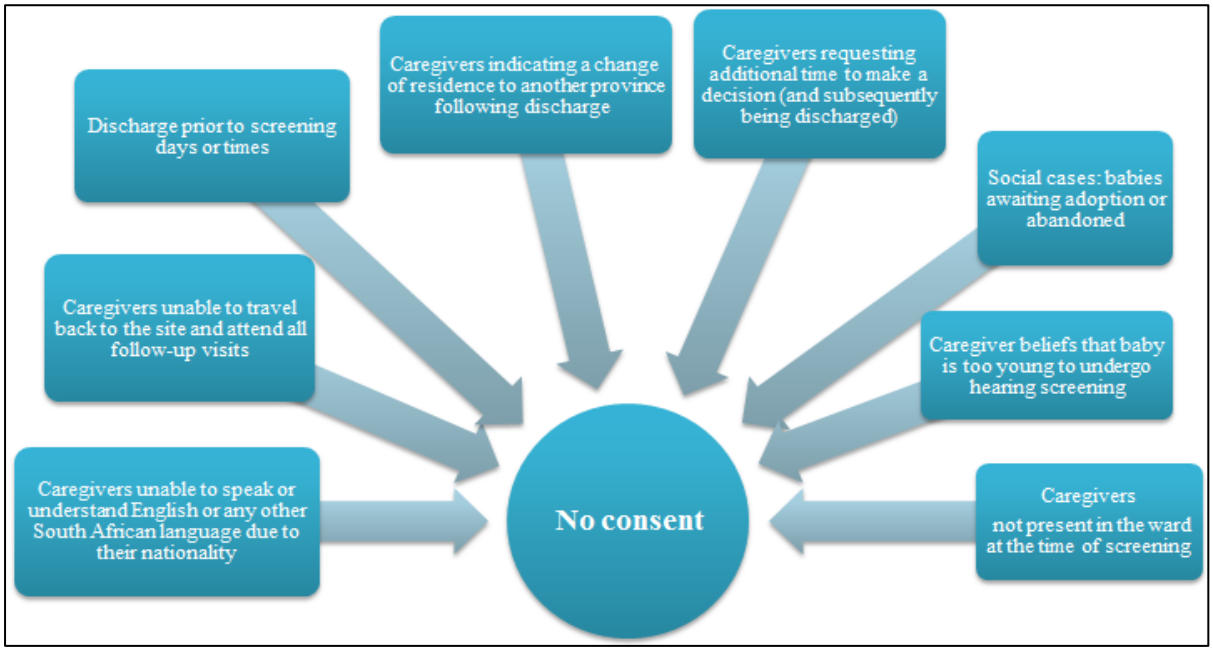


Figure 4: Reasons for consent not being obtained for participants

8.2.1 Demographic profile of participants and caregivers

8.2.1.1 Demographic profile of participants

The total study sample at the initial, in-hospital hearing screening comprised 325 participants. Of these 325 participants, 77.8% were from RMMCH and 22.2% were from CMJAH. For the purposes of the current study, participants were combined into a single sample, and results were analysed in terms of the total sample as demographics of participants from the respective research sites did not differ markedly. The sample consisted of more females than males. One hundred and seventy eight (54.8%) of the participants were female and 147 (45.2%) were male (the male to female ratio was 0.83). The majority of the participants were Black African (85.5%), followed by Coloured (10.2%), White (2.5%) and Indian (1.9%). The gestational age of participants was recorded and is described in the sub-section related to case history information. Although the initial sample consisted of 325 participants, the number of participants decreased at the repeat hearing screening sessions, and further declined at the diagnostic assessment session due to attrition. Where known, reasons for attrition are presented as part of the study's final secondary objective that relates to follow-up return rate.

8.2.1.2 Description of caregivers of participants

Caregiver demographic information consisted of maternal age, nationality, spoken home language, highest level of education and whether or not they were first time mothers. With regards to maternal age, the majority of caregivers (54.8%) were between the ages of 25 years and 35 years. The mean maternal age was 28.1 years (sd 6.3 years; range 16-45 years). The distribution of ages is depicted in Figure 5 using midpoint values.

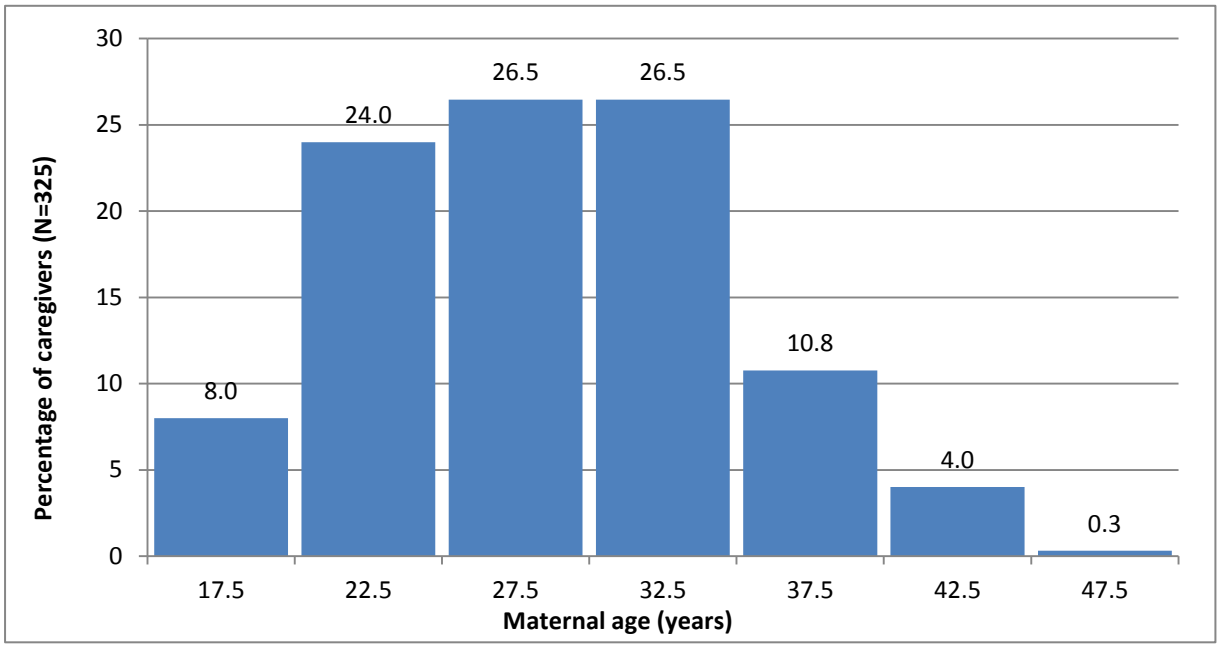


Figure 5: Distribution of age of caregivers of participants

With regard to nationality, there was a wide variety of nationalities represented by the caregivers of participants. A large majority of the mothers were South African (74.2%), with the second most common nationality being Zimbabwean (18.2%). The remaining 7.6 % of caregivers were from other parts of Africa, with one caregiver having an Indian nationality (Figure 6).

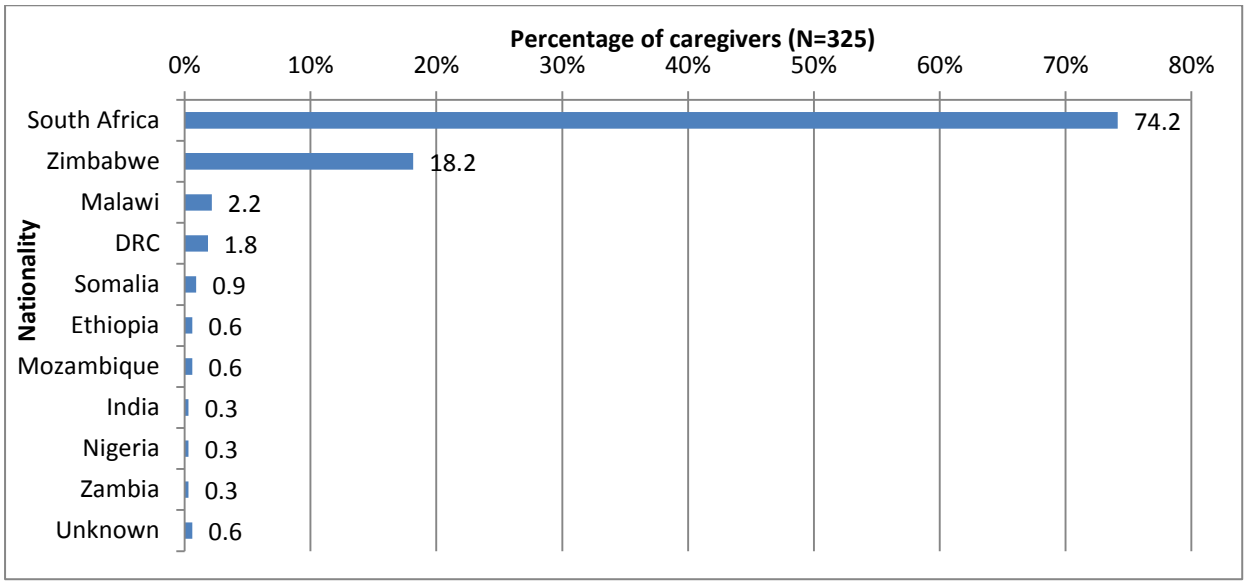


Figure 6: Distribution of nationality of caregivers of participants

The distribution of home languages spoken by caregivers was in alignment with the distribution of nationality. A great diversity of languages was spoken by the caregivers of participants in the study group. The most common home language was Zulu (21.8%), followed by Ndebele which was the spoken home language by 38 caregivers (11.7%). The 11 official South African languages were the most represented languages, making up 90.2% of the study group (Figure 7).

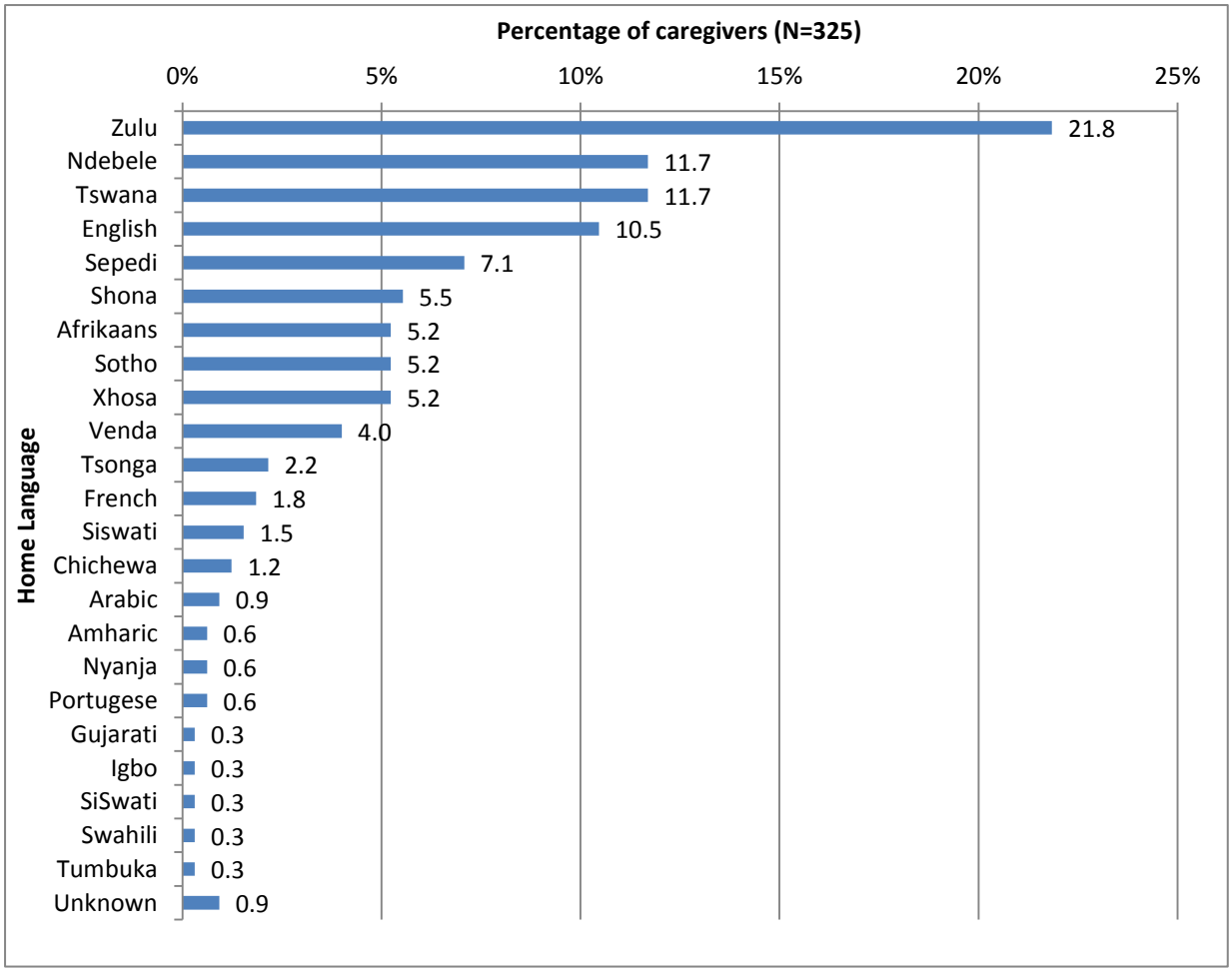


Figure 7: Distribution of home languages of caregivers of participants

The highest level of education of caregivers was categorised according to primary, secondary or tertiary education which assisted in grouping levels of education from various schooling systems as a result of the varied distribution of nationalities within the study group. The majority of caregivers had secondary schooling (84.6%), while 14.5% had some form of tertiary education. One mother had no schooling, while the educational level of 0.6% of caregivers in the study group was unknown.

Over half of the caregivers of participants in the study group reported having other children (59.1%) and the rest (40.9%) indicated that they were first time mothers.

8.2.2 Description of case history factors

All case history information was recorded from participant files at the time of the initial hearing screening. The presence of additional case history factors was also recorded at the time of repeat screening and diagnostic assessment. Case history factors were grouped and descriptively analysed; and the following grouping system was adopted:

a. The first set of case history factors described consists of baseline clinical data which pertains to information recorded in participant files at the time of birth, as well during hospitalisation after birth (postnatal factors).
b. The second set of case history factors described consists of any developmental concerns, new diagnoses of medical conditions or re-admissions to hospital post initial discharge.

8.2.2.1 Baseline clinical information of participants

The following baseline clinical information was gathered and recorded from participant files:

- Mode of delivery
- Birth weight
- Gestational age
- APGAR scores
- Length of hospital stay which included length of stay in NICU, high care and or KMC wards
- Ventilation which included the type and duration
- Aspects related to bilirubin levels which included the diagnosis (neonatal jaundice/kernicterus/hyperbilirubinemia), the number of days that bilirubin levels exceeded 10 milligrams/decilitre (mg/dl), whether treatment was in the form of exchange blood transfusion (EBT), phototherapy (PTT) or both, the number of EBTs and the number of days of PTT
- The presence of in-utero infections
- RVD exposure
- Ototoxic medication administered with details regarding the type of medication, dosage and duration

- Syndromes
- Neurological conditions
- Additional medical history

In addition to the above mentioned information, the presence of family history of hearing loss was documented from caregiver reports. The above mentioned baseline clinical data will be described in the order in which it has been listed.

8.2.2.1.1 Mode of delivery and birth weight

Two hundred and twenty four participants (69%) were delivered by caesarean section and 101 (31.1%) by natural vaginal delivery. Of the participants delivered by caesarean section, 159 (48.9%) were delivered by emergency caesarean section whilst 65 (20%) were delivered by planned or elective caesarean section. The median birthweight of participants was 1390 grams (interquartile range-IQR 1190-1555 grams; range 690-4020 grams). The distribution of birth weight is depicted in Figure 8. Birth weight was further categorised into normal birth weight (≥2500 grams), LBW (1500 grams – 2499 grams), VLBW (1000 grams- 1499 grams) and ELBW (≤ 999 grams) (WHO, 2004). The majority of participants (59%) had VLBW followed by those with LBW (29%), with only 13 (4%) of the participants in the study group being of normal birth weight (Figure 9).

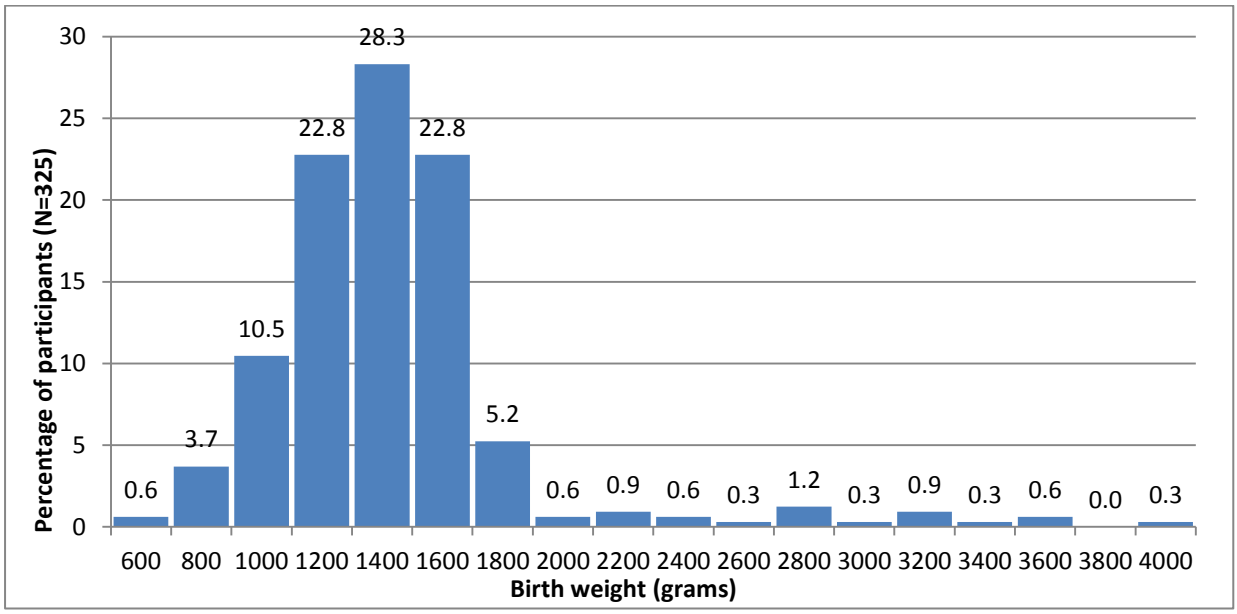


Figure 8: Distribution of birth weight in grams

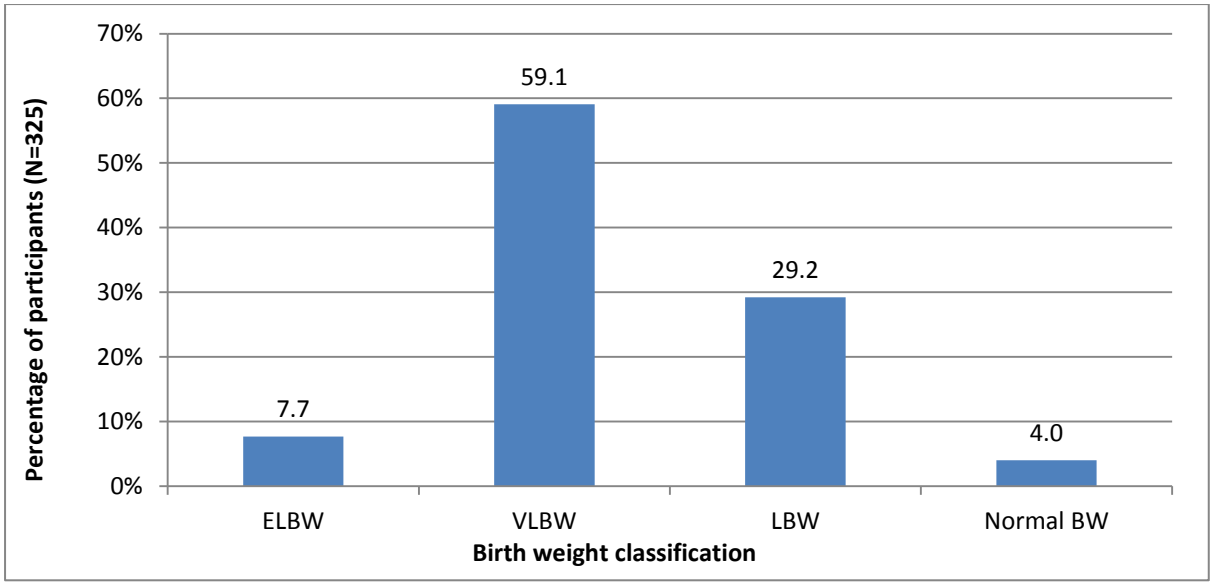


Figure 9: Classified distribution of birth weight

8.2.2.1.2 Gestational age

The mean gestational age was 31.3 weeks (sd 2.8 weeks; range 25-41 weeks). Guidelines by the American Congress of Obstetricians and Gynecologists (ACOG) were used to classify gestational age. Gestational age was classified into full term (39-40 weeks), early term (37-38 weeks), preterm (< 37 weeks) and late term (41 weeks) (ACOG, 2012). The majority of participants were preterm (95.7%) with very few classified as early term (1.8%) or full term (2.2%). Only one participant was classified as being late term. Birth weight was closely linked to gestational age as 58.5% (n=190) of the participants who were preterm were of VLBW while a further 28.6% (n=93) who were preterm were of LBW (Table 13).

Table 13: Distribution between classified birth weight and gestational age

Classification of Birth weight	Classification of gestational age				
	Preterm	Early term	Full term	Late term	Total
ELBW	25				25
VLBW	190	2			192
LBW	93	1	1		95
Normal birth weight	3	3	6	1	13
Total	311	6	7	1	325

8.2.2.1.3 APGAR scores

APGAR scores that were recorded in participant files were classified as low (between zero and three), intermediate (between four and six) and normal (between seven and 10) (ACOG, 2006). The classification of APGAR scores was also done in conjunction with a consultant

paediatrician working in the neonatal wards at the time of data collection. These classifications were applied to the APGAR scores at five and ten minutes. The one minute score was not considered during classification as it has not demonstrated to be a predictor of clinical outcome (ACOG, 2006); and this was the position adopted by the current researcher. Two hundred and seventy eight participants presented with a normal APGAR score, with only 11 participants of the total sample presenting with a low APGAR score (Figure 10). The APGAR scores were unknown for 25 participants as 19 were born before admission (BBA) to the hospital and scores were not recorded in the remaining six participants' files.

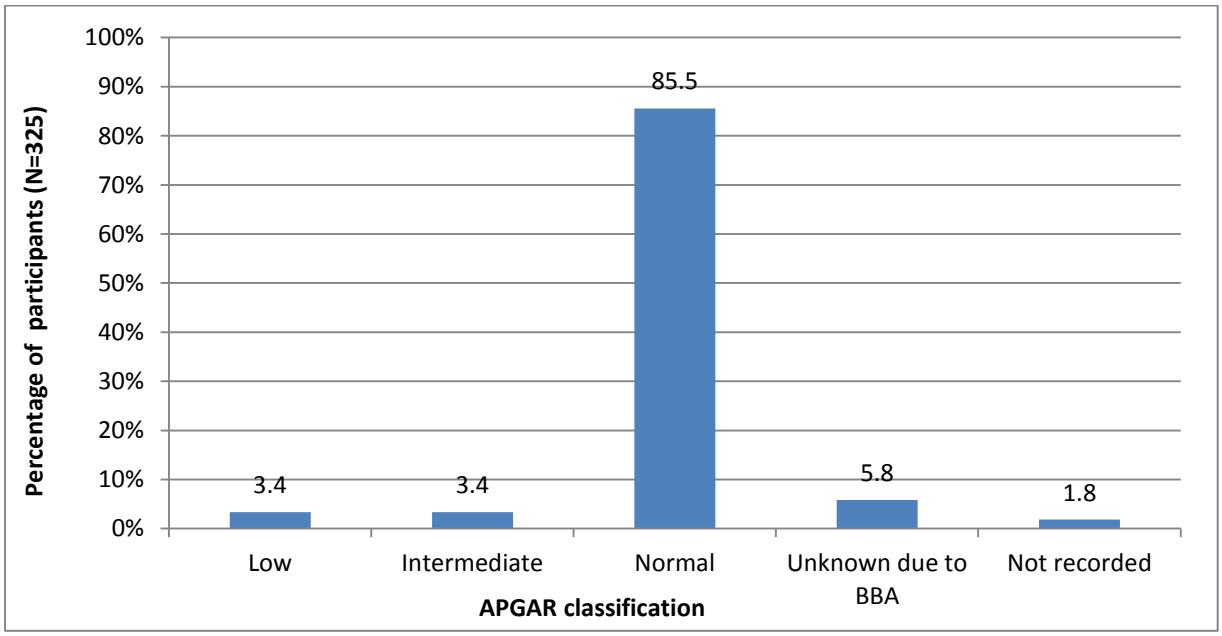


Figure 10: Distribution of classified APGAR scores

8.2.2.1.4 Length of hospital stay

The total length of hospital stay was calculated as the total length of stay in the NICU, high care and/or KMC wards. Ninety five participants were admitted to the NICU with the minimum length of stay being one day and the maximum length of stay being 56 days. The median length of the total hospital stay was 23 days (IQR 16-35 days; range 3-97 days). Figures 11, 12, 13 and 14 illustrate the distribution of length of stay in each of the wards as well as the total length of hospital stay using midpoint values along the x-axis.

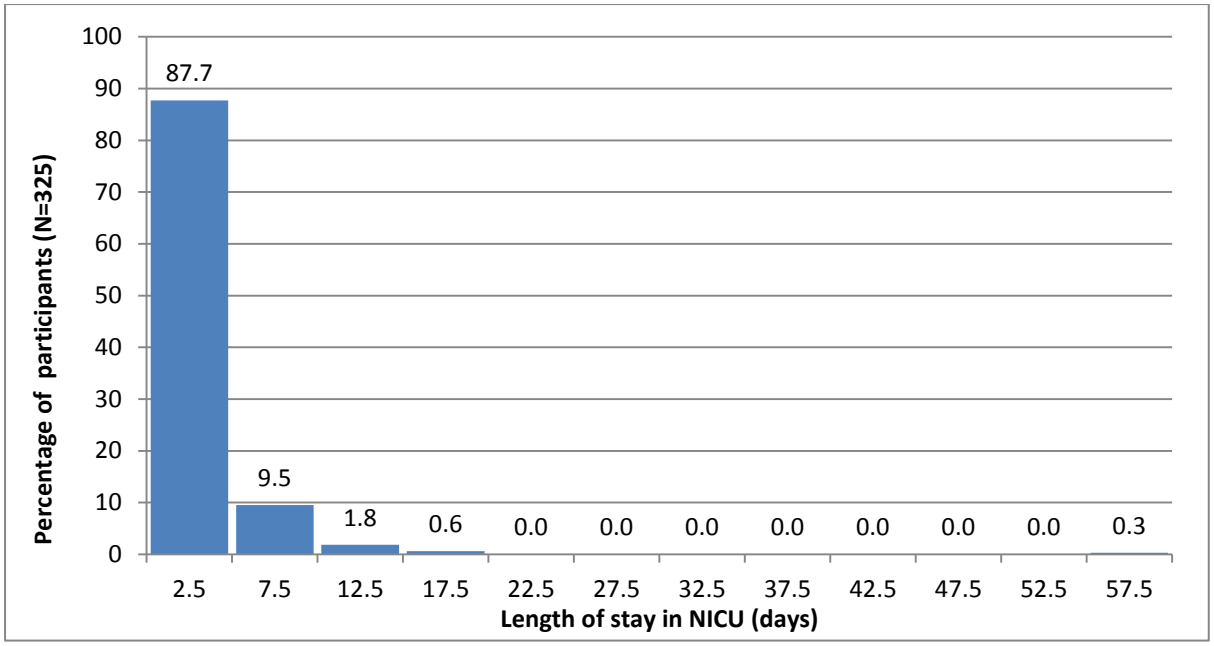


Figure 11: Distribution of length of stay in NICU

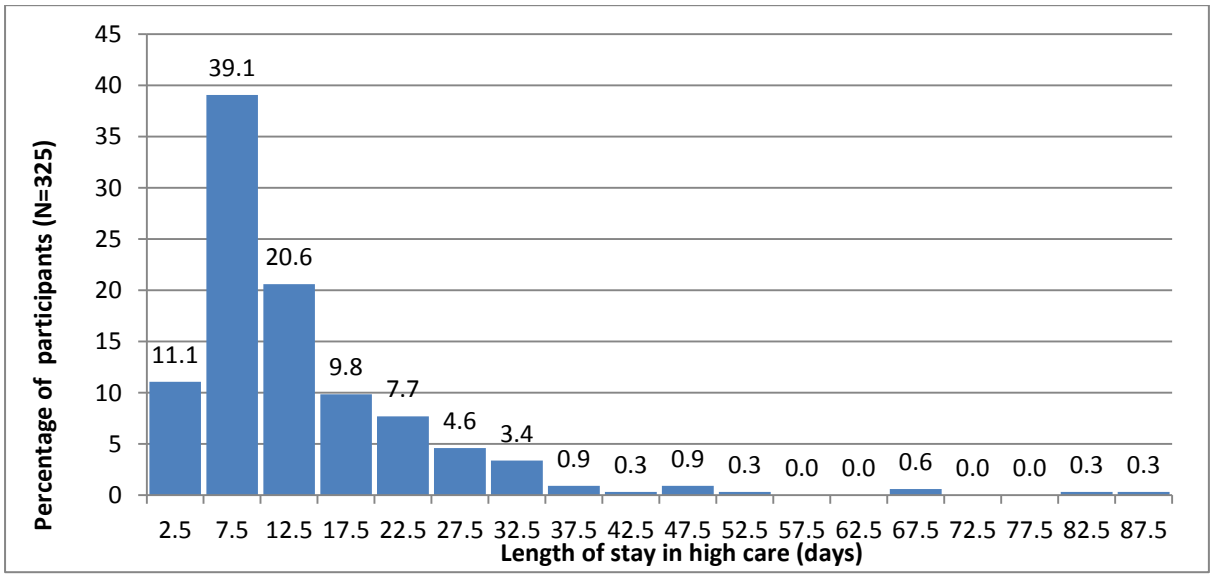


Figure 12: Distribution of length of stay in the high care ward

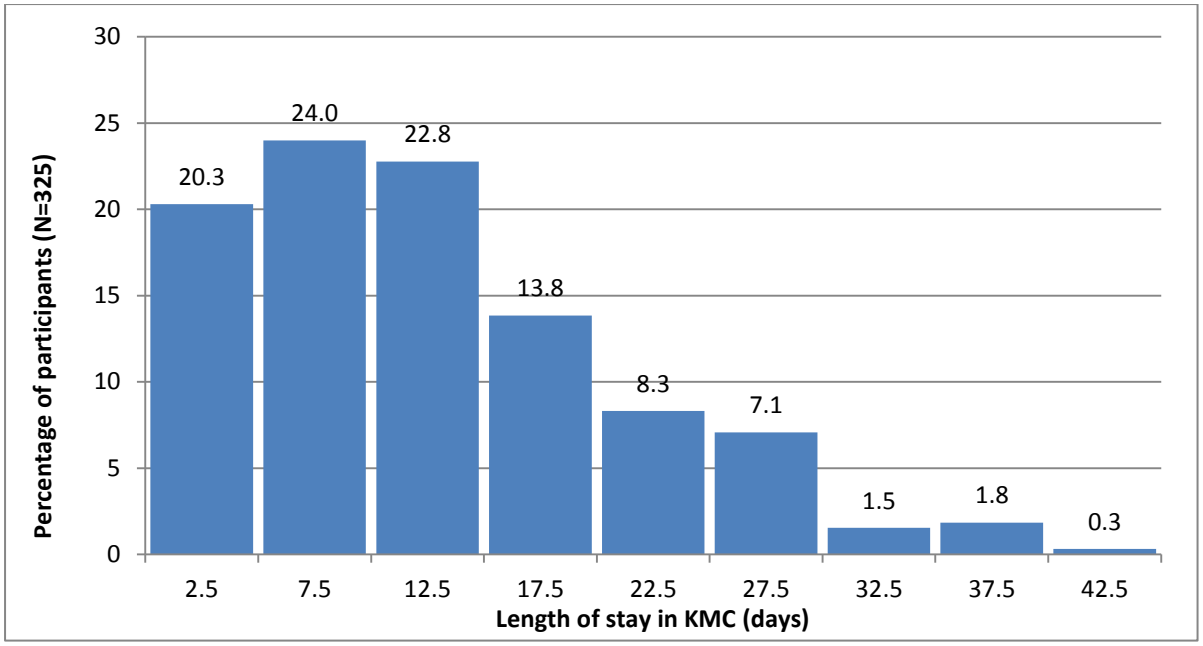


Figure 13: Distribution of length of stay in KMC

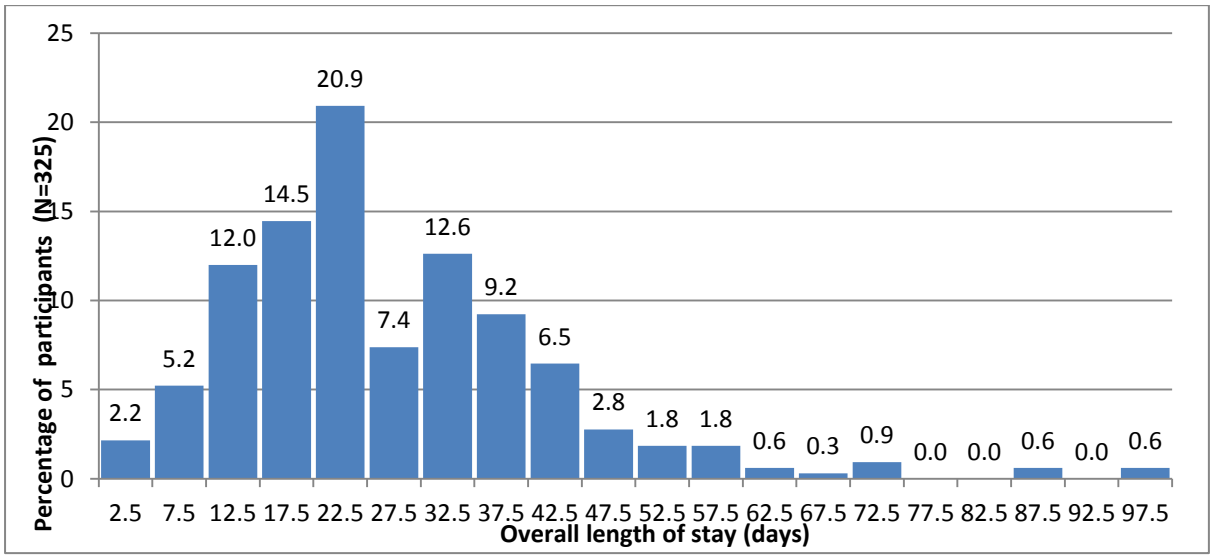


Figure 14: Distribution of total length of hospital stay

8.2.2.1.5 Ventilation

During the hospital stay, 114 (35.1%) of participants received ventilation via CPAP and/or IPPV. Of these 114 participants, 93.9% received CPAP and 23.7% had IPPV, with some participants having received both CPAP and IPPV. The median duration of CPAP was 2 days (IQR 1-3 days; range 1-8 days). Similarly, the median duration of IPPV was 2 days (IQR 1-3 days; range 1-10 days).

8.2.2.1.6 Aspects related to bilirubin levels, outcome and treatment

Bilirubin levels were recorded for 297 (91.4%) participants in the total study sample. The recorded levels for 27 of these participants were not associated with a diagnosis of NNJ. Of the 297 participants with recorded bilirubin levels, 43.4% had bilirubin levels > 10 mg/dl on at least one day (Figure 15).

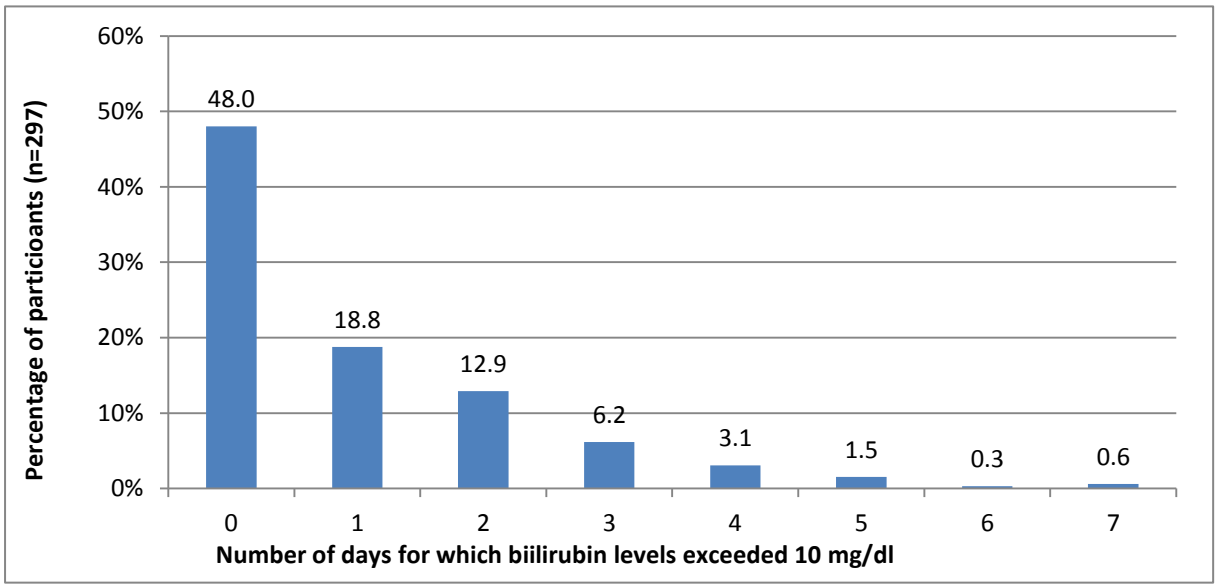


Figure 15: Distribution of the number of days on which bilirubin levels exceeded 10mg/dl

The number of days for which bilirubin levels exceeded 10mg/dl was analysed as this may indicate participants at risk for bilirubin encephalopathy or bilirubin induced neurological dysfunction (E. Ho, personal communication, July 1, 2015). Of the total study sample, 262 (80.6%) participants were diagnosed with NNJ, while a further seven participants (2.2%) were diagnosed with hyperbilirubinemia, and one participant (0.3%) was diagnosed with kernicterus.

Within the group of 270 participants who were diagnosed with one of the three conditions (NNJ, hyperbilirubinemia or kernicterus), 243 (90.0%) received PTT, seven (2.6%) received both PTT and EBT, 10 (3.7%) received no treatment, and the treatment of 10 (3.7%) of the participants was not documented in files, and therefore remains unknown for the purposes of the current study. Of the seven participants who received EBT, four received one transfusion, while three received two transfusions. For the 250 infants who received PTT, the median number of days of PTT was four days (IQR 3-6 days; range 1-16 days).

8.2.2.1.7 In-utero infections

In-utero infections were present in five (1.5%) participants. Two of these participants presented with congenital syphilis, one had congenital rubella, one had congenital cytomegalovirus and one presented with X-ray features of congenital rubella.

8.2.2.1.8 RVD exposure

In addition to in-utero infections, 69 (21.2%) of the participants were RVD-exposed, with information about RVD exposure of four (1.2%) participants being unknown.

8.2.2.1.9 Type, dosage and duration of administered ototoxic medication

Participant exposure to ototoxic medication was noted in the current study group. The administered ototoxic medications included Gentamycin, Imipenem, Vancomycin, Amikacin, Erythromycin, Furosemide and Amphotericin. The proportion of participants who received each type of medication is shown in Figure 16 below.

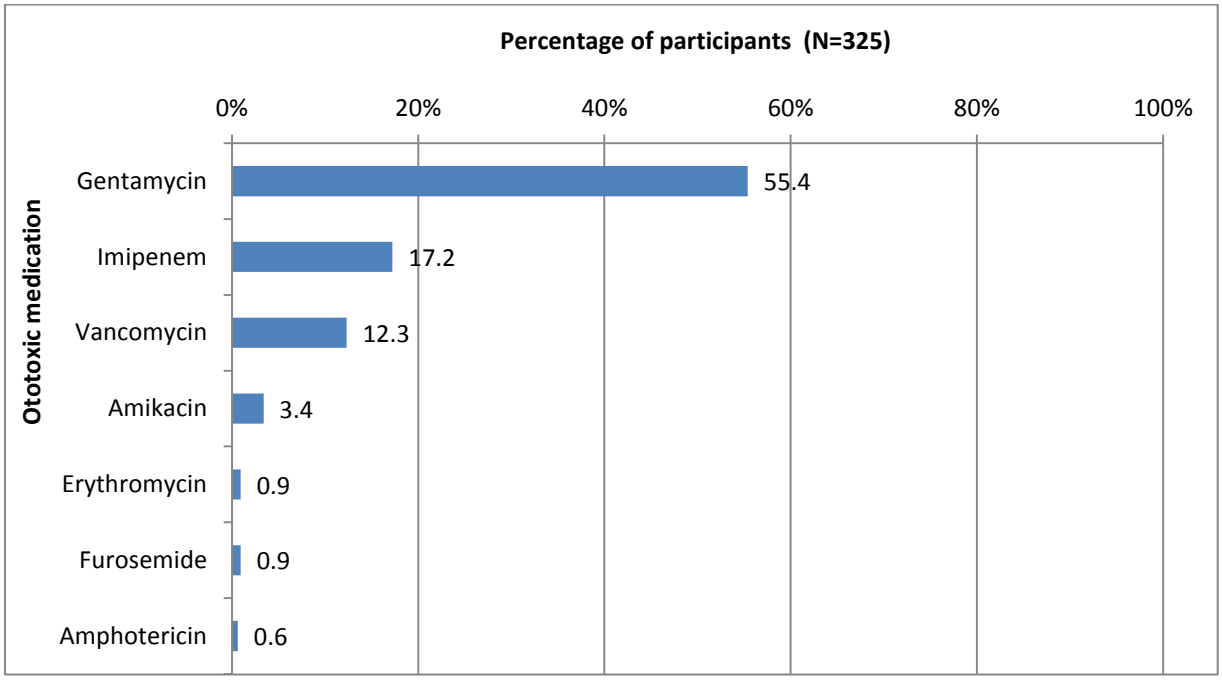


Figure 16: Proportion of participants that received each type of ototoxic medication

The percentages do not sum to 100% since some participants received more than one type of medication. Gentamycin was the most commonly prescribed medication, administered in 180 (55.4%) participants. Univariate analysis was conducted for the dosage and duration of each type of medication that was administered, and the findings are depicted in Table 14.

Table 14: Dosage and duration of administered medication

Medication	n	Mean	sd	Median	IQR		Minimum	Maximum
Amikacin dose (mg)	11	17.7	11.0	18	12	21	2	45
Amikacin duration (days)	11	3.3	1.6	3	2	4	1	6
Amphotericin dose (mg)	2	1.0	0.0	1	1	1	1	1
Amphotericin duration (days)	2	11.0	4.2	11	8	14	8	14
Erythromycin dose (mg)	3	13.7	5.1	15	8	18	8	18
Erythromycin duration (days)	3	3.0	1.7	2	2	5	2	5
Gentamycin dose (mg)	179	7.4	2.7	7	6	8	1	18
Gentamycin duration (days)	180	2.7	1.3	2	2	3	1	9
Imipenem dose (mg)	54	21.8	16.1	25	4	34	2	67
Imipenem duration (days)	56	5.9	4.2	5	4	7	1	24
Furosemide dose (mg)	3	1.2	0.3	1	1	1.45	1	1.45
Furosemide duration (days)	3	1.0	0.0	1	1	1	1	1
Vancomycin dose (mg)	39	13.2	7.2	14	11	17	1	36
Vancomycin duration (days)	40	3.7	2.2	3	2	5.5	1	8

The median dosage was highest for Imipenem (IQR 4-34 mg), followed by Amikacin (IQR 12-18 mg) and Erythromycin (IQR 8-18 mg). It is evident from Table 14 that there were differences in dosage and duration, which is possibly influenced by medications being administered according to individual needs in different typical dosages. Due to this variation in dosage and duration, a comparison of dosages between different medications was deemed irrelevant.

8.2.2.1.10 Syndromes and neurological conditions

With regard to syndromes and neurological diagnoses, only five (1.5%) participants presented with a syndrome or dysmorphic features associated with a syndrome as noted in their hospital file, while 29 participants presented with some form of neurological condition. As far as the syndromes were concerned; one participant presented with Trisomy 13 with cleft lip and palate, two presented with low set ears, micrognathia and/or a thickened nasal bridge, one participant presented with hydraencephaly and macrocephaly and the other participant was classified as having Isotretinoin syndrome. As far as the neurological conditions were concerned, a range of conditions were found; and these are depicted in Table 15.

Table 15: Specific neurological conditions in case history findings (n=29)

Neurological condition	n	%
Bilateral Interventricular haemorrhage (IVH) Grade I, neonatal encephalopathy	1	3.4
Birth asphyxia	1	3.4
Grade II-III IVH	1	3.4
Grade III IVH Bilaterally, neonatal encephalopathy	1	3.4
HIE Grade I	2	6.9
HIE Grade II	1	3.4
HIE Grade II and birth asphyxia	1	3.4
IVH Grade I	3	10.3
IVH Grade I on left hemisphere and IVH Grade II on right hemisphere	2	6.9
IVH Grade II	2	6.9
IVH Grade II on left and right choroid plexus cyst	1	3.4
IVH Grade III-right and IVH Grade IV-left	1	3.4
IVH Grade IV	1	3.4
IVH Grade II and perinatal asphyxia	1	3.4
Left ventricle larger than right ventricle	1	3.4
Mixed cerebral palsy	1	3.4
Perinatal asphyxia	4	13.8
Query mild ventriculomegaly	1	3.4
Query Perinatal asphyxia	2	6.9
Bilateral IVH Grade I and perinatal asphyxia	1	3.4

The most common type of neurological conditions were IVH of varying degrees, birth/perinatal asphyxia and HIE with ventriculomegaly being the least common condition.

8.2.2.1.11 Additional medical history

Other medical history data recorded included factors such as respiratory distress syndrome (RDS), sepsis, hyperglycaemia, hypoglycaemia, anaemia and apnoeas. All other medical case history data noted in files is presented in Table 16 below.

Table 16: Additional medical case history factors noted in participant files.

Additional medical case history factors	n	%
None	184	56.6
RDS	70	21.5
Anaemia	24	7.4
Apnoeas	16	4.9
Hyperglycaemia	16	4.9
Hypoglycaemia	14	4.3
Nosocomial sepsis	13	4.0
Necrotizing enterocolitis (NEC) II	13	4.0
Sepsis	11	3.4
Extended-spectrum beta-lactamases Klebsiella sepsis	8	2.5
Chorioamnionitis	5	1.5
Transient Tachypnea of the Newborn (TTN)	5	1.5
Resuscitation	4	1.2
Suspected meningitis	3	0.9
NNJ near exchange levels	2	0.6
Retinopathy of prematurity	2	0.6
Respiratory failure	2	0.6
Cyst on cranial sonar	1	0.3
Lateral ventricle mildly dilated on cranial sonar	1	0.3
Methicillin-resistant Staphylococcus aureus sepsis	1	0.3
Maternal history of substance abuse	2	0.6
Pre-auricular tag	1	0.3
Prolonged hypoxia during resuscitation	1	0.3
Seizures	1	0.3
For palliative care	1	0.3
Chronic lung disease	1	0.3
Klebsiella pneumonia	1	0.3
NEC III	1	0.3

Over half of the study sample did not present with any additional medical case history factors. Of the additional medical case history factors, RDS was the most frequently recorded case history factor, with ten of the recorded case history factors having a very low occurrence as they were each present in one participant only.

8.2.2.1.12 Family history of hearing loss

Family history of hearing loss was also documented from caregiver reports at the initial hearing screening. For the purposes of the current study, only congenital hearing loss was considered during analysis. Of the total sample, only eight participants (2.5%) were reported to have some family history of congenital hearing loss. This was reported to be present in

maternal aunts, cousins, nephews or grandfathers. One caregiver reported a family history of hearing loss as a result of Waardenburg syndrome.

8.2.2.2 Additional clinical information of participants

During the course of the current study, a total of 11 participants were readmitted into hospital. Seven participants were readmitted during the period between discharge from hospital and repeat hearing screening, while four participants were readmitted during the period prior to diagnostic assessment. Reasons for hospitalisation for the seven participants included apnoeas, influenza, NNJ and severe failure to thrive, whereas, bronchopneumonia, upper respiratory tract infections and difficulty breathing were reasons for readmission for the other four participants.

8.2.3 Description of audiological function in participants

Three hundred and twenty five (325) participants underwent the initial hearing screening conducted in hospital. The initial hearing screening was conducted bilaterally using TEOAE, DPAOE and AABR. All 325 participants were scheduled to undergo a repeat hearing screening, six weeks after discharge (consisting of all the same three screening measures) on the day of their neonatal follow-up appointment. Figure 17 below illustrates that of the 325 participants, 216 (66.5%) underwent the repeat hearing screening. Following the repeat hearing screening, 183 (84.7%) participants were booked for a diagnostic audiological assessment at six months corrected age, nine (4.2%) were booked for diagnostic ABR and 24 (11.1%) required a rescreen approximately three weeks after the repeat screening due to suspected, transient middle ear effusion or as a result of incomplete screening results.

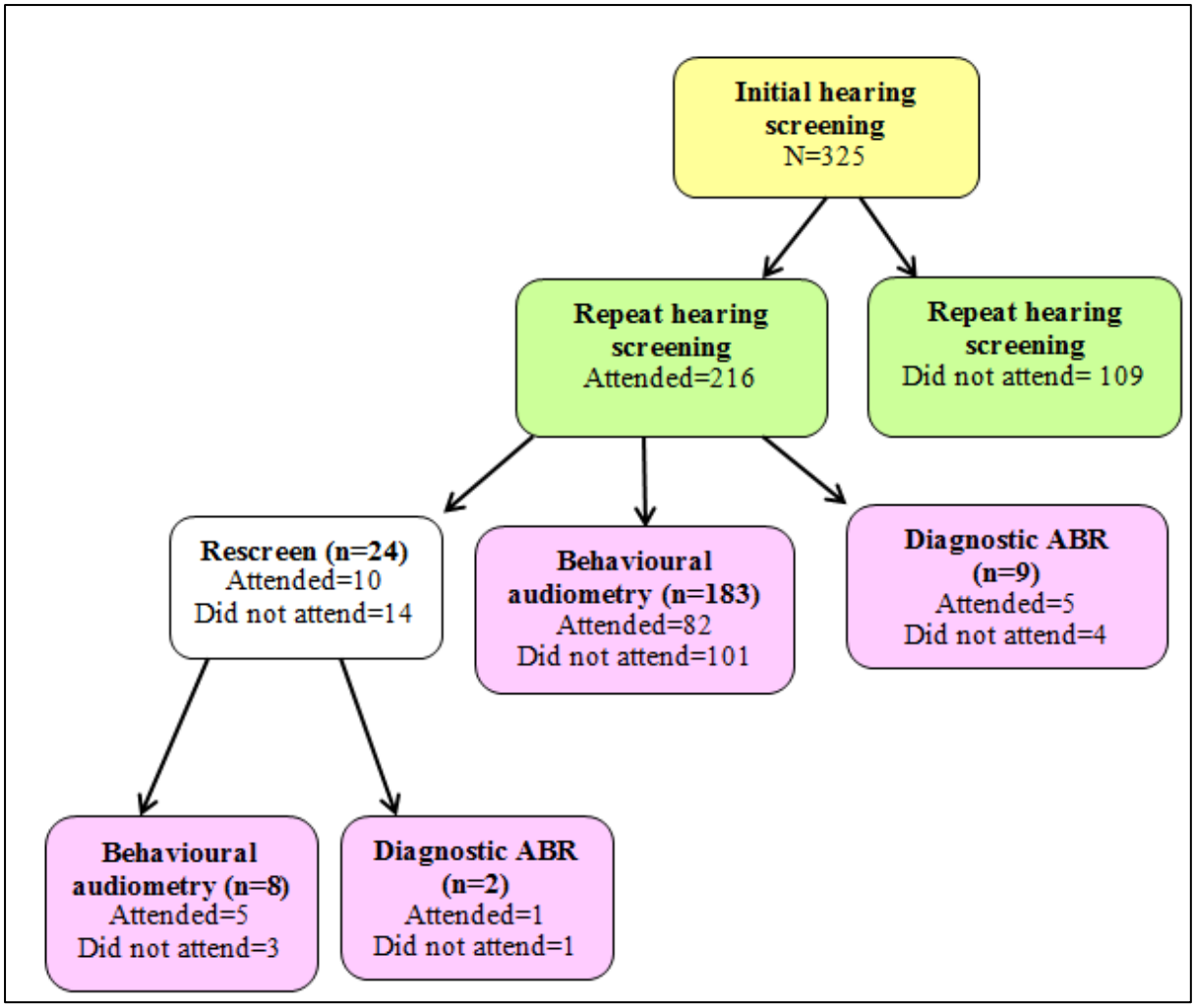


Figure 17: Summary of the number of participants at different stages in the current study

Pass/ Refer findings for each measure were recorded per participant, per ear. However, for purposes of analysis, results were further classified using the overall *pass/refer* result for each participant (in addition to per ear analysis). A bilateral *pass* criterion was used. Hence, an overall *refer* result per participant, per measure was classified if a *refer* outcome was obtained for either ear. When considering all three screening measures (TEOAE, DPOAE and AABR) an overall *refer* outcome was classified as a *refer* on any of the three screening measures employed at the screening stages of the current study.

8.2.3.1 Initial hearing screening outcome

Table 17: Initial hearing screening outcomes per screening measure and for all three measures combined

Screening measure	Outcome	Overall		Left ear		Right ear	
		n	%	n	%	n	%
DPOAE	*Pass*	227	69.8	252	77.5	255	78.5
	Refer	98	30.2	73	22.5	70	21.5
TEOAE	*Pass*	248	76.3	264	81.2	271	83.4
	Refer	77	23.7	61	18.8	54	16.6
AABR	*Pass*	219	67.4	243	74.8	243	74.8
	Refer	106	32.6	82	25.2	82	25.2
Overall result of three measures	*Pass*	192	59.1				
	Refer	133	40.9				

At initial hearing screening, a DPOAE *refer* result was obtained for 73 (22.5%) left ears and 70 (21.5%) of right ears. Using a bilateral *pass* criterion, 227 (69.8%) participants *passed* the DPOAE screening whilst 98 (30.2%) participants *referred* on this screening measure (Table 17). *Refer* findings were highest at 1kHz for both ears (Figure 18).

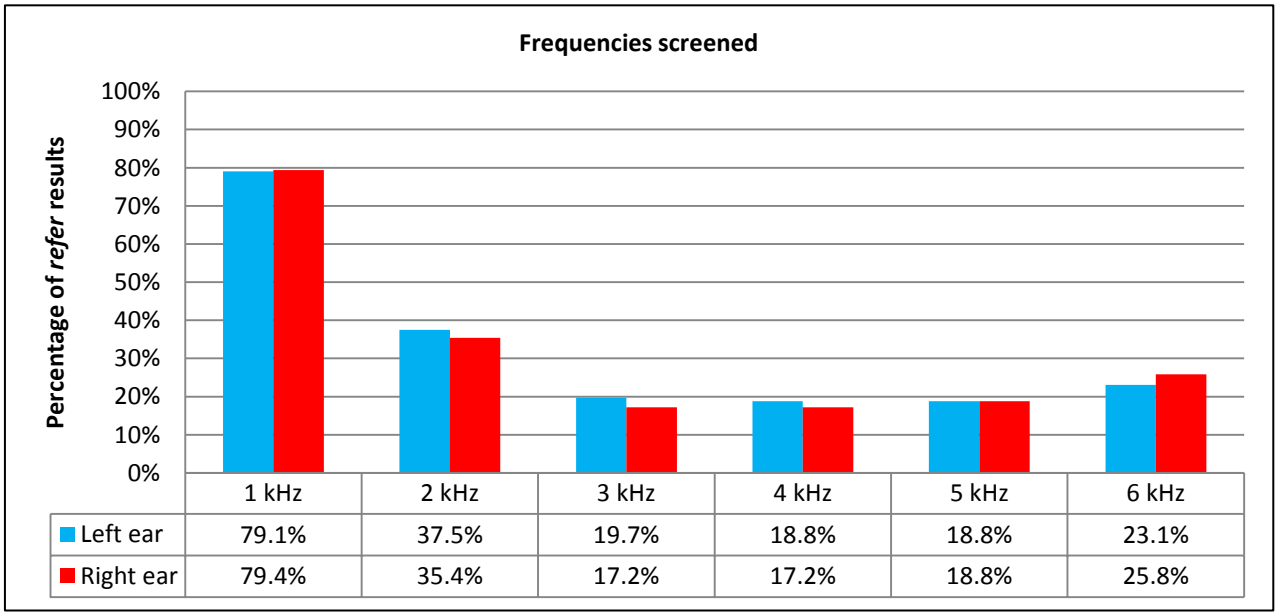


Figure 18: *Refer* results per frequency for DPOAE at initial hearing screening (N=325)

For TEOAE screening, *refer* findings were obtained for 61 (18.8%) left ears and 54 (16.6%) right ears. Using a bilateral *pass* criterion, 248 (76.3%) *passed* the initial TEOAE screening whilst 77 *referred*.

Analysis of AABR outcome at the initial hearing screening indicated *refer* results for 82 (25.2%) left ears and 82 (25.2%) right ears. In terms of the bilateral *pass* criterion, 219 (67.4%) participants *passed* the initial AABR screening and 106 (32.6%) participants *referred* on this screening measure.

Analysis of the overall outcome of all three measures combined, indicated that more than half of the sample (59.1%) *passed* the initial hearing screening, compared to those who *referred* (40.9%).

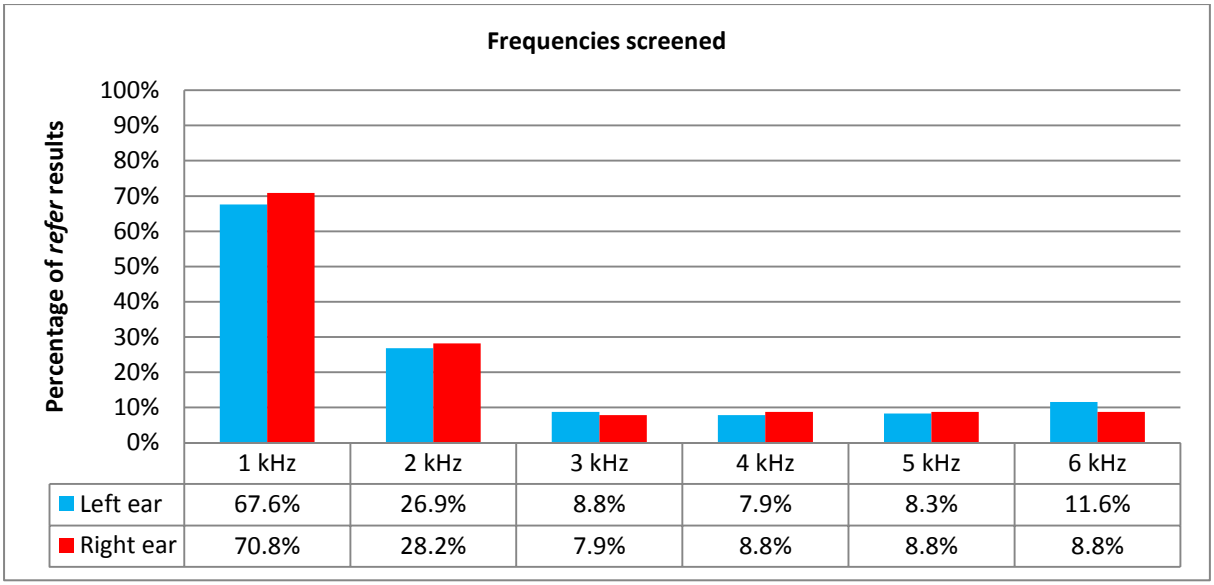
8.2.3.2 Repeat hearing screening outcome

Two hundred and sixteen participants (66.5%) underwent a repeat hearing screening six weeks post discharge. Findings from the repeat hearing screening are presented in Table 18.

Table 18: Repeat hearing screening outcomes for each screening measure and all three measures combined

Screening measure	Outcome	Overall		Left ear		Right ear	
		n	%	n	%	n	%
DPOAE	*Pass*	185	85.6	193	89.4	194	89.8
	Refer	27	12.5	20	9.3	19	8.8
	Could not test	4	1.9	3	1.4	3	1.4
TEOAE	*Pass*	194	89.8	199	92.1	200	92.6
	Refer	21	9.7	16	7.4	15	6.9
	Could not test	1	0.5	1	0.5	1	0.5
AABR	*Pass*	203	94.0	207	95.8	204	94.4
	Refer	7	3.2	4	1.9	7	3.2
	Could not test	6	2.8	5	2.3	5	2.3
Overall result of three tests	*Pass*	183	84.7				
	Refer	27	12.5				
	Incomplete	6	2.8				
Recommendations	Behavioural audiometry	183	84.7				
	Diagnostic ABR	9	4.2				
	Rescreen	24	11.1				

DPOAE refer results were obtained for 20 (9.3%) left ears and 19 (8.8%) right ears. Using the bilateral pass criterion, 185 (85.6%) participants passed the DPOAE screening whilst 27 (12.5%) participants referred on this screening measure. Refer findings were highest at 1 kHz for both ears (Figure 19). DPOAE screening was not conducted on four participants due to the participants being difficult to calm at the time of testing.



	1 kHz	2 kHz	3 kHz	4 kHz	5 kHz	6 kHz
Left ear	67.6%	26.9%	8.8%	7.9%	8.3%	11.6%
Right ear	70.8%	28.2%	7.9%	8.8%	8.8%	8.8%

Figure 19: *Refer* results per frequency for DPOAE at repeat hearing screening (n=216)

Refer findings were obtained for 16 (7.4%) left ears and 15 (6.9%) right ears for TEOAE screening. Using the bilateral *pass* criterion, 194 (89.8%) *passed* the repeat TEOAE screening whilst 21 (9.7%) *referred*. One participant could not be tested using this measure due to her being restless at the time (Table 18).

Analysis of AABR outcome at the repeat hearing screening indicated *refer* results for 4 (1.9%) left ears and 7 (3.3%) right ears. In terms of the bilateral *pass* criterion, 203 (94%) participants *passed* the repeat AABR screening and 7 (3.2%) participants *referred* on this screening measure. AABR screening could not be completed on six participants due to them being difficult to calm at the time.

Analysis of overall outcome of all three measures in combination indicated that a higher number of participants (84.7 %) *passed* the repeat hearing screening, compared to those who *referred* (12.5%). Overall, a repeat hearing screening could not be completed fully on six participants (2.8%).

Overall, screening was classified as incomplete for these six participants due to a lack of DPOAE, TEOAE and/or AABR screening results. In comparison to findings from the initial hearing screening, the *refer* rate (for each measure individually as well as when considered together using the overall outcome) was significantly lower at the repeat hearing screening (12.5%). At the initial hearing screening, the *referral* rate for each of the three individual tests was significantly lower than the overall *referral* rate (40.9%). The *referral* rate for TEOAE was significantly lower (23.7%) than that for AABR (32.6%). At the repeat hearing

screening, the *referral* rate for AABR (2.8%) was significantly lower than that for DPOAE (12.5%), TEOAE (9.7%) and the overall outcome (12.5%).

The recommendations after the repeat hearing screening were behavioural audiometry at six months corrected age (84.7%; n=183), rescreening (11.1%; n=24) and diagnostic ABR (4.2%; n=9).

8.2.3.3 Rescreen outcome

Twenty four participants were recommended to undergo a rescreen three weeks after the repeat hearing screening. Six of these 24 participants required a rescreen due to incomplete results at the repeat hearing screening as a result of challenges encountered during attempts to calm them down for the testing procedures. The remaining 18 participants had suspected transient middle ear effusion at the repeat hearing screening. These 18 participants *passed* AABR but *referred* on DPOAE and/or TEOAE screening. High frequency tympanometry findings also indicated an absence of a positive peak in these participants (Table 19).

Table 19: Rescreen outcome for each screening measure and all three measures combined

Screening measure	Outcome	Overall		Left ear		Right ear	
		n	%	n	%	n	%
DPOAE	*Pass*	8	80.0	9	90.0	8	80.0
	Refer	2	20.0	1	10.0	2	20.0
TEOAE	*Pass*	8	80.0	9	90.0	8	80.0
	Refer	2	20.0	1	10.0	2	20.0
AABR	*Pass*	10	100.0	10	100.0	10	100.0
	Refer	0	0.0	0	0.0	0	0.0
Overall result of three measures	*Pass*	8	80.0				
	Refer	2	20.0				
Recommendations	Behavioural audiometry	8	80.0				
	Diagnostic ABR	2	20.0				

Ten of the 24 participants (41.7%) returned for rescreening. Using a bilateral *pass* criterion, all 10 participants passed the AABR screening, whereas eight participants passed both DPOAE and TEOAE screening. Analysis of the overall outcome of all three measures in combination indicated a *pass* result for eight participants and a *refer* results for two participants. These two participants were booked for diagnostic ABR assessment whilst the

eight participants who *passed* were booked for behavioural audiometry at six months corrected age.

8.2.3.4 Diagnostic audiological assessment outcomes

Out of a total of 202 participants referred for diagnostic audiological assessment, a total of 93 participants attended. Diagnostic audiological assessment consisted of behavioural audiometry at six months corrected age for those who presented with an overall *pass* screen outcome (at the repeat hearing screening or rescreen) or a diagnostic ABR for those who presented with an overall *refer* screen outcome (at the repeated screening or rescreen).

Eleven participants were recommended to undergo a diagnostic ABR assessment, nine following the repeat hearing screening outcome (at six weeks post hospital discharge) and two following the rescreen outcome (three weeks after the repeat hearing screening) (Figure 17). Six of the 11 participants attended the diagnostic ABR appointment. Of these six participants, five presented with estimated hearing within normal limits, and results for one participant was inconclusive due to incomplete testing. This participant was subsequently booked for another appointment but did not arrive.

One hundred and ninety one participants were booked for a six month behavioural assessment, 183 following the repeat hearing screening and eight following the rescreen. Of these 191 participants, 87 attended the behavioural assessment. Of the 87 participants that attended the six month behavioural assessment, 86 (98.8%) presented with hearing within normal limits and one had inconclusive findings. This participant was booked for a follow-up diagnostic audiological assessment but did not arrive. The proportion of true hearing loss based on diagnostic audiological findings (diagnostic ABR and diagnostic behavioural assessment) was thus 0% (95% CI: 0.0-4.0%) for those that attended all three sessions.

Of the caregivers of the 93 participants who underwent diagnostic assessment, none reported parental concern for hearing loss. Appropriate developmental milestones were reported by 91 of the 93 caregivers of participants. Two caregivers reported delayed developmental milestones. Of the two participants with delayed developmental milestones, one presented with mixed cerebral palsy and the other with hypotonia.

8.2.4 Relationship between case history factors and audiological function

The most common case history factor found in the current study was preterm birth (95.7%, n=311); followed by exposure to at least one type of ototoxic medication (87.69%, n=285) and NNJ (80.6%, n=262), specifically NNJ requiring PTT. Amongst the less frequently occurring case history factors were in-utero infections (congenital rubella, congenital syphilis and congenital cytomegalovirus), neurological conditions, hyperbilirubinemia, kernicterus, and syndromes such as Trisomy 13. A summary of the case history factors is provided in Table 20.

Table 20: Summary of occurrence of case history factors in the total sample, from most frequently to least frequently occurring (n=325)

Case history factor	n	%
Preterm*	311	95.7
Exposure to ototoxic medication (at least one or more types of ototoxic medications)	285	87.7
NNJ*	262	80.6
Birth weight (<1500 grams)*	217	66.7
Ventilation (IPPV and/or CPAP)*	114	35.0
NICU stay	95	29.2
RVD exposure*	69	21.2
Neurological condition*[a]	29	8.9
Family history of congenital hearing loss	8	2.5
Hyperbilirubinemia*	7	2.1
Congenital syphilis	2	0.6
Congenital rubella*	1	0.3
X-ray features of congenital rubella	1	0.3
Congenital cytomegalovirus*	1	0.3
Kernicterus	1	0.3
Trisomy 13 with cleft lip and palate*	1	0.3

**- denotes case history factors present in participants that passed away in the current study sample*

[a] *Conditions such as IVH, HIE, perinatal asphyxia*

The percentages do not sum up to 100% as some participants presented with more than one case history factor.

The purpose of exploring the relationship between case history factors and audiological function was to determine the case history factors associated with hearing loss in diagnosed cases of hearing impairment. However, due to the proportion of true hearing loss in the current sample being 0% following diagnostic audiological assessment (behavioural audiometry or diagnostic ABR evaluation), the association between case history variables and auditory function could not be investigated. Analysis was also conducted to determine the association between case history factors and hearing screening outcome. These case history factors included birth weight classification, gestational age classification, bilirubin outcome,

RVD exposure of baby, ventilation, presence of a neurological condition, NICU admission, and exposure to ototoxic medication. Association between gestational age classification and hearing screening outcome was conducted for both initial and repeat hearing screening as there has been contrary findings in literature regarding the influence of age on screening outcome (Müller-Mazzotta, Zemlin, Berger, & Hanschmann, 2012; Patel, et al., 2011; van Dommelen, van Straaten, & Verkerk, 2011).

The early term, preterm, full term and late term classification for gestational age could not be used in the analysis due to very low groups sizes in the early term (n=2) and full-term (n=3) groups. Therefore, for the purposes of the current study, participants were classified as less than, or more than 34 weeks gestational age (<34w / 34w+). In the total sample, 82.5% of the participants had a gestational age of less than 34 weeks. With regards to bilirubin outcome, hyperbilirubinemia was excluded due to the very small group size. The analysis was thus conducted based on the presence or absence of NNJ. Participants with RVD exposure that was "unknown" were excluded from analysis.

There was no significant association between categorised gestational age and DPOAE, TEOAE, AABR or overall hearing screening outcome at the initial screening (Fisher's exact test; p=0.43, 0.23, 0.35 and 0.18 respectively). Similarly, there was no significant association between gestational age, or other case history factors and DPOAE, TEOAE, AABR or overall hearing screening outcome at the repeat screening. The p-values for each of the associations are provided in Table 21.

Table 21: P-values from analysis between case history factors and repeat hearing screening outcome

Case history variable	***p-value***			
	DPOAE	TEOAE	ABR	Overall
Birth weight (categorised)	0.49	0.21	0.23	0.51
Gestational age (categorised as <34w/34w+)	1.00	0.54	0.09	1.00
Bilirubin outcome	0.30	0.34	1.00	0.26
RVD exposure of infant	0.83	0.65	0.46	0.80
Ventilation required	0.27	0.81	1.00	0.27
Presence of neurological condition	0.32	0.70	0.54	0.32
NICU admission	0.82	0.80	1.00	0.82
Exposure to ototoxic medication	0.54	1.00	0.60	0.54

8.2.5 Comparison of combinations of audiological screening measures

8.2.5.1 Combinations of audiological screening measures providing true- positive and true- negative results, at and across time

The purpose of this objective was to determine the combination of screening measures that yielded the best sensitivity and specificity. The sensitivity of a measure refers to the ability of the measure to correctly identify individuals with a disease or target condition whereas the specificity of a measure refers to the ability of a measure to correctly identify individuals without the disease or target condition (ASHA, 1997). More specifically, in audiology, sensitivity represents the percentage of individuals labelled positive on screening (by a *refer* result) of all those who truly have a hearing loss. Specificity represents the percentage of individuals labelled negative on screening (by a *pass* result) of all those that do not have a hearing loss (ASHA, 1997; Johnson, 2002a). In order to determine sensitivity and specificity, controlled clinical trials must be conducted, whereby screening results are compared to diagnostic assessment findings or findings from a test that is considered an appropriate reference or gold standard for verification of the individual's true status (ASHA, 1997; ASHA, 2013). Hence, in order to calculate the percentage of TP (sensitivity) and TN (specificity) findings in the current study, only participants who had been followed up with diagnostic testing, and had conclusive diagnostic findings (n=91) could be included in the calculation.

Due to the absence of participants with hearing loss in the current study sample, analysis could only be conducted in relation to specificity (percentage of TN findings), and not sensitivity. Results from combinations of audiological screening measures at the initial and repeat hearing screening were analysed in relation to the final diagnostic outcome (n=91) which was considered the gold standard. Analysis was conducted using the overall screening outcome per measure, per participant. The screening result was further classified as *refer* if the outcome for any one screening measure within the specified combination was *refer*. The percentage of TN findings for each of the combinations of screening measures is tabulated below (Table 22).

Table 22: Specificity of various combinations of screening measures (n=91)

Combination of screening measures / tests	n	%TN	95% CI for %TN
DPOAE + AABR at initial screen	91	61.5	51.3-70.9
TEOAE + AABR at initial screen	91	63.7	53.5-72.9
DPOAE + TEOAE + AABR at initial screen	91	60.4	50.2-69.9
DPOAE + AABR at repeat screen	91	89.0	80.9-93.9
TEOAE + AABR at repeat screen	91	91.2	83.6-95.5
DPOAE + TEOAE + AABR at repeat screen	91	89.0	80.9-93.9
AABR at initial and repeat screen	91	68.1	58.0-76.8

The percentage of TN findings was highest at the repeat hearing screening (six weeks post discharge) using any combination of tests when compared to findings for any combination of tests from the initial hearing screening. There was no significant difference between the specificity of any test combinations within the initial hearing screening or within the repeat hearing screening.

Although differences were not significant, TEOAE combined with AABR (TEOAE/AABR), DPOAE combined with AABR (DPOAE/AABR) and the combination of all three screening measures yielded the highest percentage specificity at the repeat hearing screening.

8.2.5.2 Comparison of test time with different combinations of screening measures

Additional analysis was conducted related to the combinations of screening measures and test time (at the initial and repeat hearing screening), which apart from specificity, also contributes toward the logistics of the implementation of a NHS programme. Analysis was conducted using the paired t-test (or one-way repeated measures ANOVA for more than two groups) (Table 23).

Table 23: Comparison of test time (in minutes) for different combinations of screening measures

Combination of screening measures	Mean test time (min)	95% CI for mean test time (min)
TEOAE + AABR at initial screen	3.7	3.5-3.9
DPOAE + AABR at initial screen	5.8	5.5-6.2
TEOAE + AABR at repeat screen	3.0	2.8-3.2
DPOAE + AABR at repeat screen	5.1	4.7-5.5

The average time taken to screen both ears was used for purposes of analysis. Results indicated that the mean test time for TEOAE/AABR (3.7 min; 95% CI 3.5-3.9 min) was significantly lower than that for DPOAE/AABR (5.8 min; 95% CI 5.5-6.2 min) at the initial hearing screening. Similarly, at the repeat hearing screening, the mean test time for TEOAE /AABR (3.0 min; 95% CI 2.8-3.2 min) was significantly lower than that for DPOAE/AABR (5.1 min; 95% CI 4.7-5.5 min).

8.2.5.3 Comparison of the overall initial and repeat hearing screening outcomes

Whilst the analysis of "screen specificity" is one aspect that contributes toward ascertaining the cost-effectiveness of a protocol, identifying the combination of screening measures yielding a low referral rate is another important aspect within a NHS programme. Hence, additional analysis was conducted by comparing the overall initial hearing screening outcome (in-hospital) to the overall repeat hearing screening outcome (six weeks post discharge). Analysis was conducted using McNemar's test for paired data, with a 5% level of significance $(p < 0.05)$.

Combinations of screening measures were analysed for participants who underwent an initial and repeat hearing screening, with complete hearing screening results at both screening sessions. These findings are depicted in Table 24.

Table 24: Comparison of agreement of screening outcome between initial and repeat screening

Combination of screening measures	% *pass* outcome at initial and repeat screen	% *refer* outcome at initial and repeat screen	% agreement across initial and repeat screen	p-value for McNemar's test
DPOAE + TEOAE + AABR	59.1	6.7	65.7	$p < 0.0001$
DPOAE + AABR	56.7	6.7	63.3	$p < 0.0001$
TEOAE + AABR	62.4	5.7	68.1	$p < 0.0001$
AABR + AABR	69.5	1.9	71.4	$p < 0.0001$

Analysis conducted using all three measures (DPOAE, TEAOAE and AABR) employed in the current study indicated a significant disagreement between the two sets of results (p<0.0001). Only 65.7% (n=210) of the outcomes agreed across the two hearing screenings; 28.1% *referred* on the initial screening but *passed* the repeat screening, while 6.2% passed the initial screening but referred on the repeat screening.

There was significant disagreement between the two sets of results for the combination of DPOAE and AABR (p<0.0001). Only 63.3% (n=210) of the outcomes agreed across the two hearing screenings; 30.5% *referred* on the initial screening but *passed* the repeat screening, while 6.2% *passed* the initial screening but *referred* on the repeat screening.

Significant disagreement was also noted between the two sets of results for the TEOAE /AABR combination (p<0.0001). Only 68.1% of the outcomes agreed across the two screenings; 27.1% *referred* in the initial screening but *passed* the repeat screening, while 4.8% *passed* the initial screening but *referred* on the repeat screening.

There was significant disagreement between the two sets of results when comparing AABR findings at the two screening sessions (p<0.0001). Only 71.4% of the outcomes agreed across the two screenings; 27.1% *referred* in the initial screening but *passed* the repeat screening, while 1.4% *passed* the initial screening but *referred* on the repeat screening.

There was no significant difference between the percentage agreement over the four test combinations (63-71%). However, based on the *referral* rate at the initial hearing screening, the *referral* rate at the repeat hearing screening was significantly lower for the AABR-only combination (1.9%) than the other three combinations of screening measures (5.7-6.7%).

8.2.6 Percentage of true-positive and true-negative screening results in the total sample

In order to determine the percentage of TP and TN screening results, participants had to have undergone an initial hearing screening, repeat hearing screening as well as a diagnostic assessment. Attendance of and determination of conclusive diagnostic findings were imperative for analysis to ensure valid representation of the proportion of participants with and without hearing impairment. Due to the absence of hearing impairment amongst participants with conclusive diagnostic findings, the percentage of TP screening results could not be established in the current study sample. Furthermore, it is important to recognise that the percentage of TN screening results may have varied based on analysis of the outcomes of various combinations of screening measures. These variations in TN screening results were presented in sub-section 8.2.5.1.

The protocol employed in the current study required all participants to have undergone a repeat hearing screening regardless of the outcome at the initial hearing screening. Participants had to *pass* all three audiological screening measures at the repeat hearing screening in order to be booked for a behavioural audiological assessment at six months corrected age. Participants who *passed* AABR, but *referred* on TEOAE and/ or DPOAE underwent a rescreen because of suspected transient middle ear effusion, whereas those who *referred* on OAEs and AABR were booked for a diagnostic ABR assessment. For the purposes of this secondary objective, results were analysed in alignment with the protocol employed in the current study. Hence, findings are described according to the overall screening outcome for all three screening measures combined, at each of the screening sessions (Table 25).

Table 25: Overall screening outcome and percentage of true-negative screening results at each screening session for all three screening measures combined.

Screening session	n	Overall *pass* outcome	Overall *refer* outcome	% TN	Recommendation			
					Repeat hearing screening	Rescreen	Diagnostic ABR	Behavioural audiological assessment
Initial	91	55	36	60.4	91			
Repeat	91	81	10	89.0		6	4	81
Rescreen	6	5	1				1	5

An overall *pass* outcome was defined as a *pass* result for all three screening measures, while an overall *refer* outcome was defined as a *refer* result on any of the three screening measures.

The total sample for analysis was 91 as this was the total number of participants who underwent an initial hearing screening, repeat hearing screening and/or a rescreen, as well as a diagnostic audiological assessment. Of these 91 participants, 55 presented with an overall *pass* outcome (TN finding) and 36 with an overall *refer* outcome (FP finding) at the initial hearing screening. The percentage of TN screening results at the initial hearing screening was 60.4%.

Findings differed at the repeat hearing screening, whereby 81 of the 91 participants presented with an overall *pass* outcome, while 10 presented with an overall *refer* outcome. The percentage of TN screening results at the repeat hearing screening was 89.0%, higher than that of the initial hearing screening.

Six of the ten participants that presented with an overall *refer* outcome at the repeat hearing screening underwent a rescreen due to suspected transient middle ear effusion (as indicated by a *refer* outcome on OAEs, accompanied by a *pass* outcome on AABR, and no discernible positive peak on high frequency tympanometry). Five of the six participants presented with an overall *pass* outcome at the rescreening, while one presented with an overall *refer* outcome. Due to the small number of participants that underwent a rescreening, a TN percentage was not calculated.

Furthermore, the overall, combined screening outcome from the initial and repeat hearing screening sessions was analysed in terms of TP, TN, FP and FN findings (Table 26).

Table 26: False-negative and false-positive findings using the overall outcome from initial and repeat hearing screening combined (n=91).

Overall combined screening outcome	Diagnostic outcome (n=91)	
	Hearing loss	No hearing loss (hearing within normal limits)
Overall *refer* at initial and/or repeat hearing screening	0 (TP)	37 (FP)
Pass at both initial and repeat hearing screening	0 (FN)	54 (TN)

Although 37 of the 91 participants who initially presented with a *refer* finding at one or both screening sessions presented with confirmed hearing within normal limits, there were no FN findings amongst the 91 participants that underwent the initial hearing screening, repeat hearing screening, and diagnostic assessment. These findings highlight the accuracy of the screening measures employed in the current study as there were no "missed" cases of hearing impairment, that is to say that no participants *passed* the hearing screening that should have *referred*.

8.2.7 Factors associated with follow-up return rate for hearing screening and diagnostic audiological assessment

Factors associated with the follow-up return rate were determined for the repeat hearing screening, rescreening as well as diagnostic audiological assessments. Follow-up return rate was calculated for each of the hearing screening sessions as well as for the diagnostic audiological assessment. Caregivers of participants who did not keep appointments were contacted to determine reasons for non-attendance. Results are presented for each of the sessions. The percentage of participants that returned for follow-up are presented in Table 27, followed by the reasons for follow-up default or non-attendance. Additional analysis was also conducted by exploring the association between specific case history factors and follow-up at the repeat hearing screening and at the six month behavioural assessment.

Table 27: Number of participants expected versus those that attended for each session

Session	Number of expected participants	Number of participants that attended	% participants lost to follow-up
Repeat hearing screening	325	216	33.5
Rescreen	24	10	58.3
Diagnostic assessment	202	93	53.9

8.2.7.1 Follow-up at repeat hearing screening

All 325 participants who underwent an initial hearing screening were scheduled to undergo a repeat hearing screening on the morning of their first NNFU visit at the respective research sites. Of the 325 participants, 216 returned for the repeat hearing screening, resulting in a follow-up return rate of 66.5%. For the 109 infants who did not return, the reasons for non-attendance are illustrated in Figure 20.

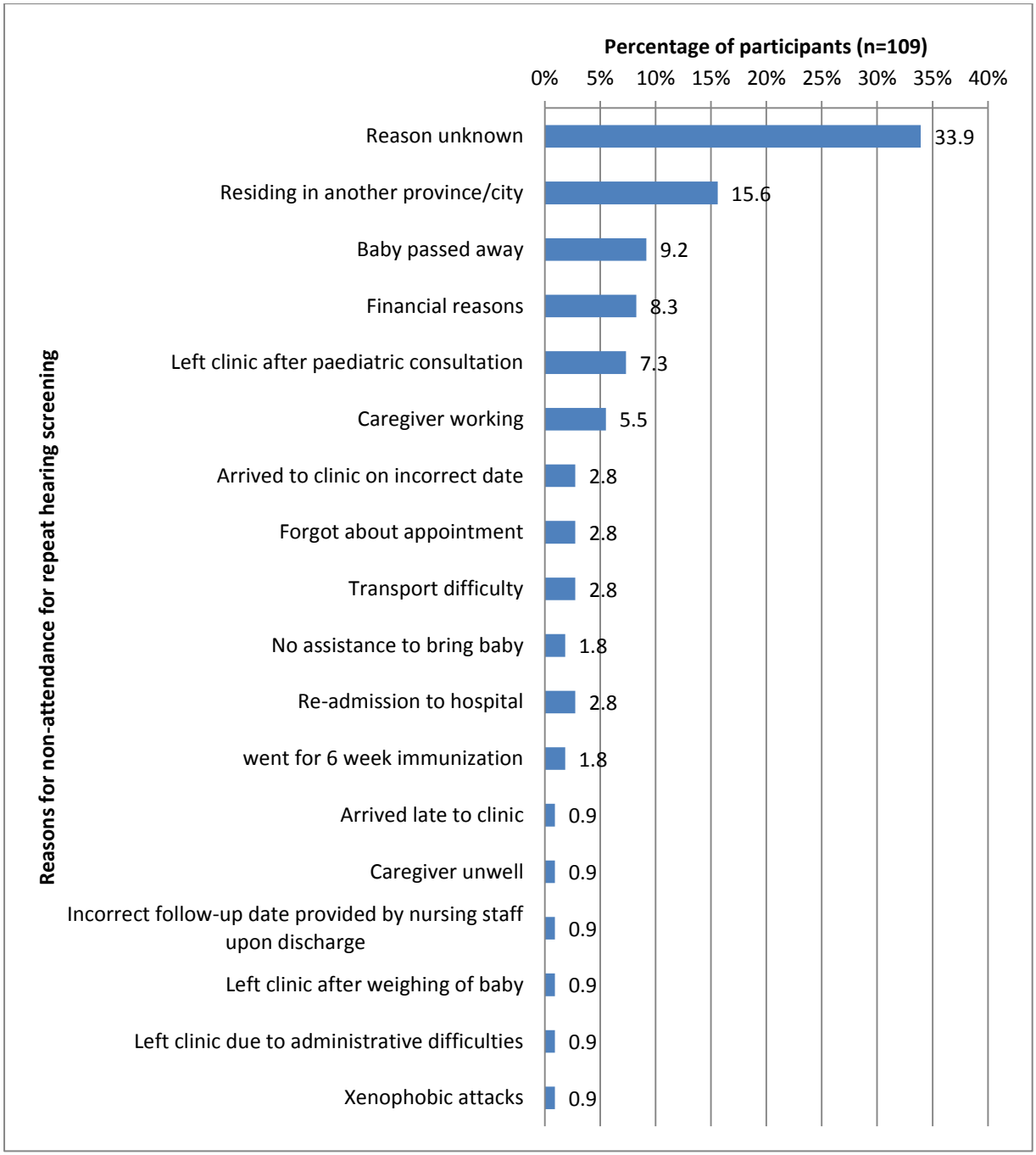


Figure 20: Reasons for follow-up default at the repeat hearing screening

For 33.9% of the sub-sample that did not attend the repeat hearing screening; reasons for non-attendance could not be established as caregivers of participants could not be reached telephonically. For the rest of the participants; reasons varied and are presented in order of frequency in Figure 20; with the most common reasons for non-attendance at the repeat hearing screening being change of residential location (15.6%), the death of the infant (9.2%); and financial reasons (8.3%).

8.2.7.2 Follow-up at rescreen (session between the repeat hearing screening and diagnostic assessment as a result of incomplete repeat hearing screening or suspected middle ear effusion following the repeat hearing screening)

Of the 216 participants that underwent a repeat hearing screening, 24 were scheduled for a rescreening three weeks following the repeat hearing screening. Ten of these participants attended the rescreening. Of the 14 participants that did not attend, reasons for non-attendance were unknown for 10 participants as caregivers of participants could not be reached telephonically. Three participants did not attend due to the caregiver working on that day, and the caregiver of one participant had forgotten about the appointment.

8.2.7.3 Follow-up at diagnostic assessment

Based on the outcome of the repeat hearing screening, as well as the attendance and outcome at the rescreen, 202 participants were scheduled for diagnostic audiological assessment (191 for behavioural audiometry and 11 for diagnostic ABR). Of these 202 participants, 93 attended the diagnostic assessment. Eighty seven of the 93 participants attended a diagnostic behavioural assessment at six months corrected age, while six underwent a diagnostic ABR. The follow-up return rate decreased significantly to below 50% for diagnostic assessment. The reasons for non-attendance among the 104 infants who did not attend the behavioural audiological assessment are illustrated in Figure 21; with over half of the participants having been unreachable to obtain a reason as a result of telecommunication challenges. Other reasons for non-attendance varied and are presented in the order of frequency in Figure 21; with the most common reasons being caregivers residing in another province/city (8.7%) caregiver employment (7.7%), and financial reasons (6.7%). Reasons for non-attendance for diagnostic ABR assessment were unknown for three participants, one participant was ill and the other passed away (Figure 21).

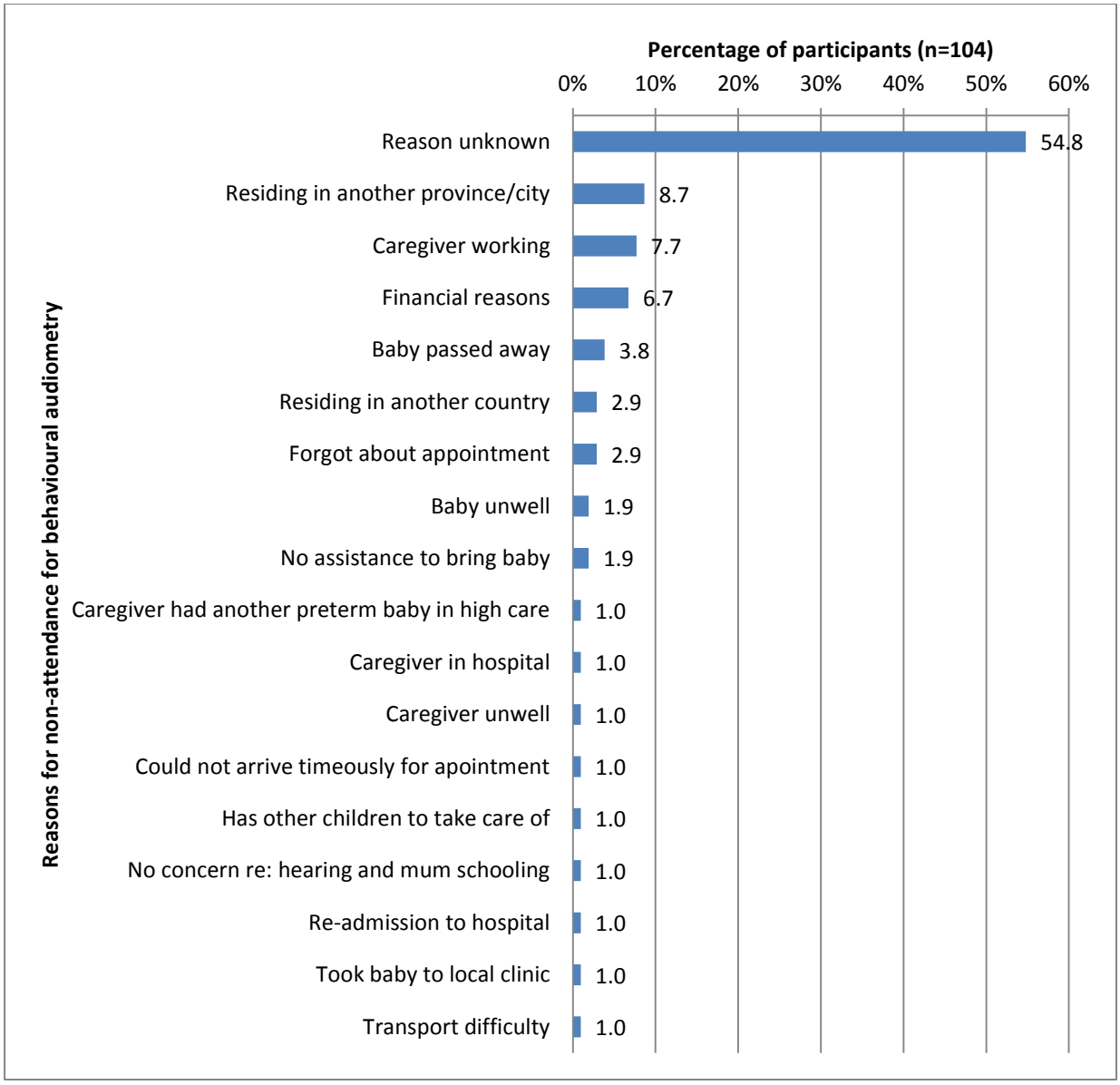


Figure 21: Reasons for follow-up default for behavioural audiometry at six months corrected age.

8.2.7.4 Association between case history factors and follow-up

The aim of this analysis was to investigate the association between various case history factors and whether or not participants returned for follow-up assessments at the repeat hearing screening, and at behavioural audiometry at six months corrected age. The various factors included the hospital where hearing screening was conducted, maternal age, maternal education level and whether or not the participant was the caregiver's first child. Analysis was conducted using the Fisher's exact test, the independent samples t-test for continuous variables, or the Wilcoxon rank sum test.

Analysis of the association between the various factors and follow-up at the repeat hearing screening was conducted using a sample of 315 participants (n=315). This sample excluded the 10 infants who had passed away and who could thus not have attended the screening (Table 28).

Table 28: Analysis of the association between case history factors and follow-up at the repeat hearing screening

Variable	Category	Overall		Attended screening				p-value for test for significant between-group difference
				No		Yes		
		n	%	n	%	n	%	
N		315		99		216		
Hospital	CMJAH	70	22.2	40	57.1	30	42.9	<0.0001
	RMMCH	245	77.8	59	24.1	186	75.9	
Maternal Education	Secondary	265	84.9	82	30.9	183	69.1	1.00
	Tertiary	47	15.1	14	29.8	33	70.2	
First child	No	186	59.0	57	30.6	129	69.4	0.81
	Yes	129	41.0	42	32.6	87	67.4	
Maternal age	Mean (sd)	28.1 (6.3)		27.4 (6.5)		28.5 (6.2)		0.14

Follow-up differed between the two hospitals (research sites) included in the current study as 42.9% of infants from CMJAH returned, while a significantly higher percentage (75.9%) from RMMCH returned. Results as depicted in Table 28 indicated a significant but weak, association between the hospital and whether or not infants returned for the repeat hearing screening (Fisher's exact test: $p<0.0001$; phi coefficient=0.30).

There was no significant association between maternal education level and whether or not infants returned for the repeat hearing screening (Fisher's exact test: p=1.00). The education category 'No schooling' (n=1) was excluded for the purposes of this analysis.

There was also no significant association between whether or not this was the caregiver's first child and whether or not participants returned for the repeat screening (Fisher's exact test: p=0.81).

Investigation of the association between maternal age and follow-up also revealed no significant association between the mean maternal age of those who did and did not return for the repeat hearing screening (t-test: p=0.14).

Analysis of the association between the various factors and follow-up at the behavioural assessment was conducted using a sample of 187 participants (Table 29). These 187 participants are inclusive of the participants who did and did not attend the behavioural assessment at six months corrected age. The four participants who passed away in the interim were excluded from the analysis.

Table 29: Analysis of the association between case history factors and follow-up at the behavioural assessment at six months corrected age

Variable	Category	Overall		Attended screening				p-value for test for significant between-group difference
				No		Yes		
		n	%	n	%	n	%	
N		187		100		87		
Hospital	CMJAH	24	12.8	10	41.7	14	58.3	0.21
	RM	163	87.2	90	55.2	73	44.8	
Maternal Education	Secondary	159	85.0	85	53.5	74	46.5	>0.99
	Tertiary	28	15.0	15	53.6	13	46.4	
First child	No	114	61.0	62	54.4	52	45.6	0.76
	Yes	73	39.0	38	52.1	35	47.9	
Maternal age	Mean (sd)	28.2 (6.3)		27.6 (6.1)		29.7 (6.2)		0.023

Results indicated no significant association between whether or not infants returned for the six month behavioural assessment and the hospital (p=0.21), maternal education level (p > 0.99), or first child/not (p=0.76). However, the mean maternal age for those who returned (29.7yrs; sd=6.2yrs) was significantly higher than the mean maternal age of those who did not return (27.6yrs; sd=6.1yrs) (p=0.022). The effect size was small (d=0.34).

Chapter summary

In this chapter, results for case history data; audiological function; TP and TN screening results and factors associated with follow-up return rate were presented. These findings will be discussed in the next chapter.

CHAPTER 9: DISCUSSION

This chapter presents a discussion of the findings in accordance with the specific aims of the study. This is done with reference to available and relevant literature in order to be able to substantiate the evidence from the current study; with the goal of extrapolating relevant evidence to contribute to the existing knowledge base; inform practice; and raise implications for the implementation of NHS programmes in South Africa.

Risk-based or TNHS has been recommended as an interim step in contexts where UNHS is not yet feasible. Although it is argued that TNHS may result in missed cases of hearing impairment, literature suggests that the rate of hearing impairment is much higher in infants with recognised risk factors than in those without risk factors (WHO, 2010). Risk factors for hearing loss have been defined by the JCIH (2007) position statement and have been adopted in many countries, with country adaptations based on contextually identified findings. These risk factors associated with hearing impairment have been based on findings related to the relationship between specific medical conditions and audiological outcomes in newborns and infants. Recommendations have also been made in the literature regarding appropriate screening measures for high-risk newborns and infants, specifically those admitted to the NICU (JCIH, 2008).

Although the types of screening measures and protocols used on specific newborn and infant populations have been standardised in some countries – mostly developed countries, differences in the screening measures and protocols adopted still exist worldwide. These differences are primarily based on outcomes related to sensitivity, specificity, and referral rates which contribute to the overall cost-effectiveness of a NHS programme. The results arising from the exploration of risk-based or TNHS in the public health care sector in Gauteng, South Africa relate to some of these recommendations, and are discussed in this chapter. Current findings are therefore believed to have particular relevance to the implementation of TNHS in public health care settings where NHS is minimally conducted, not yet implemented, or only conducted upon referral from a medical professional; a scenario typically representative of the South African context and that of the developing world generally.

Prior to the discussion of the findings for each specific aim; it was important to analyse the socio-demographic and contextual factors of the caregivers in the current sample. Caregivers of newborns and infants play a pivotal role in any NHS programme as they are responsible for providing consent for hearing screening to be conducted and for bringing the newborn or infant for follow-up appointments. Furthermore, caregivers are key decision makers throughout the EHDI process. Socio-demographic and contextual factors such as maternal age, ethnicity, maternal education, distance from health care facilities and parity may influence the use and uptake of health care services in developing countries (Babalola & Fatusi, 2009; Say & Raineb, 2007; Tsawe et al., 2015). Therefore; analysis of caregiver demographic information was believed to be appropriate due to the longitudinal nature of the current study, as well as the level of caregiver involvement required throughout the screening and diagnostic aspects employed in the current study.

Current findings specific to caregiver demographic profile revealed that caregivers of participants in the current study sample were deemed representative of the general maternal demographic profile within the South African context. Firstly, as far as maternal age was concerned; current findings revealed that caregivers comprised of mothers mostly between the ages of 25 and 35 years, with a mean age of 28.1 years. Literature indicates that the highest proportion of births in South Africa has been among women aged between 20 and 34 years. More specifically, statistical data from Gauteng indicates the highest birth occurrences among women between 25-29 years of age (Statistics South Africa, 2015). The maternal age in the current study is also in agreement with that from another South African study where mean maternal age was 25 years (Parag, McKerrow, & Naby, 2014).

Secondly, analysis of caregiver nationality and languages spoken in the current study revealed that the majority of caregivers were of South African nationality with isiZulu being the most commonly spoken home language. Apart from South African nationality, other nationalities were also represented in the demographic profile of caregivers. This is consistent with a high number of migrants as reported in the censuses in 2001 and 2011; especially for the Gauteng province. These findings highlight the aspect of migration within the South African context, which is consistent with findings related to migration patterns and streams from a community survey conducted by Statistics South Africa in 2007, as well as foreign and domestic labour migration data (MiWorc, 2013; Statistics South Africa, 2014). This migration factor of the population studied is believed to have implications for follow-up services within EHDI programmes. It is important, therefore, that EHDI initiatives within this

region take this aspect into consideration in order to appropriately plan for implementation of successful and sustainable early intervention services.

Thirdly; as far as caregiver level of education was concerned; current findings revealed that secondary schooling was the highest level of education amongst most caregivers of participants in the current sample. These findings are not contrary to the documented educational levels in South Africa. South African statistics related to educational achievement indicate that the highest level of education among females aged 25 years and above has been lower than Grade 12, followed by completion of Grade 12 (the final grade within the South African, secondary schooling system) (Statistics South Africa, 2013a). Literature argues that maternal levels of education are strongly associated with socio-economic status in studies related to access to maternal health care services in South Africa (Wabiri et al., 2013). For the current study purposes; maternal level of education has implications for EHDI, as caregivers with a lower socio-economic status and a subsequently lower level of education may require more support in navigating the EHDI system; as well as support adhering to EHDI plans. Documented evidence specific to the influence of maternal education suggests that higher educational levels are associated with timely follow-up, earlier diagnosis, and earlier intervention (Holte et al., 2012). Current findings therefore have implications for the South African context as they highlight the importance of context responsive strategies which take into cognizance the level of education; and its proven influence on the success or failure of an EHDI programme. These findings further highlight the importance of adequate provision of information regarding the processes involved within the EHDI programme (Laugen, 2013), as well as the need for appropriate and easily accessible referral pathways. The effects of multilingualism and possible language mismatch between caregivers and audiologists need to be carefully considered during interaction and information counselling within the South African context (Ramkissoon & Khan, 2003). The provision of the information would need to not only consider the levels of education; but also linguistic and cultural diversity issues which might be concomitant influencing factors. In addition, one may also need to consider the recipients of this information; particularly if grandparents are the primary caregivers instead of parents; a reality that may be specific and relevant to the context of the current study.

Apart from the demographic profile of caregivers, the general demographic profile of participants in terms of gender, ethnicity and place of birth was also analysed prior to the detailed analysis of the case history factors. Firstly, with regard to gender, the current study

sample comprised more females than males. These findings differ from recent South African gender estimates of recorded live births; which have indicated a trend of slightly more male than female births (Statistics South Africa, 2015). However, current gender profile findings are consistent with what is reported of the LBW population. Literature has indicated a higher likelihood of LBW in females (Ballot, Potterton, Chirwa, Hilburn, & Cooper, 2012; Banga, Barche, Singh, Sheehan, & Vasylyeva, 2015). These authors also report that VLBW males are more vulnerable to postnatal complications and mortality; hence, gender may influence the clinical outcome of neonates born with a lower birth weight. It is the current author's belief that the lower percentage of males in the current study sample may have influenced the frequency of postnatal complications in the current study sample, which consequently may have influenced the audiological outcome of participants in the study.

Secondly, in terms of ethnicity of participants, the current study sample mainly consisted of Black Africans, followed by Coloureds, then Whites and lastly Indians. These findings are reflective of the national estimates of the general South African population, whereby Black Africans constitute approximately 80% of the total population in South Africa, followed by Coloureds, Whites and Indians (Statistics South Africa, 2014). The distribution of ethnicity in the current study could also be linked to the vast differences in access to, and use of public versus private health care facilities in South Africa; as argued by Kon and Lackan (2008) and as reflected by Statistics South Africa (2013a). Evidence indicates that the Black African and the Coloured population groups use health facilities in the public sector (81.3% and 63.1%, respectively) whereas those from the White and the Indian/Asian population groups mostly use health facilities in the private sector (88.0% and 64.1%, respectively) (Statistics South Africa, 2013a; Statistics South Africa, 2013c).

Thirdly, with regard to place of birth, most participants in the current study sample (94.1%) were born in hospital, with a small percentage (5.9%) having been BBA to hospital. The prevalence rate of BBAs in the current sample is consistent with previously reported rates for the country of 5.4%; and that for Gauteng of 5% that were accessed and cited by Parag and colleagues from the district health information database in 2012. These rates are higher than the most recently reported ones by Parag and colleagues (2014) who reported a prevalence rate of BBA of 1.8% in a peri-urban setting in South Africa. Current findings of higher numbers of hospital births than home births is believed to have positively influenced hearing screening coverage rates in the current study, as well as the medical management and clinical outcome of participants. It is important to interpret these findings taking this into

consideration; and to deliberate the possible difference rurality might have in the South African context where hospital births may possibly not be as high as in the current study's context which was urban. A lower number of hospital births in rural areas may be due to a documented lower number of births attended by skilled health personnel in these contexts (WHO, 2011).

Case history factors in the current study were recorded for all participants at the initial, in-hospital hearing screening. The first sub-aim of the current study was to describe the recorded case history factors in a group of high-risk neonates. Although there is no one particular definition of a high-risk infant, it is the view of the current researcher that the current study sample was representative of this population as participants required special health care needs and were admitted to the NICU and/or high care wards (after birth); as defined by the AAP (2008) and Yee and Ross (2006). These infants were thereafter transferred to respective "step-down" wards or KMC wards once considered medically stable.

All case history factors were recorded from participant files. These documented case history factors were not limited to the JCIH and HPCSA position statements' stipulated risk factors for hearing loss. Current findings with regards to recorded case history factors are discussed in relation to literature in terms of their frequency of occurrence, whether they are documented as risk indicators for hearing loss, and on their documented association with hearing impairment.

From the analysis of case history factors, emergency caesarean section was the most common mode of delivery (48.9%) in the current sample, with most participants (58.5%) having been born preterm (95.7%) and with VLBW (59.1%). Although the rates of emergency caesarean section have not been specified in South African literature, caesarean section in general has been reported as an increasingly common procedure in both public and private health care sectors in South Africa (Naidoo & Moodley, 2009). A review of literature indicates that most premature babies are born between 32 and 37 weeks gestation with about 10% born between 28 to < 32 weeks gestation (Lawn et al., 2013). Furthermore, it is reported that prematurity and VLBW are often co-occurring factors in the high-risk infant population, with preterm birth being the reason for lower birth weight (Institute of Medicine (US) Committee on Understanding Premature Birth and Assuring Healthy Outcomes, 2007; Ohl, et al., 2009; WHO, 2015). Several studies investigating the risk profile of infants with hearing impairment, or the prevalence and incidence of hearing impairment in the high-risk

population have comprised of newborns and infants with prematurity and birth weight below 1500 grams in the study sample (Al-Meqbel & Al-Baghli, 2015; Bhagya, Crid, & Doddamani, 2011; Bielecki, et al., 2011; Coenraad, et al., 2010; Colella-Santos, et al., 2014; Hille, et al., 2007; Martines, et al., 2013; Mukherjee, Mukherjee, & Sarkar, 2013; Ohl, et al., 2009). However, very few of these studies have reported a statistically significant, independent association between these two case history factors (prematurity and birth weight below 1500 grams) and hearing impairment (Al-Meqbel & Al-Baghli, 2015; Bielecki, et al., 2011; Martines, et al., 2013). Birth weight below 1500 grams which was previously considered a risk indicator for hearing loss (JCIH, 1982), is no longer on the JCIH HRR as literature has indicated that the rates of hearing impairment are inversely proportional to the birth weight. However, birth weight below 1500 grams (along with prematurity) is important when associated with other risk factors or disorders that are common in newborns with prolonged NICU stay (Núñez-Batalla, et al., 2012). Although the majority of the participants in the current study were preterm with VLBW, which was one of the contributors to prolonged hospital stay; these case history factors are not necessarily associated with hearing impairment per se. Instead, they are risk indicators or risk markers that predispose the newborn or infant to other medical conditions or medical management (such as the ototoxic medication) that may be associated with or increase the risk of hearing impairment. Therefore, risk factors for hearing impairment cannot be viewed in isolation; but should be considered in relation to their interaction with multiple other risk factors.

Despite all participants in the current study having had a prolonged hospital stay (median length of 23 days), only 95 (29.2%) participants were admitted to NICU. In the current study; prolonged hospital stay was a frequently occurring case history factor. Although prolonged hospital stay, in particular, NICU stay has been documented to place a newborn or infant at risk for hearing impairment; current findings did not seem to support this position. The current author therefore argues that it is perhaps not the length of hospital stay per se, but the conditions, and severity of these conditions that determine the need for prolonged hospitalisation and/or admission to the NICU. This position is supported by Núñez-Batalla et al. (2012) who state that NICU stay for five days or longer has no pathophysiological basis as a risk factor, but has been included to encompass medical conditions that may result in hearing impairment or auditory neuropathy. The current author, therefore, supports Núñez-Batalla and colleagues' assertion that the inclusion of NICU as a risk indicator assists in

preventing cases going undetected as review of medical records for associated conditions may go unnoticed by staff conducting the hearing screening.

Further analysis of the case history factors in the current study sample revealed prematurity, exposure to ototoxic medication, and NNJ as some of the most frequently occurring conditions. Amongst the least frequently occurring case history factors were those related to in-utero infections (TORCH infections); neurological conditions; family history of congenital hearing loss; hyperbilirubinemia; kernicterus; and syndromes. Some of the medical conditions recorded in the current study sample are recognised as risk factors for hearing impairment in both the JCIH (2007) and HPCSA (2007) position statements, and have also been found to be associated with hearing impairment in the literature. Table 30 provides a summary of these case history factors, their documented frequency in the literature and whether or not they are considered to be risk indicators associated with hearing impairment. For example; Mukherjee et al (2013); Colella-Santos et al (2014); and Bielecki et al (2011) found that birth weight < 1500 grams, prematurity and hyperbilirubinemia were not associated with hearing impairment; which is consistent with current findings; whilst reports by Al-Meqbel and Al-Baghli (2015) were contrary to these findings. In addition, case history factors such as RDS; NEC II/III; RVD exposure; TTN; hyperglycaemia and hypoglycaemia that were recorded in the current study sample were not reported in study samples in cited literature. This could imply that context has an influence on the types of risk factors present within study samples at any given time as changes in disease prevalence can occur differently over time in different contexts. Furthermore, methodological aspects such as differences in sample size, statistical variation and the effects of confounding variables which can either increase or decrease true relative risk need to be considered when comparison is made between studies (Sanes & Conlisk, 2005). Therefore; the significance of current findings is that they are unique to the South African public health care context and need to be interpreted with caution when being compared to other studies related to risk factors for hearing impairment in newborns and infants. Literature review findings summarised in Table 30 highlight differences in the frequency of occurrence and definition of contextually relevant risk factors.

Table 30: Comparison of case history factors in the current study sample to high-risk registries and other literature.

Case history factor	JCIH (2007)	HPCSA (2007)	Current study sample	Statistically significant risk factor in literature	Frequency per sample size of high-risk infants	Developing/developed context	References
Anaemia			✓				
Apnoeas			✓				
Birth weight < 1500 grams *			✓	✗ ✗ ✗	17/127 153/992 359/2986	Developing & developed	(Mukherjee, et al., 2013) (Colella-Santos, et al., 2014 (Bielecki, et al., 2011)
Birth/perinatal asphyxia			✓	✓ ✓ ✓ ✓ ✗	17/200 25/147 16/1461 2068/2186 20/127	Developed & developing	(Al-Meqbel & Al-Baghli, 2015) (Bhagya, et al., 2011) (Ohl, et al., 2009) (Hille, et al., 2007) (Mukherjee, et al., 2013)
Caregiver concern regarding speech, language and or developmental delay	✓	✓					
Chemotherapy	✓			✗	1/992	Developing	(Colella-Santos, et al., 2014)

Chorioamnionitis			✓				
Craniofacial anomalies	✓	✓	✓	✓ ✓ ✗	6/127 22/992 124/2986		(Mukherjee, et al., 2013) (Colella-Santos, et al., 2014) (Bielecki, et al., 2011)
ECMO	✓	✓					
Exposure to ototoxic medication*	✓	✓	✓	✓ ✗ ✗ ✗	16/127 148/2186 239/992 985/2986	Developing & Developed	(Mukherjee, et al., 2013) (Hille, et al., 2007) (Colella-Santos, et al., 2014 (Bielecki, et al., 2011)
Family history of permanent childhood hearing loss	✓	✓	✓	✓ ✓ ✓ ✗ ✗	80/200 3/127 17/1461 7/992 142/2986	Developed & Developing	(Al-Meqbel & Al-Baghli, 2015) (Mukherjee, et al., 2013) (Ohl, et al., 2009) (Colella-Santos, et al., 2014 (Bielecki, et al., 2011)

Findings associated with a syndrome known to include sensorineural or permanent congenital hearing loss (PCHL)	✓	✓	✓	✓ ✓	232/2986 12/1461	Developed	(Bielecki, et al., 2011) (Ohl, et al., 2009)
Head trauma/basal skull and temporal bone fractures	✓	✓		✗	1/992	Developing	(Colella-Santos, et al., 2014
HIE			✓				
HIV		✓	✓ (RVD exposure)				
Hyperbilirubinemia	✓	✓	✓	✓ ✗ ✗ ✗	23/200 3/127 42/992 13/2986	Developing	(Al-Meqbel & Al-Baghli, 2015) (Mukherjee, et al., 2013) (Colella-Santos, et al., 2014 (Bielecki, et al., 2011)
Hyperglycaemia			✓				
Hypoglycaemia			✓				

In-utero infections (TORCH)	✓	✓	✓	✓ ✗ ✗	10/1461 2/127 43/992 82/2986	Developed & developing	(Ohl, et al., 2009) (Mukherjee, et al., 2013) (Colella-Santos, et al., 2014 (Bielecki, et al., 2011)
IVH			✓	✓ ✗	1/1461 19/3316	Developed	(Ohl, et al., 2009) (Coenraad, et al., 2010)
Malaria		✓					
Mechanical/assisted ventilation	✓	✓	✓	✓ ✗ ✗ ✓	815/2186 3/127 279/992 148/2986	Developed & developing	(Hille, et al., 2007) (Mukherjee, et al., 2013) (Colella-Santos, et al., 2014) (Bielecki, et al., 2011)
Meningitis	✓	✓		✓ ✓ ✗	4/1461 3/3316 93/2986	Developed	(Ohl, et al., 2009) (Coenraad, et al., 2010) (Bielecki, et al., 2011)
NEC II/III			✓				
Neurodegenerative disorders	✓	✓		✗	3/992	Developing	(Colella-Santos, et al., 2014

NICU admission *	✓	✓	✓	✗ ✗	537/992 318/2986	Developing & developed	(Colella-Santos, et al., 2014) (Bielecki, et al., 2011)
NNJ			✓	✓	47/147	Developing	(Bhagya, et al., 2011)
Postnatal infections associated with sensorineural hearing loss	✓	✓					
Prematurity *			✓	✓ ✗ ✗ ✗	77/200 7/127 508/992 484/2986	Developing & developed	(Al-Meqbel & Al-Baghli, 2015) (Mukherjee, et al., 2013) (Colella-Santos, et al., 2014 (Bielecki, et al., 2011)
RDS			✓				
Seizures			✓	✓ ✓	25/147 5/1461	Developing & developed	(Bhagya, et al., 2011) (Ohl, et al., 2009)
Sepsis			✓	✓ ✗	45/3316 12/217	Developed & developing	(Coenraad, et al., 2010) (Mukherjee, et al., 2013)

Syndromes associated with progressive or late-onset hearing loss	✓	✓					
Syphilis	✓	✓	✓				
TTN			✓				

** risk factors that were common in the study by Bielecki et al. (2011)but only appeared to be present in a small percentage of participants with sensorineural hearing loss*

It is clear from the evidence in Table 30 that not all case history factors have been found to be statistically significant risk indicators for hearing impairment. Case history factors found in the current study such as birth/perinatal asphyxia, IVH, NNJ, prematurity, seizures and sepsis are not listed on the HRRs in the JCIH (2007) and HPCSA (2007) position statements. Yet, some of these factors have been found to be associated with hearing impairment in various studies. For example, prematurity and sepsis have; although inconsistently, been reported to be associated with hearing impairment in some studies (Al-Meqbel & Al-Baghli, 2015; Bhagya, et al., 2011; Coenraad, et al., 2010). Similarly, severe birth/perinatal asphyxia and other neurological conditions related to cerebral infarction and bleeding have been more consistently reported to have an association with sensorineural hearing impairment in studies related to high-risk neonates (Bhagya, et al., 2011; Coenraad, et al., 2010; Colella-Santos, et al., 2014; Hille, et al., 2007; Ohl, et al., 2009). Severe birth asphyxia has also been listed as a risk factor in some developed contexts with established NHS programmes, and has been defined as convulsions, HIE or PPHN (Beswick, Driscoll, Kei, et al., 2012; Beswick, et al., 2013). However, Núñez-Batalla et al. (2012) suggest that acute perinatal asphyxia or HIE may be considered inappropriate as a risk factor for hearing loss in instances where medical literature has defined this condition based on the one minute APGAR score which is often questionable; but not a concerning factor in the current study's context where guidelines by the AAP and ACOG are utilized for diagnoses (AAP & ACOG, 2006). Neurological conditions and sepsis were recorded in a small percentage of participants in the current study, none of whom who returned for diagnostic assessment presented with hearing impairment. Differences between current study findings and literature are suggestive of the differences in criteria used to diagnose specific medical conditions and their severity, as well as heterogeneity of what constitutes "high risk".

The presence of several other case history factors in the current study is consistent with risk factors on the HRRs and with numerous reports in the literature. These include hyperbilirubinemia (Bielecki, et al., 2011; Colella-Santos, et al., 2014; HPCSA, 2007; JCIH, 2007), TORCH infections (Bielecki, et al., 2011; Colella-Santos, et al., 2014; HPCSA, 2007; JCIH, 2007), mechanical or assisted ventilation (Bielecki, et al., 2011; Hille, et al., 2007; HPCSA, 2007; JCIH, 2007), syndromes associated with hearing loss (Bielecki, et al., 2011; HPCSA, 2007; JCIH, 2007), family history of hearing loss (HPCSA, 2007; JCIH, 2007; Ohl, et al., 2009), exposure to ototoxic medication (Bielecki, et al., 2011; HPCSA, 2007; JCIH, 2007; Mukherjee, et al., 2013) and craniofacial anomalies (Colella-Santos, et al., 2014;

HPCSA, 2007; JCIH, 2007; Mukherjee, et al., 2013). Whilst the frequency of occurrence of each of these risk factors has been reported to be different, mechanical or assisted ventilation and exposure to ototoxic medication appeared to have a high frequency of occurrence in literature (Bielecki, et al., 2011; Colella-Santos, et al., 2014; Wrobel, et al., 2014). Although these case history factors have been defined as risk indicators and were present in the current study sample, some were of low frequency or occurrence, particularly TORCH infections, family history of congenital hearing loss and hyperbilirubinemia. Current study findings therefore highlight differences in the profile of high risk neonates and infants in different contexts, which are possibly influenced by differences in burden of disease, as well as subsequent changes in incidence and prevalence of conditions. Hence, identification of risk factors for hearing impairment is a dynamic process that requires ongoing monitoring via contextually relevant clinical research.

Analysis of these less frequently occurring case history findings in the current study sample revealed that only two participants presented with confirmed TORCH infections, one with congenital rubella and one with congenital cytomegalovirus. Although the exact incidence or burden of congenital rubella and congenital cytomegalovirus in South Africa are unknown, both these conditions are documented to cause hearing impairment (Boshoff & Tooke, 2012; Laher et al., 2010). Both participants with TORCH infections in the current study *referred* on all three screening measures; however both of them passed away prior to a diagnostic audiological assessment, which precluded the establishment of confirmed hearing impairment in these participants. Current study findings are supported by two South African studies related to congenital cytomegalovirus and congenital rubella. Boshoff and Tooke (2012) also found a low incidence of congenital rubella over a period of one year at a tertiary academic hospital in the Western Cape. Of the two identified cases in Boshoff and Tooke's study, one presented with inconclusive audiological findings, and the other resulted in mortality (Boshoff & Tooke, 2012). Similarly, a high inpatient mortality rate was found in neonates with congenital cytomegalovirus, particularly in males, and in those co-infected with HIV (Diar & Velaphi, 2014). Although RVD unexposed, the participant in the current study was of male gender which is consistent with findings reported by Diar and Velaphi (2014). Current study findings therefore highlight the influence of the severity of conditions which may result in mortality in some contexts. Findings also raise the question of the influence of advances in medical management of risk factors and their subsequent influence on audiological outcome; and emphasise the importance of implementation of primary

prevention strategies such as the inclusion of relevant vaccinations for preventable diseases within the expanded programme for immunization in South Africa which would in turn assist in the prevention of hearing impairment resulting from these conditions.

With regard to family history of hearing loss, eight participants presented with this as a case history factor in the current study. Although family history of hearing loss has been noted as a risk factor that warrants targeted surveillance or monitoring, there has been debate around its validity as a risk factor. Driscoll et al. (2015) examined family history in isolation; and found that it yielded a low prevalence rate of hearing loss, and hearing loss that was predominantly mild in degree. These authors concluded that although family history is a significant predictor of hearing loss, their findings did not support the inclusion of it as a sole risk factor for TNHS surveillance programmes. This conclusion links to findings by several authors (Bielecki, et al., 2011; Martines, et al., 2013; Ohl, et al., 2009; Wrobel, et al., 2014) that highlight the influence of the combination of multiple risk indicators on hearing impairment. In the current study; of the eight participants with family history of hearing loss none presented with hearing loss; hence supporting the debate around the validity of family history of hearing loss as a risk factor for hearing impairment. However, it should be acknowledged that information pertaining to family history of hearing loss in the current study was obtained from caregiver reports and is therefore anecdotal and not medically confirmed. The implications of current study findings along with findings of literature include the feasibility of monitoring infants who *pass* the hearing screening and present with a family history of hearing loss as the only risk factor.

In relation to hyperbilirubinemia, only seven participants presented with this as a case history factor. Of these seven participants (2.1%), only two presented with an overall *refer* result at the initial hearing screening. One participant passed away prior to the repeat hearing screening whereas the other participant subsequently presented with an overall *pass* result. This change in outcome at the repeat hearing screening highlights the possibility of the reversibility of audiological findings in participants with hyperbilirubinemia, as well as the positive influence of early medical diagnosis and management of NNJ.

Sensorineural involvement from hyperbilirubinemia is believed to occur as a result of increased, indirect bilirubin in the blood (Núñez-Batalla, et al., 2012). However, current study findings are supported by reports of no proportional relationship between sensorineural involvement and bilirubin levels reached, resulting in varying audiological outcomes (Núñez-

Batalla, et al., 2012). For example, sensorineural hearing loss has been reported to occur in cases with lower levels such as 8mg/dl , but may not occur in cases with higher levels of 25mg/dl (Núñez-Batalla, et al., 2012). This variation in audiological findings may also be due to the interaction of other risk factors present in the newborn or infant, another valid argument in support of current study findings. Upon closer inspection of OAE versus AABR screening results in the current study, the two participants with overall initial *refer* findings presented with a *refer* on TEOAE and/or DPOAE, accompanied by a unilateral *refer* for AABR in one participant, and a bilateral *pass* for AABR in the other participant. Cochlear function is often reported to remain intact as noted by the presence of OAEs, with AABR results being affected, which were not evident in the current study. However, there is a possibility of reversible AABR findings after the fall of bilirubin levels following treatment (Núñez-Batalla, et al., 2012; Polat et al., 2014). In addition, medical literature suggests that effective provision of intensive PTT in severe cases of hyperbilirubinemia can assist in reducing the need for EBTs, as well as stop the potential damage that may occur while waiting for EBTs, particularly in resource constrained settings (Olusanya, Imam, Emokpae, & Iskander, 2016). These findings in literature provide a possible explanation for the *pass* screening results obtained in participants with hyperbilirubinemia in the current study. Hence, reemphasizing the question regarding the influence that access to medical treatment and advancements in medical treatment of conditions has on the risk factors for hearing loss. For example, contexts with more advanced, effective and early medical management may present with less detected cases of hearing impairment as opposed to resource poor settings. This in turn raises the question as to whether the medical conditions, lack of management of medical conditions, or both influence the incidence and prevalence of hearing impairment; and whether the focus should be on primary prevention of conditions that are considered risk factors for hearing loss, followed by early medical management of these risk factors.

The reversibility of ABR findings in high-risk infants has frequently been reported in studies (Bovo, Trevisi, Ghiselli, Benatti, & Martini, 2015; Can, et al., 2015; Psarommatis, Florou, Fragkos, Douniadakis, & Konyrogiannis, 2011; Sobhy, Asal, & Ragab, 2015). This reversibility of findings is believed to be due to the heterogeneous auditory maturation or regeneration of nerve fibres and myelin sheaths, particularly in cases of auditory neuropathy that are secondary to other factors such as prematurity, hypoxia, LBW, immunological conditions and infectious diseases (Bovo, et al., 2015; Psarommatis, et al., 2011; Sobhy, et al., 2015). Similar improvements in audiological findings have also been reported in other

studies using repeated AABR or diagnostic ABR measures in patients with hyperbilirubinemia (Can, et al., 2015). These findings highlight the probable influence of auditory maturation, and the need for repeated AABR, ABR or other confirmatory diagnostic testing prior to any aggressive management decisions in high-risk neonates and infants. However, repeated screening or diagnostic assessment should be conducted within a reasonably stipulated time frame to prevent delays in diagnosis and intervention in cases with confirmed hearing impairment. The current study aimed to determine audiological function in a group of high risk neonates using a repeated measures design that also included confirmatory diagnostic testing.

Review of case history findings in the current study and literature revealed similarities and differences in terms of frequency of occurrence of risk factors and associated audiological screening and/or diagnostic outcome. Reasons for these differences appear to be contextual, and may also be influenced by medical management, severity of conditions, and the implementation of primary prevention strategies, all of which require further exploration.

The second sub-aim of the current study was to describe the audiological function in a group of high risk neonates. Despite the current study sample comprising of case history factors that are recognised risk factors for hearing impairment, the proportion of true hearing loss was 0% following diagnostic audiological assessment. Whilst findings from the current study are not consistent with reported estimated prevalence rates of hearing impairment in the high-risk population, similar findings have been reported in Brazil (Cavalcanti, de Melo, Buarque, & Guerra, 2014). A review of NHS in Brazil found a proportion of hearing loss that ranged from 0% to 1.09% (Cavalcanti, et al., 2014) which differs from rates found in other studies in developing countries, where reported percentages of hearing impairment ranged between 1% and 53% (Storbeck, 2012). Similar findings were also reported in an earlier study by Widen and colleagues who conducted behavioural audiometry (VRA) on all infants with risk factors for hearing loss at eight to 12 months corrected age (Widen et al., 2000). These authors found that of the total sample of the 2995 infants who were successfully assessed using behavioural audiometry, 94% presented with normal hearing sensitivity (Vohr et al., 2000). Calvalcanti and colleagues argue that the low rate of hearing loss in their study may be due to the lack of a significant number of mothers returning for rescreening and/or diagnosis. The presence of loss to follow-up or attrition may therefore be a possible source of bias in the current study as the audiological outcome of participants that were lost to follow-up may have differed from those who underwent repeat hearing screening and diagnostic audiological assessment. A low

yield of bilateral PCHL has also been reported in a review of NHS in England. In England, the rate of PCHL has been reported to be just under 1/1000 and the yield for NICU babies is reportedly declining (Wood, et al., 2015). The exact reasons for this downward trend in England are unclear, and it also remains to be determined if the reduction in prevalence of hearing impairment in the NICU population is a genuine one (Wood, et al., 2015). Although England is a developed context, parallels may be drawn between findings as this study and the current study were both conducted in urban public health care contexts. The two hospitals where the study was conducted are within an academic hospital complex; are relatively well resourced and provide specialist and sub-specialist care and support to patients referred from lower levels of health care. Advancements in medicine; diagnosis and treatment could also be argued as a contributing factor toward the declining rates of hearing loss amongst "at risk" populations. The absence of hearing impairment in high risk infants who returned for diagnostic audiological assessment in the current study also raises the question regarding the current relevance of risk factors for hearing loss and the probability of these risk factors being a primary cause of hearing impairment. It further highlights that the current study is specific to a time period and that comparison with earlier studies when medical practices differed needs to be exercised with caution.

The description of case history factors and audiological function in the current study sample was followed by an analysis of the relationship between these two variables in order to address the third sub-aim of the current study; which was to determine the relationship between the case history factors and audiological function in high-risk neonates. Analysis of data revealed two findings. Firstly, the confirmed absence of hearing impairment amongst participants who underwent diagnostic audiological assessment precluded the researcher from establishing case history factors associated with hearing impairment. Temporary hearing loss has been reported to occur in infants, particularly those of VLBW which was a common case history factor in the current study sample (Cristobal & Oghalai, 2008). This temporary hearing loss, may be influenced by transient middle ear effusion which usually resolves within weeks of discharge from hospital (Cristobal & Oghalai, 2008), or maturing of cochlear function in premature neonates (Sininger & Abdala, 1996); both of which serve as possible explanations for the *refer* findings at the repeat hearing screening which were followed by normal diagnostic ABR findings in the current study.

Secondly, analysis using screening results revealed no statistically significant association between specific case history factors (birth weight, gestational age, bilirubin outcome, RVD

exposure, ventilation, presence of a neurological condition, NICU admission, exposure to ototoxic medication) and repeat hearing screening outcome. These findings suggest that the specific case history factors used for analysis did not influence screening outcome or increase the susceptibility of participants obtaining *refer* results for screening. Although comparison was conducted using screening outcome, current study findings are consistent with a few studies in terms of the presence of normal hearing sensitivity in high risk infants (Bhagya, et al., 2011; Bielecki, et al., 2011; Colella-Santos, et al., 2014; Widen, et al., 2000). Normal hearing sensitivity has been reported in high risk infants presenting with prematurity, hyperbilirubinemia, neonatal convulsions, birth asphyxia, LBW as well as neonatal and congenital infections (Bhagya, et al., 2011; Colella-Santos, et al., 2014); factors that were present within the current study sample. The current study sample was small in comparison to other studies conducted in the high-risk population. However, studies with a larger sample size have also reported a low prevalence of hearing impairment. Bielecki et al. (2011), for example, evaluated the frequency of risk factors and their influence on hearing loss in infants. Of the 5282 infants in their study, 4.54 % presented with sensorineural hearing loss, 0.76% with conductive hearing loss and 94.7% with normal hearing. However, contrary to current findings, results from Bielecki et al.'s study indicated that syndromes associated with hearing loss and mechanical ventilation for a duration longer than five days were the most statistically significant risk factors associated with the occurrence of hearing loss in their sample. These findings along with the comparison of case history factors in Table 30, reiterate the argument by Olusanya (2011a) that the prevalence of risk factors and contributions of these risk factors to hearing loss are likely to vary between contexts and possibly from time to time. Hence, risk factors specified by the JCIH (2007) should not be considered as a gold standard with the same relative importance, as the conditions in different countries may vary significantly. This implies that the risk factors stipulated by the HPCSA (2007) position statement may not currently be relevant to the South African context, due to changes in burden of disease as well as differences in medical care and practice. Hence, risk factors require constant revision through evidence-based research.

Risk factors for hearing loss are constantly being redefined by the JCIH in order to adjust these in line with new data appearing in medical literature (Lawn, Davidge, et al., 2013; Núñez-Batalla, et al., 2012). Similarly, the relative importance of risk factors needs to be constantly evaluated in order to modify and improve lists according to current burden of disease as well as clinical practice in each context (Korres et al., 2005; Núñez-Batalla, et al.,

2012). It is therefore vital to consider differences in medical care of the high risk infant and its impact on the overall outcome of the infant. One such example relates to the shift to less intensive, more feasible respiratory support for RDS in premature babies in middle income countries (Lawn, Davidge, et al., 2013). A study in South Africa compared the use of CPAP to no ventilation among babies who were refused NICU care. This study found that CPAP reduced the number of deaths (Pieper, Smith, Maree, & Pohl, 2003), and is consistent with findings from another South African study conducted at one of the research sites included in the current study (Jardine & Ballot, 2015). Jardine and Ballot (2015) reported nasal CPAP to be an effective intervention, as it reduced morbidity and mortality associated with NICU admission and was both cost-effective and easy to use. There has also been evidence to suggest that high noise levels generated from the use of nasal CPAP in preterm babies does not result in a higher risk of hearing loss when compared to mechanical ventilation (Rastogi, Mikhael, Filipov, & Rastogi, 2013). However, the presence of confounding variables in this study may have influenced the higher risk of hearing loss associated with mechanical ventilation as opposed to nasal CPAP. These confounding variables included the presence of other, possibly more severe conditions in those who were ventilated and the influence of ambient noise in the NICU. These findings, along with the absence of ECMO as a case history factor in the current study raises the question regarding its inclusion as a risk indicator within the South African context. Findings also raise questions regarding the "permanency" of risk factors in general as a result of the direct or indirect effects that changes in medical intervention practices may have on risk factors and associated morbidities such as hearing impairment.

Several other arguments arise when comparing findings from the current study to the reported prevalence of case history findings and hearing impairment in high-risk neonates and infants. The first of these arguments relates to the definition of a high-risk neonate or infant. Review of medical literature revealed heterogeneity in the definitions provided. Audiological literature has often differentiated between the well-baby and high-risk neonate or infant based on NICU admission and stay (Coenraad, Goedegebure, & Hoeve, 2011; Coenraad, et al., 2010; Colella-Santos, et al., 2014; Hille, et al., 2007). This definition would have excluded a large majority of neonates and infants from the current study as not every participant within the current study sample was admitted to the NICU. Besides the fact that these participants were not admitted to NICU; they still presented with case history findings similar to those reported in literature related to hearing impairment in NICU infants (Coenraad, et al., 2010;

Hille, et al., 2007). This suggests a need for a new definition of high risk infant, particularly for audiological purposes. It is therefore the view of the current researcher that the definition of the high risk infant should be inclusive of those admitted to high care and/or those requiring KMC.

The second argument relates to the definition of the terms risk versus cause of hearing loss. Findings from the current study as well as literature indicating normal hearing sensitivity in the high risk population suggests that not all infants with risk indicators may present with hearing impairment (Bhagya, et al., 2011; Bielecki, et al., 2011; Colella-Santos, et al., 2014; Widen, et al., 2000). Clinical variability can occur as a result of differences in patients or characteristics of the setting in which the patients are being assessed and managed (Leeflang, Bossuyt, & Irwig, 2009). The presence of target conditions may also be influenced by disease prevalence (Leeflang, et al., 2009). For example, a low prevalence of disease may result in the condition being screened for being rarely present in more patients and clearly present in fewer patients. Thus, resulting in a lower sensitivity as it would be more difficult to detect patients with the target condition (Leeflang, et al., 2009). This may be a valid argument for the current study when considering the low occurrence of case history factors such as congenital rubella, congenital cytomegalovirus and hyperbilirubinemia. It may also be argued that a lower prevalence of hearing impairment may result in fewer diagnosed cases.

The fact that a question about the direct causal links between risk factors and hearing loss has been raised by current and previous findings also requires careful deliberation. Critical healthcare decisions; particularly in resource constrained environments are made based on the allocation of available resources; as in the context of the current study where the use of TNHS is deliberated. However, current findings raise an index of suspicion about comfortable reliance on HRRs used for TNHS. It is important to also consider whether current findings around risk factors provide additional support and explanations for why TNHS has been dubbed to miss 25-50% of cases of hearing impairment (Kountakis, et al., 2002; Sood & Kaushal, 2009).

The characteristics of the setting lead to the third argument that relates to contextual improvements in medical care which may positively influence the outcome of high risk neonates or infants. Lawn and colleagues argue that the place of birth strongly affects one's outcome. Survival is now at 80% for babies born at 25 weeks gestational age, with the risk of disability being very low for infants born beyond this threshold (Lawn, Blencowe, Darmstadt,

& Bhutta, 2013). Current study findings revealed a mean gestational age of 31.3 weeks, with only two participants born at 25 weeks gestational age, both of whom survived, attended screening and diagnostic assessment sessions and presented with hearing within normal limits. It has been documented that with basic newborn care, those babies that are now surviving are not severely disabled (Lawn, Blencowe, et al., 2013). However, the risk profile of surviving versus non-surviving neonates needs to be considered within the South African health care context where neonatal mortality is still noted as a health priority. Infant mortality was recorded for 15 (4.6%) participants of the current study sample.

Apart from variability in medical clinical practice, careful comparison needs to made between study findings that have explored audiological function and risk indicators for hearing impairment in high-risk infants. It is vital that these findings be considered in combination with the percentage of TP and TN findings, and that these findings are based on analysis using diagnostic instead of screening outcome. There are a few studies from the developing context that have used screening outcome to determine risk indicators for hearing impairment as well as to determine the sensitivity and specificity of screening measures (Olusanya, 2009b; Van Dyk, Swanepoel, & Hall, 2015). Widen and colleagues argue that due to hearing being a behavioural response, screening measures such as TEOAE, DPOAE and AABR should be compared against a behavioural measure which is the gold standard (Widen, et al., 2000). However, "in most reports on NHS, sensitivity and specificity values cannot be provided because not all screening pass results are followed by a diagnostic ABR evaluation. Consequently, the outcomes of hearing screening programs have mostly been reported using referral rate, the number diagnosed with PCHL and the number of false-positives" (Akinpelu, Peleva, Funnell, & Daniel, 2014, p. 712).

The current study aimed to explore the sensitivity and specificity of various combinations of screening measures by establishing the TP and TN results using diagnostic findings. This contributed toward the fourth and fifth sub-aims of the study. Three screening measures (TEOAE, DPOAE and AABR) were employed within a repeated measures design. Hence, unlike other studies that have explored different combinations of screening measures on different groups of participants (Benito-Orejas, et al., 2008; Berg, et al., 2011), the current study involved the same group of participants at and across time. Due to the absence of hearing loss in participants who returned for diagnostic audiological assessment, only the TN rate (specificity) could be established. Hall, Smith and Popelka (2004) state that the accurate assessment of NHS performance is not possible without knowledge of true hearing status

determined by a complete diagnostic assessment. However, these authors argue that determining true sensitivity and specificity using diagnostic assessment is impractical for two reasons. Firstly, it would require that all babies who are screened undergo a diagnostic evaluation. Secondly, it would mean that a very large number of babies would need to be screened to detect cases due to the low incidence of hearing impairment in the general population, an acknowledged limitation of the current study. These authors have therefore proposed the integrated use of two screening measures (OAE and AABR) to facilitate screening accuracy (Hall, et al., 2004). Whilst the use of two screening measures may be a relevant clinical recommendation, it may not be a reliable and valid means of conducting research on the sensitivity and specificity of screening measures. The current author believes that true hearing status cannot be assumed from screening results due to possible FP and FN findings, and therefore supports the argument by Widen and colleagues when they say that screening measures should be compared against a behavioural measure.

Current study findings indicated a significantly higher percentage of TN findings at the repeat hearing screening when compared to the initial hearing screening for all combinations of screening measures. Moreover, the TEOAE/AABR combination in the current study yielded the highest percentage of TN findings (91.2%) followed by the DPOAE/AABR (89%) and DPOAE/TEOAE/AABR (89%) combination. These results are supported by findings from literature which highlight the benefits of a combination of various screening measures. FP rates have been reported to be high when hearing screening is conducted with TEOAEs rather than with AABR (Papacharalampous, et al., 2011; Van Dyk, et al., 2015). However, these FP rates reported by van Dyk and colleagues were compared to successive screening results and not diagnostic assessment results. These results therefore do not provide a true indication of sensitivity and specificity of using AABR versus TEOAE /AABR in a screening protocol within the South African context. Nevertheless, the TEOAE/AABR combination has been employed for the screening of NICU infants in developed contexts (WHO, 2010). Similarly, in terms of FP rates, a study by Xu and colleagues revealed that DPOAE screening alone resulted in a higher FP rate of 4.96% in comparison to the combined protocol which yielded a 2% FP rate. FN rates have also been reported to be higher for the single DPOAE screening when compared to the DPOAE/AABR protocol (Xu, Cheng, & Yang, 2011). Hence, these findings imply that a combination of screening measures within a protocol increases test specificity, accuracy and validity, without affecting sensitivity for hearing loss. A combination of two screening measures may also be less time consuming and more cost-

effective when compared to the use of all three screening measures employed in the current study.

Apart from TP and TN findings, analysis of data related to the screening measures employed in the current study also revealed findings related to referral rates and how these are influenced by the combinations of screening measures, the number of screening stages within a protocol as well as the time at which screening is conducted.

Findings from the current study indicated a significantly lower referral rate for the AABR-only combination when compared to the other three combinations of screening measures. These findings are consistent with results from a South African study by van Dyk and colleagues (2015) that revealed a lower *refer* rate at initial and repeat screening using AABR in comparison to TEOAE. Similarly, findings from a review of studies revealed that a one-step AABR screening appeared to have the lowest initial referral rate in comparison to a one step, two-step and three-step TEOAE screening process (Papacharalampous, et al., 2011). Current findings from the current study are further supported by an earlier study by de Freitas et al. (2009) that compared three screening protocols using TEOAE; AABR and TEOAE/AABR in combination. The sole use of a two-stage TEOAE protocol resulted in four times the number of referrals for diagnostic assessment in comparison to the two-stage AABR protocol which yielded a lower *referral* rate, the lowest FP rate and better specificity.

On the contrary, a review of findings from several studies suggests that the TEOAE/AABR combination in a two-stage screening protocol provides the most favourable combination of specificity, sensitivity, *referral* rates and cost-effectiveness. A TEAOE/AABR combination has also been reported to significantly reduce the *referral* rate within a NHS programme (Papacharalampous, et al., 2011). Although TEOAE can be conducted within a shorter test time in comparison to AABR, it is argued that it cannot completely replace AABR and needs to be carefully considered within a two-stage protocol, particularly in contexts where return rate for outpatient screening and testing is difficult. In these instances, using both OAE and AABR at the initial hearing screening session may be advantageous as it may result in a lower percentage of initial *referral* rates (Jewel, Varghese, Singh, & Varghese, 2013), which assists in lowering of the cost of the programme as well as reducing the level of parental anxiety (Papacharalampous, et al., 2011).

In comparison to the initial hearing screening, the *referral* rate in the current study was lower at the repeat hearing screening, which highlights the value of a two-stage screening protocol

in reducing the *referral* rates. *Referral* rates for AABR have been shown to decrease with a two stage (test-retest) screening protocol. Results from a recent study revealed that the *referral* rate for neonates who underwent one-stage screening was 18.6% in comparison to 4.1% in the group of neonates who were enrolled in a two-stage screening protocol (Colella-Santos, et al., 2014). Similar findings have been reported by Chen and colleagues (2012) using TEOAEs where the overall *refer* rate was 29.2% for the initial screening, which significantly decreased to 4% upon repeat screening.

The *referral* rate at the repeat hearing screening in the current study was slightly above the recommended benchmark of 4% (HPCSA, 2007). This reduction in *referral* rate is particularly important in the public health care context in South Africa where diagnostic electrophysiological equipment is only available for assessment at regional and tertiary levels of service delivery, and where manpower shortage is a commonly reported barrier and a reality. Hence, the test-retest or two-stage protocol employed in the current study has demonstrated benefit in reducing the referral rate which would assist in decreasing unnecessary referrals for diagnostic ABR, thereby positively influencing the overall cost-effectiveness of a NHS programme.

Referral rates have also been reported to decrease with an increase in age at the repeat hearing screening, as well as when the time between the initial and repeat screening period is longer. These factors may have contributed toward findings in the current study as the repeat hearing screening was conducted six weeks after the initial hearing screening. Results from an earlier study specific to TEOAE -based NHS indicated a trend toward an increase in the percentage of *pass* results with increased age at the initial hearing screening (less than 24 hours of age versus less than 36 hours of age) (Maxon, White, Culpepper, & Vohr, 1997). The influence of the time and age of screening is further substantiated by two, more recent South African based studies. The first study conducted on a group of low-risk infants revealed a DPOAE screening *refer* rate of 83.8% at the first screening which took place within six hours after birth. This *referral* rate decreased significantly to 0.7% at the second screening on day three after birth (Khoza-Shangase & Harbinson, 2015). Similar findings have been reported in another study where *referral* rate progressively decreased with increasing age (Van Dyk, et al., 2015). These findings in the literature support current study findings, emphasising the clinical importance of ensuring appropriate timing of the initial hearing screening within a hospital-based NHS programme.

In addition to the age at which screening is conducted, the frequencies used for screening may also influence the outcome. Hearing screening involving higher frequencies (e.g. 2-4 or 2-5kHz) has demonstrated lower *referral* rates than screening involving lower frequencies such as 1kHz (Akinpelu, et al., 2014). These findings are of clinical significance when considering DPOAE screening protocols and *pass/refer* criteria employed in a NHS programme, and are consistent with current study findings which indicated the highest percentage of DPOAE *refer* results at 1kHz. Therefore highlighting the possible exclusion of 1kHz within the DPOAE protocol, particularly if the goal of NHS is to identify high frequency sensorineural hearing loss. The exclusion of 1kHz may also assist in reducing the effects of ambient noise which would in turn influence the overall *pass/refer* outcome.

The JCIH (2007) position statement recommends that protocols within screening programmes should be based on what is practicable and suitable for practice. It is vital that practicality and suitability for practice is defined by the combination of sensitivity, specificity and *referral* rates. Current study findings highlight the benefit of using a two-stage screening protocol as it assisted in reducing the *refer* rate at the repeat hearing screening and thus minimised FP results. The TN rate and *referral* rate were both better at the repeat screening post-discharge. Findings from the current study raise debate regarding when screening should be conducted and suggest better outcomes six weeks post-discharge. However, it may also be argued that the lack of initial, in-hospital screening would result in the inability to establish true coverage rates in a hospital setting. In addition, there may be the risk of missed cases if an initial, in-hospital screening is not performed and caregivers do not attend the NNFU, outpatient clinic.

Following comparison between current study findings and literature, it is evident that screening protocols have varied with regard to the age of the newborn at the initial hearing screening, the number of screening sessions and the use of multiple screening measures. For example, some screening programmes employ a combination of screening measures at both screening sessions, whereas others employ an initial OAE screening followed by AABR at the repeat hearing screening if an OAE *refer* result was present. In addition to differences in protocol, the use of different screening equipment in literature should be acknowledged as this influences the frequencies screened and the signal to noise ratio used for *pass* criteria. It is therefore likely that these variations affect *referral* rates reported in studies (Akinpelu, et al., 2014). A high rate of *refer* results and FP suggests the need for complementary screening measures or multi-stage screening protocols, but also increases the risk of newborns being lost to follow-up which compromises the overall quality of a NHS programme

(Papacharalampous, et al., 2011; Vos, Lagasse, & Levêque, 2014). Hence, follow-up return rates are also important when considering the protocols adopted within NHS programmes, as the choice, and/or combination of screening measures used may assist in reducing unnecessary referrals (Akinpelu, et al., 2014).

Adequate follow-up from initial hearing screening through to diagnosis is important for the success of any NHS programme (Cavalcanti & Guerra, 2012). Cavalcanti and Guerra (2012) believe that follow-up return rates for screening or diagnostic assessment depict parental commitment more accurately than the initial screening in hospital which only requires maternal consent (Cavalcanti & Guerra, 2012). Follow-up return rates as well as the reasons for follow-up default were investigated in the current study in order to address the fifth and final sub-aim.

The initial sample in the current study comprised 325 participants. Due to the attrition associated with the longitudinal, repeated measures design employed in the current study, all participants did not undergo the repeat hearing screening and diagnostic audiological assessment. The number of participants declined throughout the course of the study, with the highest attrition rate at the diagnostic follow-up.

Follow-up return rate in the current study was better at the repeat hearing screening (66.5%) than the diagnostic assessment (46%). Findings from the current study are consistent with results reported in a review of NHS programmes in maternity hospitals in Brazil (Cavalcanti, et al., 2014). A high loss to follow-up was reported for diagnostic assessment which ranged from 5% to 66% in public hospitals and from 28% to 100% in private and mixed hospitals. In general, there was a lower adherence for diagnostic follow-up in comparison to rescreening, with one of the proposed reasons being that diagnostic evaluations were conducted outside the maternity hospital (Cavalcanti, et al., 2014). This is consistent with the protocol employed in the current study whereby initial and repeat hearing screenings were conducted at the hospital, with diagnostic follow-up conducted outside of this context due to a lack of equipment and/or equipment malfunction which would have compromised the reliability and validity of diagnostic findings. Findings are further supported by a smaller, unpublished study that emerged from the current study. This study explored the factors influencing follow-up through semi-structured interviews with a small group (n=10) of caregivers who returned for follow-up appointments in the current study. A few of the caregivers who returned for diagnostic follow-up reported the change of site to be challenging as they found it difficult to

navigate an unfamiliar setting (Krabbenhoft, 2015). These findings are of clinical significance when designing NHS programmes, and suggest the value of having a single site for follow-up where possible.

It should however be noted that the return rates for the repeat hearing screening in the current study differed between the two research sites. A significant association was noted between the research site and whether or not infants returned for the repeat hearing screening (Fisher's exact test: $p<0.0001$; phi coefficient=0.30). A better follow-up return rate was noted at RMMCH where the focus is on maternal and child health. The follow-up return rate at CMJAH was 42.9%, while a significantly higher percentage (75.9%) from RMMCH returned. This follow-up return rate at RMMCH is in alignment with the recommended HPCSA (2007) benchmark of 70%. These differences in follow-up return rate in the current study raise the question of possible influencing factors such as quality of care, maternal attendance at antenatal clinics or more specific and specialised care at maternal and child health care facilities, which require further investigation. High follow-up return rates have also been reported in other maternal and child health care settings in South Africa, such as the Midwife Obstetric Unit (MOU) three day assessment clinic. A study conducted in the MOU setting indicated a follow-up return rate of 96%. However, this study consisted of low risk newborns as the newborns enrolled within a clinic setting or system do not present with risk factors. Those presenting with prenatal and perinatal risk factors are referred to the hospital setting (Khoza-Shangase & Harbinson, 2015). Ng et al. (2004) report the assessment clinic to be an ideal time for screening and suggest that it also results in attendance being less costly for the parents as they attend a single appointment to see several professionals. Similarly, in the current study, the repeat hearing screening was aligned with NNFU clinic which involves weighing and measuring of babies by nursing staff followed by a medical evaluation by paediatricians. Hence, the current author believes that findings from the current study support the model of aligning appointments with medical follow-up, particularly for high risk newborns and infants who undergo follow-up medical evaluation and treatment in the hospital setting.

Findings from the current study are further supported by earlier suggestions in literature. Bevilacqua and colleagues suggest the integration of NHS into other federal programs such as neonatal screening tests or growth and development monitoring programs performed in outpatient clinics as a means of reducing the drop-out rate (Bevilacqua, Alvarenga, Costa, & Moret, 2010). Coinciding hearing screening with immunization visits has also been proposed

in South Africa and Northwest India (Jewel, et al., 2013; Swanepoel, et al., 2006). This approach may be more time consuming, and accompanied by the limitation of being unable to accurately identify and record risk factors required for distinguishing between a likely congenital/early onset hearing loss and later onset/acquired hearing loss (Wood, et al., 2013). Despite these limitations, conducting hearing screening at immunization clinics has been used as a means of addressing follow- up.

Reports from earlier published literature on hearing screening in NICU are in accordance with the overall follow-up return rate in the current study. Lieu and colleagues indicated poor follow-up return rate (below the 70% benchmark) in their study. These authors suggest that lack of follow-up may be due to multiple factors such as inadequate resources (audiologists, sedation services) to conduct timely diagnostic ABR assessment; poor communication with NICU staff ; parent and/or paediatricians disregarding the scheduling of diagnostic ABR testing; a newborn population with other medical priorities or needs; lack of parental reminders about follow-up testing; or socioeconomic factors associated with poor compliance (Lieu, Karzon, & Mange, 2006). Similar reasons for loss to follow- up have been documented by the ASHA (2008) working group who consulted with a range of sources. In addition to system issues such as a lack of communication amongst service providers, lack of funding, shortage of audiology professionals or absence of audiology involvement in programmes, other contributing factors were noted. These included proximity to resources and difficulty scheduling appointments due to having to care for other children and transportation.

Reasons for non-attendance at follow-up appointments were recorded in the current study. Although reasons were unknown for a large proportion of participants, migration to another province or city; caregiver employment; and financial difficulties such as a lack of funds for transport were among the more commonly established reasons. Migration to another province or city has seldom been reported as a reason for non-attendance in literature, but current study findings are reflective of migration patterns within the South African context. These findings highlight that reasons for follow-up are contextually based and indicate the need for an effective data system, and well established referral pathways to ensure follow-up and tracking of newborns and infants enrolled in EHDI programmes.

Predictors of non-compliance for the second-stage of screening were investigated by Cavalcanti and colleagues (Cavalcanti & Guerra, 2012). These authors found that mothers with a primary education only, mothers with five or less prenatal visits and families with a

minimum salary or less were more at risk of not attending the second-stage hearing screening. On the other hand, first time mothers were less likely to default on follow-up. These authors argue that scheduling of appointments may be more difficult in families with more than one child and that mothers of more than one child may be more independent and experienced in decision making and less compliant to recommendations or health instructions.

Contrary to literature, analysis of the influence of maternal factors on follow-up in the current study indicated no statistically significant association between maternal age, maternal education, the presence of other children and whether or not caregivers returned for the repeat hearing screening. However, the mean maternal age for those who returned for diagnostic assessment (29.9y; sd=5.9y) was significantly higher than the mean maternal age of those who did not return (27.7y; sd=6.4y) (p=0.023). Reasons for follow-up default that have been noted in literature have differed, with very few having been found in the current study. Table 31 outlines these reasons for follow-up default and indicates the consistency with current study findings. Reasons for follow-up default from the current study that are consistent with literature include financial difficulties, transportation, low maternal age and a migrant population.

Table 30: Reasons for follow-up default in literature and the current study

Study	Reasons for follow-up default
(Chen, et al., 2012)	• lack of knowledge about the hearing screening and hearing impairment • no financial means of attending the follow-up appointment * • no hearing problems noticed *
(Armstrong et al., 2013)	• parental difficulty in navigating the system • reluctance to continue with further evaluations
(Todd, 2006)	• poor maternal socio-demographic characteristics, difficulty accessing services (including the lack of insurance) • low maternal age* • presence of two or more other children • substance abuse • lack of prenatal education about NHS • lack of integration between hospital information and public health
(Ohl, et al., 2009)	• Transfer of babies to regional hospitals as soon as they were medically stable • lack of information by parents who were not fully aware of the consequences of SNHL • babies being discharged from the hospital earlier than expected
(Shulman et al., 2010)	• travelling to an unfamiliar location for diagnostic evaluation (less likely to travel to another location for follow-up other than the hospital at which their child was born) • lack of transportation with families having to travel long distances * • access to early intervention services proved challenging for families who move often and are unable to access continuous services * • language barriers between screeners and caregivers as screening results and details regarding follow-up could not always be explained

**factors present in the current study*

Strategies aimed at facilitating follow-up have been proposed by several authors, some of which were already implemented in the current study. Gilbey and colleagues reported that persistent telephone reminders by screening staff facilitated relatively high rates for follow-up for full diagnostic testing (Gilbey, et al., 2013). The use of a second contact name and number (apart from the mother's) has also been suggested as a means of ensuring that families can be located (Russ, Hanna, DesGeorges, & Forsman, 2010). Although both these strategies were implemented in the current study, they did not always facilitate follow-up return rate due to various contextual reasons which have been documented in the results chapter. Other authors (Papacharalampous, et al., 2011) report that systematic support before and after NHS, coupled with a friendly approach to caregivers would assist in reducing loss to follow up and yield benefits in terms of cooperation from caregivers. Laugen (2013) discusses factors that assist in ensuring high quality follow-up in NHS programmes. The first factor is related to suggestions by Papacharalampous et al. (2011) as it involves cooperation between screening personnel and the audiology departments for mutual exchange of information as well as ensuring that screening personnel are competent and make sure that families are being followed. These findings are in agreement with reports by caregivers in the smaller study that emerged from the current study (Krabbenhoft, 2015). All ten caregivers in this study reported that a clear line of communication and a friendly audiologist were positive influencing factors (Krabbenhoft, 2015). The second factor is related to parents' suggestion of having one specific professional that they are able to contact for purposes of security which also creates a sense of accessibility to services (Laugen, 2013). This factor was implemented in the current study with the researcher having conducted hearing screenings and diagnostic assessments.

The significant decrease in follow-up return rate for the six month diagnostic assessment in the current study gives rise to the debate regarding the feasibility of risk-based surveillance. Risk-based surveillance has been recommended for the identification of late onset hearing loss in babies who *pass* the hearing screening but present with risk factors for hearing loss (JCIH, 2007). The need for monitoring has been highlighted in a study that found sensorineural hearing loss in a group of children who *passed* the NHS (Dedhia, Kitsko, Sabo, David, & Chi, 2013). However, this study had several limitations. As it was a retrospective medical chart review; the cause of hearing loss could not be established; NHS results were mainly based on reports by parents who could have misinterpreted the results; and the absence of all screening results prevented the analysis of possible FN screening results

(Dedhia, et al., 2013). Despite these limitations, findings highlight the need for further audiological testing or monitoring at specific ages during childhood.

However, more recently, the use of the risk-based surveillance model has been questioned by some well-established programmes (Beswick, Driscoll, Kei, et al., 2012). This debate around the implementation of risk-based surveillance is further supported by evidence from a study by Wood, Davis and Sutton (2013). These authors found that take-up for the targeted surveillance appointments were low, which is similar to the findings in the current study for the six month follow-up appointment. Based on only just over half (55%) of the children attending the targeted surveillance appointment, Wood and colleagues argue that this may not be valued as important by families as they may feel reassured by the NHS result; paired with their own observations of their child's auditory behaviour and response to stimuli. Based on observations of auditory behaviour, one caregiver in the current study reported no concern regarding hearing as being the reason for non-attendance at the six month follow-up. These authors further argue that the presence of other medical conditions in children with risk factors may result in other, frequent appointments, resulting in hearing not being perceived as a priority (Wood, et al., 2013). In addition, results from the study by Wood and colleagues revealed that the surveillance program was not necessarily the mechanism that led to the identification of hearing loss as 77% that did not attend had a recorded outcome of satisfactory hearing at their most recently attended assessment.

The NHS protocol from the current study may therefore be a more feasible option for targeted/risk-based surveillance, as follow-up hearing screening appointments were in alignment with the first medical check-up with paediatricians at NNFU. In addition, infants attending this specialist clinic are reviewed every few months by paediatricians until at least two years of age. The use of this model could ensure involvement of physicians who can facilitate timely referral for audiological evaluation. The Canadian position statement (Patel, et al., 2011) highlights the important role of the physician and emphasises that paediatricians are expected to be familiar with normal patterns of language development and need to provide ongoing developmental surveillance, particularly in infants with known risk factors who require close monitoring. It is also important that paediatricians are updated on the risk factors for hearing loss in order to prevent delays in diagnosis (Dorros, Kurtzer-White, Ahlgren, Simon, & Vohr, 2007).

Findings from the current study and literature clearly highlight follow-up default as an ongoing challenge within NHS programmes. Strategies aimed at addressing follow-up return rate need to address the contextual needs or challenges experienced by caregivers. Whilst alignment of paediatric services and appointments may assist with return rates, the feasibility of conducting diagnostic follow-up on infants without risk factors for delayed onset hearing loss (who *passed* the hearing screening) requires careful consideration, particularly in resource constrained contexts.

Chapter summary

This chapter provided a discussion of the results from the current study in accordance with the specific objectives of the study. The discussion provided careful integration of the results in relation to existing evidence. The discussion also carefully highlighted both the limitations and implications that have arisen from the analysis of the data. These implications may be relevant to public health care contexts in South Africa where TNHS is being conducted, where NHS programmes are in the start -up phase or where they are yet to be implemented. These implications may also encourage further research in this area, and are detailed in the following chapter, along with careful considerations of the limitations in the design which are deemed important for accurate interpretation of findings and conclusions.

CHAPTER 10: CONCLUSIONS, LIMITATIONS & RECOMMENDATIONS

The implementation of EHDI programmes has been advocated worldwide. There is no doubt that there has been extensive research within the field of EHDI, particularly with regard to the effective implementation of UNHS programmes. However, most of this research has been conducted in developed countries where context differs with regard to adopted neonatal protocols, resources, manpower, screening personnel, burden of disease, health priorities as well as medical intervention. UNHS is the recommended approach to early detection of hearing loss. However, implementation of UNHS within the South African context has proven to be difficult for a number of documented reasons. These reasons include the focus on other health priorities related to MDGs and burdens of disease; a lack of audiological screening and diagnostic equipment at various levels of service delivery and manpower shortages in the public health care sector. The development of effective TNHS programmes needs to therefore be seriously considered as an interim step towards UNHS in South Africa. The audiologist plays a key role in the planning, management and coordination of NHS programmes.

The need for further research into all aspects of EHDI, particularly the use of alternative approaches to NHS is apparent by the limited data available in the South African context. Research conducted in the South African context will assist in the shift from Eurocentric models to more Afrocentric, contextual, practical and feasible models. This chapter provides a summary of the key points discussed in the thesis; highlights the key findings that emerged from the study; and presents conclusions drawn from these findings. The limitations that were identified during the study are also acknowledged, followed by clinical recommendations, as well as recommendations in terms of future directions.

10.1 Theoretical Framework and Context of the Study

EHDI is governed by specific principles and guidelines, from NHS to early identification and intervention. These guidelines and principles are undoubtedly supported by the broader principles and approaches to ECI which may be viewed in relation to primary, secondary and tertiary prevention strategies aimed at addressing preventable causes of hearing impairment. Knowledge of both ECI and EHDI principles are important in guiding research within this field.

The current study focused on the early identification component of EHDI, by exploring TNHS in a hospital setting. Implementation of a NHS programme requires a thorough understanding of the setting and how it fits into the broader South African health care context, particularly with regard to health care priorities, levels of service delivery and referral pathways. An overview of the South African health care context was deemed essential in providing a contextual background for the study. Due to TNHS being the focus of the current study, it was considered appropriate to provide discussion on the risk factors and etiologies of hearing impairment. Discussion of risk-based surveillance was also included as the current study protocol involved follow-up of participants (who *passed* the repeat hearing screening or rescreening) at six months corrected age. Furthermore, it seemed fitting to provide a comparison of NHS programmes and protocols worldwide, with a particular focus on cost-effectiveness and the use of electrophysiological measures for screening. Discussion related to follow-up was also necessary as one of the objectives of the current study was aimed at exploring reasons for follow- up default.

In comparison to developed contexts such as the United States of America, United Kingdom and Australia, roll-out and implementation of EHDI in South Africa has been slow and non-standardised. The lack of implementation of EHDI in South Africa poses further challenges in terms of motivating for the mandating of services as true prevalence and incidence rates of hearing impairment cannot be established. In addition, the lack of NHS programmes prevents analysis and establishment of cost-effective programmes, as well as retrospective record reviews of case history factors or risk factors associated with hearing loss.

Research into EHDI in South Africa has, to date, revealed late diagnosis of hearing impairment (Butler, et al., 2013; Khoza-Shangase & Michal, 2014). Furthermore, recommendations in terms of the implementation of NHS programmes have differed provincially. Implementation of NHS at the PHC level has been recommended from studies conducted in the Western Cape region; whereas studies conducted in the Northwest and Gauteng provinces have indicated multiple challenges that need to be addressed prior to national implementation at this level of service delivery. These challenges include a lack of equipment, coupled with budgetary and manpower challenges which have frequently been reported in other studies conducted at a hospital level within the South African public health care sector. (Khoza-Shangase & Michal, 2014; Swanepoel, 2006; Theunissen & Swanepoel, 2008). Despite these documented challenges, intermediate solutions need to be sought. The current researcher believes that one such solution would be to focus on smaller, achievable

goals such as thorough piloting and implementation of TNHS programmes that can be maintained by audiologists who are currently the only screening personnel in public sector hospital contexts. The current study explored the implementation on TNHS within hospital contexts, of which the summary of main findings is as follows:

10.2 Summary of Main Findings

- Preterm birth (95.7%), exposure to ototoxic medication (87.7%), NNJ (80.6%) and birthweight below 1500 g (66.7%) were the most frequently occurring case history factors in the study sample. Amongst the least commonly occurring case history factors were TORCH infections, hyperbilirubinemia, kernicterus, syndromes such as Trisomy 13 and family history of congenital hearing loss.
- Three hundred and twenty five participants underwent an initial hearing screening, of which 216 returned for a repeat hearing screening six weeks post hospital discharge. Following the repeat hearing screening, 183 (84.7%) participants were booked for a diagnostic audiological assessment at six months corrected age, and nine (4.2%) were booked for diagnostic ABR. Twenty four participants (11.1%) required a rescreen approximately three weeks after the repeat screening due to suspected transient middle ear effusion or as a result of incomplete screening results.
- Analysis of the overall initial hearing screening outcome (all three measures combined), indicated that a higher number of participants (59.1%) *passed* the initial hearing screening, compared to those who *referred* (40.9%). Similarly, a higher number of participants (84.7 %) *passed* the repeat hearing screening, compared to those who *referred* (12.5%).
- A total of 93 participants attended the diagnostic audiological assessment. None of the caregivers reported concern for hearing loss. Six of the 11 participants (66.7%) attended the diagnostic ABR appointment. Of these six participants, five presented with estimated hearing within normal limits, whereas results for one participant were inconclusive due to incomplete testing. Of the 87 participants that attended the six month behavioural assessment, 86 (98.8%) presented with hearing within normal limits and one had inconclusive findings.
- The proportion of true hearing loss based on diagnostic audiological findings (diagnostic ABR and diagnostic behavioural assessment) was 0%.

- The association between case history variables and auditory function could not be investigated using diagnostic audiological findings, as none of the participants with conclusive diagnostic findings presented with hearing impairment.
- There was no significant association between categorised gestational age and DPOAE, TEOAE, AABR or overall hearing screening outcome at the initial screening. Similarly, there was no significant association between bilirubin outcome; RVD exposure; ventilation; presence of a neurological condition; NICU admission; and exposure to ototoxic medication and DPOAE, TEOAE, AABR or overall hearing screening outcome at the repeat screening.
- The percentage of TN findings was higher at the repeat hearing screening when compared to findings from the initial hearing screening.
- The *referral* rate at the repeat screening was significantly lower for the AABR-only combination (1.9%) than the other three combinations of screening measures (5.7-6.7%).
- Reasons for non-attendance were mostly unknown for both the repeat hearing screening and behavioural audiological assessment, as caregivers of participants could not be reached telephonically. Common reasons for non-attendance at the repeat hearing screening were relocation (15.6%), and the death of the infant (9.2%).
- Results indicated a significant, but weak association between the hospital (research site) and whether or not infants returned for the repeat screening. A significantly higher percentage of participants from RMMCH returned.
- There was no significant association between maternal education level, number of children, maternal age and whether or not infants returned for the repeat screening. However, the mean maternal age for those who returned for behavioural assessment was significantly higher than the mean maternal age of those who did not return.

10.3 Limitations of the Study

Results from the current study have the potential to contribute toward the implementation of TNHS programmes in public sector hospitals in South Africa. However, these results need to be considered in relation to the following, identified methodological weaknesses which serve as limitations to the current study:

- NHS was not conducted every day which may have resulted in missed babies due to discharges on weekends or on weekdays when the researcher (the only audiologist conducting NHS) was not present. Similar challenges or limitations were reported in a study by Khoza-Shangase and Harbinson (2015) whereby there was only one audiologist on site to conduct NHS. The audiologist adhered to normal working hours which results in several newborns being unintentionally missed at the initial hearing screening.
- The current study protocol required caregivers to travel to another site for diagnostic assessment. Although the use of this site ensured availability of regularly calibrated equipment, and the researcher reimbursed caregivers for transport costs; the use of this site may have contributed toward attrition. Follow-up return rate may have been better if diagnostic assessments were conducted at the hospital of birth.
- The researcher contacted caregivers to remind them of follow-up appointments. However, the researcher had no control over attrition and follow-up default. This poor follow-up return rate further contributed to a smaller, final sample size for diagnostic audiological assessment.
- The sample size was small when considering that prevalence rates for hearing loss are reported per 1000. Hall et al (2004) indicate that a very large number of newborns would have to be screened in order to have sufficient numbers of hearing impaired cases because of the rather low incidence of hearing impairment in the general population.
- A cost analysis of the TNHS programme employed in the current study was not conducted. This may have added value to the study, particularly as cost is a commonly reported challenge or barrier to the implementation of NHS programmes.
- The number of *refer* cases (dependent variable) was less than the number of parameters that the researcher wished to estimate for the independent variables (case history factors). As a result of the small number of parameters (independent variables), the use of univariate analysis was more appropriate when exploring relationships between certain variables and hearing screening outcome. Multivariate analysis would have provided insight into the relationship between combinations of case history factors and screening outcome.

- The current study was conducted at two hospitals within an academic hospital complex in a single province. This prevents generalisability of results to other provinces and levels of service delivery in South Africa.

10.4 Conclusions

There are a number of factors that contribute toward positive outcomes in infants and children diagnosed with hearing impairment. One such factor is the early detection and diagnosis of hearing loss followed by prompt early intervention. These positive outcomes of EHDI have been documented in a number of studies from developed contexts (Fulcher, et al., 2012; Kennedy, et al., 2006; Sininger, et al., 2010).

The implementation of NHS initially began with TNHS using specified HRRs. Since the year 2000, NHS programmes have progressed toward the successful implementation of UNHS, particularly in developed contexts. South Africa's initial step toward EHDI was in 2007 with the release of the HPCSA position statement. However, these recommendations have not been consistently implemented by professionals working in the public health care sector in South Africa, which is evident from published literature (Butler, et al., 2013; Khoza-Shangase & Michal, 2014; Theunissen & Swanepoel, 2008). This lack of implementation has in turn resulted in a lack of data that can be used to determine context specific risk factors for hearing loss. The identification of context specific risk factors for hearing impairment not only assists in establishing comprehensive TNHS programmes, but also contributes to information about risk factors that may be addressed through primary, secondary and tertiary prevention strategies.

Current study findings have revealed that the type and frequency of risk factors for hearing loss differ amongst contexts. Possible reasons for these differences may be varying burdens of disease as well as changes in prevalence and incidence rates of these diseases and other conditions over time. Hence, risk factors for hearing loss require constant review based on contextually relevant, evidence-based research. Consideration of the extent to which certain medical conditions in the high risk neonate or infant impact audiological outcome is also important as this may be influenced by a variety of other factors which require further investigation. These factors include medical assessment and management practices; severity of conditions; and availability and implementation of primary prevention strategies within the South African context.

Instead of using existing HRRs for TNHS in South Africa, it may be more beneficial to screen all neonates with a prolonged hospital stay, whether in NICU, high care or KMC. This will allow for a greater coverage rate and lessen the chances of missed cases in this population. Findings can also be used retrospectively to conduct research and update the list of risk indicators associated with hearing impairment. It has been stressed in literature that implementation of NHS programmes needs to be based on what is feasible for each context (Olusanya, et al., 2004a; WHO, 2010). Although UNHS is the gold standard for early detection of hearing loss, the use of TNHS has been reported as a feasible method in some contexts (Abalo, et al., 2009). It is imperative that feasibility of NHS programmes be evaluated based on evidence from thoroughly planned pilot programmes, which should be guided by a needs assessment. Apart from the logistics related to the context, evaluation should include equipment and screening protocols; tracking and data management; as well as aspects related to diagnostic follow-up and intervention, with consideration of appropriate referral pathways where necessary.

With regard to screening protocols, inclusion of AABR has commonly been recommended for screening of high risk infants (JCIH, 2007; JCIH, 2008). The current study explored the use of different combinations of screening measures. Although there was no significant difference in these combinations of screening measures, the best specificity was noted with the inclusion of AABR. Current study findings therefore suggest the use of AABR only or a TEOAE/AABR combination. *Referral* rates in the current study were also noted to be lower with AABR at the repeat hearing screening. These findings contribute toward achieving a cost-effective protocol as screening measures with a low *referral* rate but good specificity would facilitate unnecessary referrals for diagnostic assessment, particularly in contexts such as South Africa where manpower challenges are consistently reported. Conducting high frequency tympanometry on participants that passed the AABR but referred on OAEs at the repeat hearing screening was useful in differentiating between the need for a diagnostic ABR or a rescreen three weeks later due to possible transient middle ear effusion. Findings from the current study further highlight the value of a repeat hearing screening, six weeks post discharge, on the day of the first NNFU visit.

Risk-based or TNHS works if aligned with medical follow-up, particularly in settings that are focused on maternal and child health. It needs to be acknowledged that one approach to hearing screening may not necessarily be applicable to all provinces within South Africa due to differences in structure and allocated health care resources. From the literature as well as

findings from the current study, the current researcher is of the view that a two-tiered approach seems appropriate. This two-tiered approach would involve hearing screening of high-risk babies in the hospital setting, with screening of the well-babies at clinic level. This will address the earlier discharge of well-babies which will result in missed cases in the hospital setting. It will also address follow-up and monitoring of high risk infants who undergo regular follow-up at specialist clinics within a hospital setting.

The feasibility of a risk-based surveillance programme needs to be carefully deliberated. Whilst the six month follow-up of babies who *passed* the hearing screening in the current study provided valuable information in terms of diagnostic outcome, it may not have been feasible when considering the high follow-up default rate. Counselling parents may be a more feasible option, except in cases where infants present with risk factors for delayed onset or progressive hearing loss. The role of the paediatrician would also be imperative in the monitoring of developmental milestones at follow-up visits. Paediatricians may then make necessary referrals to audiologists who would form a valuable role within a multidisciplinary team at these follow-up clinics.

The availability of diagnostic audiological equipment at all secondary and tertiary hospitals (where audiologists are employed) would also assist in ensuring prompt diagnosis at the newborn or infants' place of delivery which would also indirectly assist with follow-up. Caregivers would not have to travel to another site and navigate the system at another hospital for diagnostic follow-up, unless migration to another city or province is indicated, as noted in the current study. In these instances, appropriate referral pathways are essential for adequate follow-up of infants. The development of a national database would therefore be essential for EHDI programmes in South Africa to allow for tracking of infants. The establishment of adequate follow-up and tracking would assist in evaluating the ongoing development, effectiveness and benefits of EHDI programmes.

10.5 Recommendations in terms of Future Directions

Despite the acknowledged limitations of the current study, the results have significant implications. Apart from exploring the audiological function in high risk neonates and infants as well as exploring aspects related to audiological screening measures, the current study provided insight into the possibility of implementing TNHS within an academic hospital complex. Furthermore, the current study highlights the important role that audiologists play in the design, piloting and implementation of NHS programmes; as well as the need for

audiologists to understand context and setting when fulfilling this role. Hence, implications raised by the current study provide insight into clinical recommendations, educational recommendations; as well as recommendations for policy formulation and future research.

10.5.1 Clinical recommendations for the implementation of NHS

- Case history findings from the current study highlight heterogeneity with regard to the profile of high risk newborns and infants, and suggest that the use of the existing HRR be exercised with caution in TNHS programmes. Screening of all newborns and infants with a prolonged hospital stay would be more appropriate with the recording of all case history factors from medical charts and hospital files. This will allow for constant comparison between case history factors and diagnostic audiological outcome which will facilitate identification of contextually relevant risk factors for hearing impairment.
- Audiological findings from the present study indicate that not all high risk newborns may present with hearing impairment. However, as a result of factors such as maturation and transient hearing loss in this population, conducting a repeat hearing screening is important in minimising the percentage of FP results.
- Results from the current study have the potential to contribute toward the screening measures and protocols used within NHS programmes. Using a combination of screening measures (OAE/AABR) or AABR alone within a two-stage screening protocol, assists with ensuring good specificity, and reducing FP and FN rates. The use of both OAE and AABR may also act as a cross-check principle within the screening programme to assist in differentiating between suspected transient conductive hearing loss and sensorineural hearing loss. These screening protocols may further assist in ensuring good sensitivity which requires further investigation as the current study did not present with any participants with hearing impairment.
- A two -stage screening protocol is useful if properly aligned with other NNFU visits. The implementation of two stages of hearing screening improves the specificity of a protocol as it results in a higher percentage of TN findings. The alignment of the repeat hearing screening with NNFU visits could further assist in improving follow-up return rates as well as reducing unnecessary referrals for diagnostic ABR assessment. It will also allow audiologists to detect missed cases and screen these infants who did not undergo the initial, in-hospital screening. In addition, it will

facilitate a multidisciplinary team involvement which forms an important component of ECI. Paediatricians involved in the NNFU clinics may also assist with the developmental monitoring of high risk infants who *passed* the hearing screening.

10.5.2 Recommendations for education of team members

- It is recommended that results from the current study be used to educate various team members involved in the care and management of high risk newborns and infants. Results suggesting the need for contextually relevant risk factors may encourage these team members to ensure that all newborns and infants with a prolonged hospital stay undergo a hearing screening prior to discharge. It may further encourage these team members to maintain good medical record keeping practices.
- Caregivers form an essential component of the EHDI team. Results from the current study suggest the need to educate caregivers on speech, language and hearing development as not all caregivers return for follow-up. Education regarding appropriate developmental milestones will empower them to be active members of the team in terms of targeted monitoring or surveillance.
- Provision of relevant information about NHS at antenatal clinics will not only create awareness of the audiological services offered at facilities, but will also allow caregivers time to decide if they would want their babies enrolled in a NHS programme.

10.5.3 Recommendations for policy formulation

- Findings from the current study provide information that can be used practically at CMJAH and RMMCH in terms of budget and resource management and planning. Results from this study could be used to motivate for funds to be made available to assist with implementation of EHDI. Funding may be used to motivate for the purchase of screening and/or diagnostic equipment. Appropriate resource allocation for EHDI could enable piloting, implementation and ongoing monitoring of programmes. Outcomes from these programmes can in turn be used to motivate for the mandating of EHDI services, thus potentially impacting on South African health care policy and resource allocation at a provincial and national level for newborns and infants attending public health care facilities.

- Policy frameworks that are developed for maternal and child health need to include NHS for early detection of hearing impairment.

10.5.4 Recommendations for future research

Due to limited, longitudinal research related to NHS in high risk neonates and infants in the public health care sector in South Africa, it is hoped that findings from the current study may contribute toward the clinical implementation of TNHS; as well as provide a basis for future research in this area. Specific recommendations for future research include the following:

- The absence of diagnosed hearing impairment in the current study highlights the need for constant research into risk factors associated with hearing impairment. In contexts with good record keeping and consistent use of reliable audiological screening and diagnostic equipment, a retrospective study may be useful to correlate documented case history factors and diagnostic audiological outcome. This will assist in exploring the risk indicators for hearing loss within the South African context. Retrospective analysis will also provide insight into the likely onset of hearing impairment in the paediatric population in South Africa. It will further assist in developing an appropriate audiological definition of a high risk newborn or infant.
- The influence of different medical assessment and intervention practices needs to be explored in high risk newborns enrolled in NHS programmes.
- Analysis of combinations of case history factors and audiological outcome in a group of high risk newborns or infants would facilitate an understanding of the interaction of multiple risk factors and their cumulative influence on audiological outcome.
- Conducting a cost analysis study using different combinations of screening measures will provide insight into the most cost-effective screening protocol which is necessary in resource stricken contexts.
- Future research should be conducted on the same sample of participants, over a longer time frame to allow the use of a developmental checklist between their 12 and 24 month NNFU visits. Developmental monitoring will not only guide the development of an appropriate audiological checklist for paediatricians, but will also assist in the referral of infants with suspected delayed onset hearing loss or of audiological concern.

- The current study should be replicated on a larger sample size at different levels of service delivery.
- The differences in follow-up return rate between the two contexts in the current study suggest the need to further explore the factors influencing follow-up return rate at different settings; especially between maternal and child health contexts versus contexts offering generalised health care services.
- The recent piloting of NHI services in South Africa suggests the need to pilot EHDI programmes within this proposed health care model. The selected NHI sites should have established referral pathways and should have the capacity to provide screening, diagnostic and intervention services.
- Careful consideration regarding other screening personnel is also needed in order to improve coverage rates which may assist with both the current TNHS approach, and the future goal of UNHS. The training and employment of other screening personnel in South Africa needs to be considered within the NHI framework, with possible personnel being from the district clinical specialist teams. Furthermore, the use of mid-level workers needs to be considered in contexts where audiologists are not employed, such as the PHC level.
- Since there has been discussion around the use of mid- level workers, and the need for the development of training and implementation guidelines for screeners, the use of these guidelines should be piloted in order to facilitate this transition in roles from the audiologist. Successful development of training guidelines will facilitate the provision of NHS in public sector hospital contexts, where manpower shortage is frequently reported as a challenge.

The current thesis focused on a targeted, “high risk” population; the results of which are important to the context in which the study was conducted. In general, the current thesis suggests that TNHS is possible to implement within a hospital setting provided that appropriate planning and multidisciplinary team involvement is initiated by the audiologist within existing structures of the setting, as was done by the current researcher. Findings further highlight the positive role that the audiologist can play within the team at NNFU clinics.

Results from the current study suggest differences in the type and frequency of case history factors in high risk newborns or infants. Furthermore, current study findings strongly suggest

that not all neonates or infants who are considered to be medically at risk will necessarily present with hearing impairment. These findings therefore suggest the need for further, ongoing exploration of context specific risk factors associated with hearing impairment, either retrospectively or prospectively. With regards to the combinations of screening measures used in TNHS programmes, current findings suggest that the use of a combination of two screening measures is useful in ensuring a cross-check principle, specificity and minimal to no FN findings, particularly when employed within a two-stage screening protocol. A two-stage screening protocol can be achieved by conducting a repeat hearing screening post discharge. The repeat hearing screening assists in ruling out FP findings from the initial hearing screening, thereby reducing the *referral* rate. Findings from the current study further suggest that follow-up return rate remains a challenge, but that appropriate alignment with other medical follow-up appointments is advantageous. These results have the potential to contribute toward improving NHS programmes in public sector hospital contexts. However, audiologists need to play an active role in the piloting, planning, implementation and management of NHS programmes and training processes, especially if mid-level workers or screeners are to take over the screening role in future.

REFERENCES

AAP. (2008). Hospital Discharge of the High-Risk Neonate. *Pediatrics, 122*(5), 1119-1126.

AAP, & ACOG. (2006). The Apgar score. *Pediatrics, 117*(4), 1444-1447.

Abalo, M. C. P., Vazquez, J. A. G., Lopez, G. S., Gonzalez, M. P., de Leon Mola, M. P., & Castillo, M. S. (2009). A 25-Year Review of Cuba's Screening Program For Early Detection of Hearing Loss. *MEDICC Review, 11*(1), 21-28.

ACOG. (2006). The APGAR score. *Obstetrics & Gynecology, 107*, 1209–1212.

ACOG. (2012). Obstetric Data Definitions Issues and Rationale for Change: GESTATIONAL AGE & TERM, from http://www.acog.org/-/media/Departments/Patient-Safety-and-Quality-Improvement/201213IssuesandRationale-GestationalAgeTerm.pdf?dmc=1&ts=20150827T0852270905

Agresti, A., & Kateri, M. (2011). *Categorical data analysis*. Heidelberg: Springer.

Akinpelu, O. V., Peleva, E., Funnell, W. R. J., & Daniel, S. J. (2014). Otoacoustic emissions in newborn hearing screening: A systematic review of the effects of different protocols on test outcomes. *International Journal of Pediatric Otorhinolaryngology, 78*, 711-717.

Al-Meqbel, A., & Al-Baghli, H. (2015). The prevalence of hearing imapirment in high-risk infants in Kuwait. *Auditory and vestibular Research, 24*(1), 11-16.

Alvarez, A. E. (2008). An Evaluation of the Virginia Early Hearing Detection and Intervention Program. Retrieved from http://www.infanthearing.org/states/documents/evaluation_tools/Virginia%20VEHDIP_Evaluation_July2008.pdf

Armstrong, M., Maresh, A., Buxton, C., Craun, P., Wowroski, L., Reilly, B., & Preciado, D. (2013). Barriers to early cochlear implantation. *International Journal of Pediatric Otorhinolaryngology, 77*, 1869-1872.

ASHA. (1997). Guidelines for Audiologic Screening, from http://www.asha.org/policy/GL1997-00199/

ASHA. (2008). Loss to Follow-Up in Early Hearing Detection and Intervention [Technical Report]. Retrieved from http://www.asha.org/policy

ASHA. (2013). Evidence-Based Systematic Review of Newborn Hearing Screening Using Behavioral Audiometric Threshold as a Gold Standard. Retrieved from http://www.asha.org/uploadedFiles/EBSR-Newborn-Hearing-Screening.pdf

Babalola, S., & Fatusi, A. (2009). Determinants of use of maternal health services in Nigeria - looking beyond individual and household factors. *BMC Pregnancy and Childbirth, 9*(43), 1-13.

Babbie, E. (2008). *The Basics of Social Research*. Belmont: Thomson Wadsworth.

Baiduc, R. R., Poling, G. L., Hong, O., & Dhar, S. (2013). Clinical measures of auditory function: The cochlea and beyond. *Disease- a-Month, 59*, 147-156.

Baldwin, M., Sutton, G., Gravel, J., & Low, R. (2008). *Tympanometry in babies under 6 months: A Recommended Test Protocol*. Retrieved from http://hearing.screening.nhs.uk/audiologyprotocols

Baleta, A. (2011). South Africa takes steps to reduce perinatal mortality. *Lancet 377*(9774), 1303-1304.

Ballot, D. E., Potterton, J., Chirwa, T., Hilburn, N., & Cooper, P. A. (2012). Developmental outcome of very low birth weight infants in a developing country. *BMC Pediatrics, 12*(11), 1-10.

Bamford, L. (2013). Maternal, Newborn and Child Health. *South African Health Review*(2012/13), 49-66.

Banga, G., Barche, A., Singh, R., Sheehan, C., & Vasylyeva, T. L. (2015). Sex-Related Health Disparities among Preterm Babies. *International Journal of Integrative Pediatrics and Environmental Medicine*, 1-6.

Benito-Orejas, J. I., Ramirez, B., Morais, D., Almaraz, A., & Fernandez-Calvo, J. L. (2008). Comparison of two-step transient evoked otoacoustic emissions (TEOAE) and automated auditory brainstem response (AABR) for universal newborn hearing screening programs. *International Journal of Pediatric Otorhinolaryngology, 72*, 1193-1201.

Berg, A. L., Prieve, B. A., Serpanos, Y. C., & Wheaton, M. A. (2011). Hearing Screening in a Well-Infant Nursery: Profile of Automated ABR-Fail/OAE-Pass. *Pediatrics, 127*, 269-275.

Berninger, E., & Westling, B. (2011). Outcome of a universal newborn hearing screening programme based on multiple transient-evoked otoacoustic emissions and clinical brainstem response audiometry. *Acta Oto-Laryngologica, 131*, 728-739.

Beswick, R., Driscoll, C., & Kei, J. (2012). Monitoring for Postnatal Hearing Loss Using Risk Factors: A Systematic Literature Review. *Ear and Hearing, 33*(6), 747-756.

Beswick, R., Driscoll, C., Kei, J., & Glennon, S. (2012). Targeted surveillance for postnatal hearing loss: A program evaluation. *International Journal of Pediatric Otorhinolaryngology, 76*, 1046-1056.

Beswick, R., Driscoll, C., Kei, J., Khan, A., & Glennon, S. (2013). Which Risk Factors Predict Postnatal Hearing Loss in Children? *Journal of the American Academy of Audiology, 24*(3), 205-213.

Bevilacqua, M. C., Alvarenga, K. F., Costa, A. O., & Moret, A. L. M. (2010). The universal newborn hearing screening in Brazil: from identification to intervention. *International Journal of Pediatric Otorhinolaryngology, 74*, 510-515.

Bhagya, V., Crid, S. V., & Doddamani, M. (2011). Incidence of hearing loss in infants at risk. *International Journal of Biological & Medical Research, 2*(4), 1102-1105.

Bielecki, I., Horbulewicz, A., & Wolan, T. (2011). Risk factors associated with hearing loss in infants: an analysis of 5282 referred neonates. *International Journal of Pediatric Otorhinolaryngology, 75*(7), 925-930.

Bielecki, I., Horbulewicz, A., & Wolan, T. (2012). Prevalence and risk factors for Auditory Neuropathy Spectrum Disorder in a screened newborn population at risk for hearing loss. *International Journal of Pediatric Otorhinolaryngology, 76*, 1668–1670.

Blaiser, K. (2012). Supporting Communicative Development of Infants and Toddlers with Hearing Loss. *Seminars in Speech and Language, 33*(4), 273-279.

Blumberg, L., Frean, J., & Moonasar, D. (2014). Successfully controlling malaria in South Africa. *South African Medical Journal, 104*(3 Suppl. 1), 224-227.

Boone, R. T., Bower, C. M., & Martin, P. F. (2005). Failed newborn hearing screens as presentation for otitis media with effusion in the newborn population. *International Journal of Pediatric Otorhinolaryngology, 69*, 393-397.

Borkoski Barreiro, S. A., Falcon Gonzalez, J. C., Yanes, J. B., Perez Bermudez, J. L. P., Cano, Z. L., & Mazxias, A. R. (2013). Results of an Early Hearing Detection Program. *Acta Otorrinolaringológica Española, 64*(2), 92-96.

Boshoff, L., & Tooke, L. (2012). Congenital rubella: Is it nearly time to take action? *South African Journal of Child Health, 6*(4), 106-108.

Boudewyns, A., Declau, F., Van den Ende, J., Van Kerschaver, E., Dirckx, S., Van den Brandt, A. H., & Van de Heyning, P. (2011). Otitis Media With Effusion: An

Underestimnated Cause of Hearing Loss in Infants. *Otology & Neurotology, 32*, 799-804.

Bovo, R., Trevisi, P., Ghiselli, S., Benatti, A., & Martini, A. (2015). Is very early hearing assessment always feasible in selecting patients for cochlear implants? A case series study. *International Journal of Pediatric Otorhinolaryngology, 79*, 725-731.

Burke, M., Shenton, R. C., & Taylor, M. J. (2012). The economics of screening infants at risk of hearing impairment: An international analysis. *International Journal of Pediatric Otorhinolaryngology, 76*, 212-218.

Burton, R. (2013). Maternal health: There is cause for optimism. *South African Medical Journal, 103*(8), 520-521.

Butler, I. (2010). Vaccine offers meningitis hope. *Nature, 468*, 143.

Butler, I. (2012). Identification and management of childhood hearing loss. *Continuing Medical Education, 30*(9), 314-317.

Butler, I., Basson, A., Britz, E., de Wet, R., Korsten, G. B., & Joubert, G. (2013). Age of diagnosis for congenital hearing loss at Universitas Hospital, Bloemfontein. *South African Medical Journal, 103*(7), 474-475.

Can, E., Verim, A., Başer, E., & İnan, N. (2015). Auditory neuropathy in late preterm infants treated with phototherapy for hyperbilirubinemia. *International Journal of Audiology, 54*, 89-95.

Canale, A., Favero, E., Lacilla, M., Recchia, E., Schindler, A., Roggero, N., & Albera, R. (2006). Age at diagnosis of deaf babies: A retrospective analysis highlighting the advantage of newborn hearing screening. *International Journal of Pediatric Otorhinolaryngology, 70*, 1283-1289.

CASLPA. (2010). CASLPA Position Paper on Universal Newborn Hearing Screening in Canada. Retrieved from http://www.caslpa.ca/PDF/position%20papers/Universal_Newborn_Hearing_Screening_Position_Paper_2010.pdf

Cavalcanti, H. G., de Melo, L. P. F., Buarque, L. F. S. F., & Guerra, R. O. (2014). Overview of newborn hearing screening programs in Brazilian maternity hospitals. *Brazilian Journal of Otorhinolaryngology, 80*(4), 346-353.

Cavalcanti, H. G., & Guerra, R. O. (2012). The role of maternal socioeconomic factors in the commitment to universal newborn hearing screening in the Northeastern region of Brazil. *International Journal of Pediatric Otorhinolaryngology, 76*, 1661-1667.

Chapchap, M. J., & Segre, C. M. (2001). Universal newborn hearing screening and transient evoked otoacoustic emissions: new concepts in Brazil. *Scandanavian Audiology, 30*(Suppl 53), 33-36.

Chen, G., Yi, X., Chen, P., Dong, J., Yang, G., & Fu, S. (2012). A large-scale newborn hearing screening in rural areas in China. *International Journal of Pediatric Otorhinolaryngology, 76*(12), 1771-1774.

Chetwood, J. D., Ladep, N. G., & Taylor-Robinson, S. D. (2015). Research partnerships between high and low-income countries: are international partnerships always a good thing? *BMC Medical Ethics, 16*, 36-40.

Ching, T. Y. C., Dillon, H., Marnane, V., Hou, S., Day, J., Seeto, M., . . . Yeh, A. (2013). Outcomes of early- and late-identified children at 3 years of age: findings from a prospective population-based study. *Ear and Hearing, 34*(5), 535-552.

Choo, D., & Meinzen-Derr, J. (2010). Universal newborn hearing screening in 2010. *Current Opinion in Otolaryngology & Head and Neck Surgery, 18*, 399-404.

Chopra, M., Lawn, J. E., Sanders, D., Barron, P., Karim, S. S. A., Bradshaw, D., . . . Coovadia, H. (2009). Achieving the health Millennium Development Goals for South Africa: challenges and priorities. *The Lancet, 374*, 1023–1031.

Chukwuokolo, J. C. (2009). Afrocentrism or Eurocentrism: The Dilemma of African Development. *OGIRISI: a New Journal of African Studies, 6*, 24-39.

CIOMS. (2002). International Ethical Guidelines for Biomedical Research Involving Human Subjects. Retrieved from http://www.fhi360.org/training/fr/retc/pdf_files/cioms.pdf

Coenraad, S., Goedegebure, A., & Hoeve, L. J. (2011). An initial overestimation of sensorineural hearing loss in NICU infants after failure on neonatal hearing screening. *International Journal of Pediatric Otorhinolaryngology, 75*, 159-162.

Coenraad, S., Goedegebure, A., van Goudoever, J. B., & Hoeve, L. J. (2010). Risk factors for sensorineural hearing loss in NICU infants compared to normal hearing NICU controls. *International Journal of Pediatric Otorhinolaryngology, 74*, 999-1002.

Colella-Santos, M. F., Hein, T. A. D., De Souza, G. L., Do Amaral, M. I. R., & Casali, R. L. (2014). Newborn Hearing Screening and Early Diagnostic in the NICU. *BioMed Research International, 2014*, 1-11. doi: doi:10.1155/2014/845308

Colgan, S., Gold, L., Wirth, K., Ching, T., Poulakis, Z., Rickards, F., & Wake, M. (2012). The cost-effectiveness of universal newborn screening for bilateral permanent congenital hearing impairment: Systematic review. *Academic Pediatrics, 12*(3), 171-180.

Connolly, J. L., Carron, J. D., & Roark, S. (2005). Universal newborn hearing screening: Are we achieving the Joint Committe on Infant Hearing (JCIH) objectives? *Laryngoscope, 115*, 232-236.

Coovadia, H., Jewkes, R., Barron, O., Sanders, D., & McIntyre, D. (2009). The health and health system of South Africa: Historical roots of current public health challenges. *Lancet, 374*(9692), 817-834.

Costello, A., & Zumla, A. (2000). Moving to research partnerships in developing countries. *BMJ, 321*, 827-829.

CPS. (2011). Position Statement: Universal newborn hearing screening. *Paediatric Child Health, 16*(5), 301-305.

Cristobal, R., & Oghalai, J. S. (2008). Hearing loss in children with very low birth weight: current review of epidemiology and pathophysiology. *Archives of Disease in Childhood Fetal and Neonatal Edition, 93*, F462-F468.

Cullinan, K. (2006). Health services in South Africa: A basic introduction. Retrieved from http://www.health-e.org.za/wp-content/uploads/2013/04/Health_services_briefing_doc.pdf

da Mata Lupoli, L., Garcia, L., Anastasio, A. R. T., & Fontana, A. C. (2013). Time after birth in relation to failure rate in newborn hearing screening. *International Journal of Pediatric Otorhinolaryngology, 77*, 932–935.

De Capua, B., Costantini, D., Martufi, C., Latini, G., Gentile, M., & De Felice, C. (2007). Universal neonatal hearing screening: The Siena (Italy) experience on 19,700 newborns. *Early Human Development, 83*, 601-606.

de Freitas, V. S., de Freitas Alvarenga, K., Bevilacqua, M. C., Martinez, M. A. N., & Costa, O. A. (2009). Critical analysis of three newborn hearing screening protocols. *Pro-Fono Revista de Atualizacao Cientifica, 21*(3), 201-206.

de Vos, A. S., Strydom, H., Fouche, C. B., & Delport, C. S. L. (2005). *Research at Grass Roots: For the Social Sciences and Human Service Professions* (3rd ed.). Pretoria: Van Schaik.

Declau, F., Boudewyns, A., Van den Ende, J., Peeters, A., & van den Heyning, P. (2008). Etiologic and Audiologic Evaluations After Universal Neonatal Hearing Screening: Analysis of 170 Referred Neonates. *Pediatrics, 121*(6), 1119-1126.

Dedhia, K., Kitsko, D., Sabo, D., David, H., & Chi, M. D. (2013). Children with Sensorineural Hearing Loss After Passing the Newborn Hearing Screen. *JAMA Otolaryngology-Head & Neck Surgery, 139*(2), 119-123.

Diar, H. A., & Velaphi, S. (2014). Characteristics and mortality rate of neonates with congenital cytomegalovirus infection. *South African Journal of Child Health, 8*(4), 133-137.

do Carmo, M. P., Almeida, M. B., & Lewis, D. R. (2012). 226 Hz and 1 kHz tympanometry in infants with risk indicators for hearing loss. *Revista da Sociedade Brasileira de Fonoaudiologia, 17*(1), 66-72.

DoH. (2000). *The Primary Health Care Package for South Africa – a set of norms and standards*. Pretoria: Retrieved from www.doh.gov.za/docs/policy/norms/full-norms.html.

DoH. (2010). *National Department of Health Strategic Plan 2010/11-2012/13*. Pretoria: Retrieved from http://www.nationalplanningcycles.org/sites/default/files/country_docs/South%20Africa/south_africa_strategic_health_plan_2010-2013.pdf

DoH. (2011). *National Health Insurance: Policy Paper*. Retrieved from http://www.bowman.co.za/FileBrowser/ContentDocuments/NHI.pdf.

DoH. (2012a). Annual Helath Statistics.

DoH. (2012b). *Guideline for the prevention of hearing impairment due to otitis media at clinic level*. Retrieved from www.doh.gov.za/docs/policy/2012/hearingguide.pdf.

DoH. (2012c). *Human Resources for Health South Africa HRH Strategy for the Health Sector: 2012/13–2016/17*. Retrieved from www.doh.gov.za/docs/stratdocs/2012/hrhstrat.pdf.

DoH. (2012d). *Strategic Plan for Maternal,Newborn, Child and Women's Health (MNCWH) and Nutrition in South Africa 2012 - 2016*. Retrieved from www.doh.gov.za/docs/stratdocs/2012/MNCWHstratplan.pdf.

DoH. (2015). *National Health Insurance for South Africa: Towards Universal Health Coverage*. Retrieved from http://www.bhfglobal.com/wp-content/uploads/2015/03/National_Health_Insurance_White_Paper_10Dec2015.pdf.

Doherty, J., Conco, D., Couper, I., & Fonn, S. (2013). Developing a new mid-level health worker: lessons from South Africa's experience with clinical associates. *Global Health Action, 6*, 147-156.

Dookie, S., & Singh, S. (2012). Primary health services at district level in South Africa: a critique of the primary health care approach. *BMC Family Practice, 13*, 67-70.

Dorros, C., Kurtzer-White, E., Ahlgren, M., Simon, P., & Vohr, B. (2007). Medical home for children with hearing loss: physician perspectives and practices. *Pediatrics, 120*(2), 288-294.

Driscoll, C., Beswick, R., Doherty, E., D'Silva, R., & Cross, A. (2015). The validity of family history as a risk factor in pediatric hearing loss. *International Journal of Pediatric Otorhinolaryngology, 79*, 654-659.

Durieux-Smith, A., Fitzpatrick, E., & Whittingham, J. (2008). Universal newborn hearing screening: A question of evidence. *International Journal of Audiology, 47*, 1-10.

Durieux-Smith, A., & Whittingham, J. (2000). The rationale for neonatal hearing screening. *Journal of Speech Language Pathology and Audiology, 24*, 59-67.

Econex. (2013). The South African Private Healthcare Sector: Role and Contribution to the Economy.

Eras, Z., Konukseven, O., Aksoy, H. T., Canpolat, F. E., Genc, A., Sakrucu, E. D., . . . Dilmen, U. (2014). Postnatal risk factors associated with hearing loss among high-risk preterm infants: tertiary centre results from Turkey. *European Archives of Otolaryngology, 271*, 1485-1490.

Farr, K. (2015). *Hearing Screening and Audiological Monitoring Practices in Newborns and Infants with Risk Factors for Hearing Loss*. Research Report. Speech Pathology and Audiology. University of the Witwatersrand. Johannesburg.

Ferro, L. M., Tanner, G., Erler, S. F., Erickson, K., & Dhar, S. (2007). Comparison of universal newborn hearing screening programs in Illinois hospitals. *International Journal of Pediatric Otorhinolaryngology, 71*, 217-230.

Feucht, U. D. (2013). Keeping children alive and healthy in South Africa-how do we reach this goal? Perspectives from a paediatrician in a District Clinical Specialist Team. *South African Journal of Child Health, 7*(4), 124-126.

Fitzpatrick, E., Crawford, L., Ni, A., & Durieux-Smith, A. (2011). A Descriptive Analysis of Language and Speech Skills in 4- to 5 - Yr- Old Children with Hearing Loss *Ear and Hearing, 32*(5), 605-616.

Fitzpatrick, E., Durieux-Smith, A., Eriks-Brophy, A., Olds, J., & Gaines, R. (2007). The impact of newborn hearing screening on communication development. *Journal of Medical Screening, 14*, 123-131.

Fitzpatrick, E., Whittingham, J., & Durieux-Smith, A. (2014). Mild bilateral and unilateral hearing loss in childhood: a 20-year view of hearing characteristics, and audiologic practices before and after newborn hearing screening. *Ear and Hearing, 35*, 10-18.

Friderichs, N., Swanepoel, D., & Hall, J. W. (2012). Efficacy of a community-based infant hearing screening program utilizing existing personnel in Western Cape, South Africa. *International Journal of Pediatric Otorhinolaryngology, 76*, 552-559.

Fulcher, A., Purcell, A. A., Baker, E., & Munro, N. (2012). Listen up: Children with early identified hearing loss achieve age-appropriate speech/language outcomes by 3 years -of- age. *International Journal of Pediatric Otorhinolaryngology, 76*, 1785-1794.

Gates, G. A., Klein, J. O., Lim, D. J., Mogi, G., Ogra, P. L., Pararella, M. M., . . . Tos, M. (2002). Recent advances in otitis media. Definitions, terminology, and classification of otitis media. *Annals of Otology, Rhinology and Laryngology, 111*, 8-18.

Gauteng Provincial Speech Therapy & Audiology Levels of Service Delivery Workgroup, & HPCSABoardforSpeech-Language&HearingProfessions. (2014). A guideline for planning STA services at all levels of health care Retrieved 19th October, 2014, from http://www.hpcsa.co.za/Uploads/editor/UserFiles/downloads/speech/guidelines/guideline_planning_STA_services_at_all_levels_health%20care.pdf

Ghogomu, N., Umansky, A., & Lieu, J. E. C. (2014). Epidemiology of Unilateral Sesorineural Hearing Loss with Universal Newborn Hearing Screening. *Laryngoscope, 124*(1), 295-300.

Gilbey, P., Kraus, C., Ghanayim, R., Sharabi-Nov, A., & Bretler, S. (2013). Universal newborn hearing screening in Zefat, Israel: The first two years. *International Journal of Pediatric Otorhinolaryngology, 77*, 97-100.

Gilson, L., & McIntyre, D. (2007). Post-apartheid challenges: Household access and use of health care in South Africa. *International Journal of Health Services, 37*(4), 673-691.

Grosse, S. D., Ross, D. S., & Dollard, S. C. (2008). Congenital cytomegalovirus (CMV) infection as a cause of permanent bilateral hearing loss: A quantitative assessment. *Journal of Clinical Virology, 41*, 57-62.

Guastini, L., Mora, R., Dellepiane, M., Santamauro, V., Mora, M., Rocca, A., & Salami, A. (2010). Evaluation of an automated auditory brainstem response in a multi-stage infant hearing screening. *European Archives of Otolaryngology, 267*, 1199-1205.

Guralnick, M. J. (2001). A developmental systems model for early intervention. *Infants and Young Children, 14*(2), 1-18.

Hall, J. W. (2000). *Handbook of Otoacoustic Emissions*. New York: Thomson Delmar Learning.

Hall, J. W. (2007). *New Handbook of Auditory Evoked Responses*. Boston: Pearson Education.

Hall, J. W., & Mueller, H. G. (1997). *Audiologists' Desk Reference: Diagnostic Audiology Principles, Procedures, and Practices* (Vol. I). London: Singular Publishing.

Hall, J. W., Smith, S. D., & Popelka, G. R. (2004). Newborn Hearing Screening with Combined Otoacoustic Emissions and Auditory Brainstem Responses. *Journal of the American Academy of Audiology, 15*, 414-425.

Hall, J. W., & Swanepoel, D. (2010). *Objective Assessment of Hearing*. San Diego: Plural Publishing.

Harris, B., Goudge, J., Ataguba, J. E., McIntyre, D., Nxumalo, N., Jikwana, S., & Chersich, M. (2011). Inequities in access to health care in South Africa. *Journal of Public Health Policy, 32*(S1), S102-S123.

Hatzopoulos, S., Qirjazi, B., & Martini, A. (2007). Neonatal hearing screening in Albania: Results from an ongoing universal screening program. *International Journal of Audiology, 46*, 176-182.

Hergils, L. (2007). Analysis of measurements from the first Swedish universal neonatal hearing screening program. *International Journal of Audiology, 46*, 680-685.

Hille, E. T. M., van Straaten, H. L. M., & Verkerk, P. H. (2007). Prevalence and independent risk factors for hearing loss in NICU infants. *Acta Paediatrica, 96*, 1155-1158.

Holte, L., Walker, E., Oleson, J., Spratford, M., Moeller, M. P., Roush, P., . . . Hua, O. (2012). Factors Influencing Follow-up to Newborn Hearing Screening for Infants who are Hard-of-Hearing. *American Journal of Audiology, 21*(2), 163-174.

Howell, D. C. (2002). *Statistical Methods for Psychology* (5th ed.). California: Thomson Learning.

HPCSA. (2007). Early Hearing Detection and Intervention Programmes in South Africa, Position Statement Year 2007. Retrieved from http://www.hpsca.co.za/hpcsa/default.aspx?id=137

HPCSA. (2012). Number of Registered Healthcare Practitioners 31 March 2012, from http://www.hpcsa.co.za/statistics.php

HSRC. (2012). Informed Consent Guidelines re Minors (including orphans and vulnerable children (OVC)) and Parental Substitutes. Retrieved from http://www.hsrc.ac.za/uploads/pageContent/5498/Guidelines%20for%20research%20with%20minors%202012.pdf

Huang, H., Chiang, S., Shiau, Y., Yeh, W., Ho, H. C., Wang, L., . . . Hsiao, K. (2013). The universal newborn hearing screening program of Tapei City. *International Journal of Pediatric Otorhinolaryngology, 77*, 1734-1737.

Huang, L. H., Zhang, L., Tobe, R. G., Qi, F., Sun, L., Teng, Y., . . . Han, D. (2012). Cost-effectiveness analyis of neonatal hearing screening program in china: should universal screening be prioritized? *BMC Health Services Research, 12*, 97.

Hyde, M. L. (2005). Newborn hearing screening programs: Overview. *Journal of Otolaryngology, 34*, S70-S78.

Institute of Medicine (US) Committee on Understanding Premature Birth and Assuring Healthy Outcomes. (2007). Neurodevelopmental, Health, and Family Outcomes for Infants Born Preterm. In R. E. Behrman & A. S. Butler (Eds.), Preterm Birth: Causes, Consequences, and Prevention. Washington: National Academies Press. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK11356/?report=classic.

Jackson, S. L. (2009). Quasi-experimental and single case designs. In S. L. Jackson (Ed.), *Research Methods and Statistics: A critical thinking approach* (3rd edition ed., pp. 316-338). Belmont: Wadsworth Cengage Learning.

Jakubikova, J., Kabatova, Z., & Zavodna, M. (2003). Identification of hearing loss in newborns by transient otoacoustic emissions. *International Journal of Pediatric Otorhinolaryngology, 67*, 15-18.

Jardine, C., & Ballot, D. E. (2015). The use of nasal CPAP at the Charlotte Maxeke Johannesburg Academic Hospital. *South African Journal of Child Health, 9*(2), 45-48.

JCIH. (1982). Position Statement. Retrieved from http://www.jcih.org/JCIH1982.pdf

JCIH. (2000). Year 2000 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. *American Journal of Audiology, 9*, 9-29.

JCIH. (2007). Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs. *Pediatrics, 120*(4), 898-921.

JCIH. (2008). Clarification for Year 2007 JCIH Position Statement. Retrieved from http://www.jcih.org/Clarification%20Year%202007%20statement.pdf

JCIH, Muse, C., Harrison, J., Yoshinago-Itano, C., Grimes, A., Brookhouser, P. E., . . . Martin, B. (2013). Supplement to the JCIH 2007 Position Statement: Principles and Guidelines for Early Intervention After Confirmation That a Child is Deaf or Hard of Hearing. *Pediatrics, 131*(4), e1324- e1349.

Jewel, J., Varghese, P. V., Singh, T., & Varghese, A. (2013). Newborn Hearing Screening-Experience at a Tertiary Hospital in Northwest India. *International Journal of Otolaryngology and Head & Neck Surgery, 2*, 211-214.

Johnson, C. (2002a). Hearing and Immittance Screening. In J. Katz (Ed.), *Handbook of Clinical Audiology* (5th ed., pp. 481-494). Baltimore: Lippincott Williams and Wilkins.

Johnson, C. D. (2002b). Special Populations. In J. Kats, R. F. Bukard & L. Medwetsky (Eds.), *Handbook of Clinical Audiology* (5th ed., pp. 481-494). Baltimore: Lippincott Williams & Wilkins.

Kamal, N. (2013). Newborn hearing screening: Opportunities and challenges. *Egyptian Journal of Ear, Nose, Throat and Allied Sciences, 14*, 55-58.

Kanji, A., & Khoza-Shangase, K. (2012). The occurrence of high-risk factors for hearing loss in very low-birth-weight neonates: A retrospective exploratory study of targeted hearing screening. *South African Journal of Communication Disorders, 59*, 3-7.

Kanji, A., Khoza-Shangase, K., & Ballot, D. (2010). Hearing screening follow-up return rate in a very low birth weight project: A retrospective record review. *South African Journal of Child Health, 4*(4), 95-99.

Kanji, A., & Opperman, J. (2015). Audiological practices and findings post HPCSA position statement: Assessment of children aged 0 - 35 months. *South African Journal of Child Health, 9*(2), 38-40.

Keleher, H. (2001). Why primary health care offers a more comprehensive approach for tackling health inequities than primary care. *Australian Journal of Primary Health, 7*(2), 57-61.

Kemp, D. T. (2002). Otoacoustic emission, their origin in cochlear function, and use. *British Medical Bulletin, 63*, 223-241.

Kennedy, C. R., McCann, D. C., Campbell, M. J., Law, C. M., Mullee, M., Petrou, S., . . . Stevenson, J. (2006). Language Ability after Early Detection of Permanent Childhood Hearing Impairment. *New England Journal of Medicine, 354*(20), 2131-2141.

Khoza-Shangase, K., Barratt, J., & Jonosky, J. (2010). Protocols for early audiology intervention services: Views from early intervention practitioners in a developing country. *South African Journal of Child Health, 4*(4), 100-105.

Khoza-Shangase, K., & Harbinson, S. (2015). Evaluation of universal newborn hearing screening in South African primary care. *African Journal of Primary Health Care and Family Medicine, 7*(1), 1-12.

Khoza-Shangase, K., & Michal, G. (2014). Early Intervention in Audiology: Exploring the Current Status from a Developing Country Context. *British Journal of Medicine & Medical Research, 4*(11), 2238-2249.

Khoza-Shangase, K., & Turnbull, T. (2009). Hearing screening in a group of paediatric patients attending an HIV/AIDS clinic: A pilot study. *African Journal of Infectious Diseases, 3*(2), 57-68.

Kon, Z., & Lackan, N. (2008). Ethnic Disparities in Access to Care in Post-Apartheid South Africa. *American Journal of Public Health, 98*(12), 2272-2277.

Korres, S., Nikolopoulos, T. P., Komkotou, V., Balatsouras, D., Kandiloros, D., Constantinou, D., & Ferekidis, E. (2005). Newborn Hearing Screening: Effectiveness, importance of high-risk factors, and characteristics of infants in the neonatal intensive care unit and well-baby nursery. *Otology Neurotology, 26*, 1186-1190.

Korres, S. G., Balatsouras, D. G., Gkoritsa, E., Eliopoulos, P., Rallis, E., & Ferekidis, E. (2006). Success rate of newborn and follw-up screening of hearing using otoacoustic emissions. *International Journal of Pediatric Otorhinolaryngology, 70*, 1039- 1043.

Korver, A. M. H., de Vries, J. J. C., Konings, S., de Jonga, J. W., Dekker, F. W., Vossen, A. C. T. M., . . . Oudesluys-Murphy, A. M. (2009). DECIBEL study: Congenital cytomegalovirus infection in young children with permanent bilateral hearing impairment in the Netherlands. *Journal of Clinical Virology, 46S*, S27–S31.

Korver, A. M. H., Konings, S., Dekker, F. W., Beers, M., Wever, C. C., Frijns, J. H. M., & Oudesluys-Murphy, A. M. (2010). Newborn Hearing Screening vs Later Hearing Screening and Developmental Outcomes in Children with Permanent Childhood Hearing Impairment. *Journal of the American Medical Association, 304*(15), 1701-1708.

Korver, A. M. H., van Zanten, G. A., Meuwese-Jongejeugd, A., van Straaten, H. L. M., & Oudesluys-Murphy, A. M. (2012). Auditory neuropathy in a low-risk population: A review of the literature. *International Journal of Pediatric Otorhinolaryngology, 76*, 1708–1711.

Kountakis, S. E., Skoulas, I., Phillips, D., & Chang, C. Y. (2002). Risk factors for hearing loss in neonates: A prospective study. *American Journal of Otolaryngology, 23*(3), 133-137.

Krabbenhoft, K. (2015). *Audiological follow-up in a risk-based hearing screening programme: Influencing factors*. Research report. Speech Pathology and Audiology. University of the Witwatersrand. Johannesburg.

Kumar, A., Chowdareddy, N., Sodhi, K., Dalal, S. S., Venkateshwar, & Ravi Chander, B. (2014). Feasibility of two staged newborn hearing screening and identification of risk factors for hearing loss other than those included in High Risk Registry (HRR) given by Joint Committee on Infant Hearing (JCIH). *International Journal of Medical Science and Public Health, 3*(3), 257-260.

Kumar, S., & Mohapatra, B. (2011). Status of newborn hearing screening program in India. *International Journal of Pediatric Otorhinolaryngology, 75*, 20-26.

Lachowska, M., Surowiec, P., Morawski, K., Pierchala, K., & Niemczyk, K. (2014). Second stage of Universal Neonatal Hearing Screening- A way for diagnosis and beginning of proper treatment for infants with hearing loss. *Advances in Medical Sciences, 59*, 90-94.

Laher, F., Ashford, G., Cescon, A., Cullen, C., Lazarus, E., Puren, A., & Visser, L. (2010). Held to Ransom- CMV Treatment in South Africa. *The Southern African Journal of HIV Medicine, April*, 31-34.

Lammens, F., Verhaert, N., Devriendt, K., Debruyne, F., & Desloovere, C. (2013). Aetiology of congenital hearing loss: A cohort review of 569 subjects. *International Journal of Pediatric Otorhinolaryngology, 77*, 1385–1391.

Langer, A., Brockow, I., Nennstiel-Ratzel, U., & Menn, P. (2012). The cost-effectiveness of tracking newborns with bilateral hearing impairment in Bavaria: a decision-analytic model. *BMC Health Services Research, 12*, 418-427.

Laugen, N. J. (2013). Providing Information to Families in Newborn Hearing Screening Follow-up: Professional Challenges. *Seminars in Hearing, 34*, 11-18.

Lawn, J. E., Blencowe, H., Darmstadt, G. L., & Bhutta, Z. A. (2013). Beyond newborn survival: the world you are born into determines your risk of disability-free survival. *Pediatric Research, 74*(s1), 1-3.

Lawn, J. E., Davidge, R., Paul, V. K., von Xylander, S., Johnshon, J., Costello, A., . . . Molyneux, L. (2013). Born Too Soon: Care for the preterm baby. *Reproductive Health, 10*(Suppl 1), 1-19.

Leeflang, M. M. G., Bossuyt, P. M. M., & Irwig, L. (2009). Diagnostic test accuracy may vary with prevalence: implications for evidence-based diagnosis. *Journal of Clinical Epidemiology, 62*, 5-12.

Lehmann, U. (2008). Strengthening Human Resources for Primary Health Care. In P. Barron & J. Roma-Reardon (Eds.), South African Health Review (pp. 163-177). Durban:

Health Systems Trust. Retrieved from http://www.hst.org.za/uploads/files/chap11_08.pdf.

Lieu, J. E. C. (2004). Speech-Language and Educational Consequences of Unilateral Hearing Loss in Children. *Archives of Otolaryngology Head and Neck Surgery, 130*, 524-530.

Lieu, J. E. C., Karzon, R. K., & Mange, C. C. (2006). Hearing Screening in the Neonatal Intensive Care Unit: Follow-up of Referrals. *American Journal of Audiology, 15*, 66-74.

Lin, H., Shu, M., Lee, K., Lin, H., & Lin, G. (2007). Reducing False Positives in Newborn Hearing Screening Program: How and Why. *Otology & Neurotology, 28*, 788-792.

Liu, C., Farrell, J., MacNeil, J. R., Stone, S., & Barfield, W. (2008). Evaluating loss to follow-up in newborn hearing screening in Massachusetts. *Pediatrics, 121*, e335-343.

Lloyd, L. G., & de Witt, T. W. (2013). Neonatal mortality in South Africa: How are we doing and can we do better? *South African Medical Journal, 103*(8), 518-519.

MADHS. (No Year). Michigan's Early Hearing Detection and Intervention System: Guidelines for Hearing Screening. Retrieved from http://www.infanthearing.org/stateguidelines/Michigan/Screening%20Guidelines.pdf

Mahulja-Stamenkovic, V., Prpic, I., Zaputovic, N., Kirincic, E., Tomasic-Martinis, E., & Dujmovic, A. (2005). Universal newborn hearing test-frequency of hearing loss in high risk infants. *Medicana, 42*(1), 25-30.

Martin, F. N., & Clark, J. G. (2009). *Introduction to Audiology* (10th ed.). Boston: Pearson Education.

Martines, F., Martines, E., Mucia, M., Sciacca, V., & Salvago, P. (2013). Prelingual sensorineural hearing loss and infants at risk: Western Sicily report. *International Journal of Pediatric Otorhinolaryngology, 77*(4), 513-518.

Martines, F., Porrello, M., Ferrara, M., Martines, M., & Martines, E. (2007). Newborn hearing screening project using transient evoked otoacoutic emissions. *International Journal of Pediatric Otorhinolaryngology, 71*, 107-112.

Martines, F., Salvago, P., Bentivegna, D., Bartolone, A., Dispenza, F., & Martines, E. (2012). Audiologic profile of infants at risk: Experience of a Western Sicily tertiary care centre. *International Journal of Pediatric Otorhinolaryngology, 76*, 1285-1291.

Matsoso, M. P., & Fryatt, R. (2013). National Health Insurance: The first 18 months. *South African Medical Journal, 103*(3), 156-158.

Maxon, A. B., White, K. R., Culpepper, B., & Vohr, B. R. (1997). Maintaining Acceptably Low Referral Rates in TEOAE-based Newborn Hearing Screening Programs. *Journal of Communication Disorders, 30*(6), 457-475.

Maxwell, D. L., & Satake, E. (2006). *Research and Statistical Methods in Communication Sciences and Disorders*. New York: Thomson Delmar Learning.

Mayosi, B. M., Lawn, J. E., van Niekerk, A., Bradshaw, D., Karim, S. S. A., & Coovadia, H. M. (2012). Health in South Africa: changes and challenges since 2009. *Lancet, 380*, 2029-2043.

Mazlan, R., Kei, J., Hickson, L., Gavranich, J., & Linning, R. (2010). Test-retest reproducibility of the 1000Hz tympanometry test in newborn and six-week-old healthy infants. *International Journal of Audiology, 49*, 815-822.

McGurgan, I. J., & Patil, N. (2014). Neonatal hearing screening of high-risk infants using automated auditory brainstem response: a retrospective analysis of referral rates. *Irish Journal of Medical Science, 183*, 405-410.

McPherson, B., & Olusanya, B. O. (2008). Screening for Hearing Loss in Developing Countries. In B. McPherson & R. Brouilette (Eds.), *Audiology in Developing Countries* (pp. 75-106). New York: Nova Science Publishers.

Meinzen-Derr, J., Wiley, S., & Choo, D. I. (2011). Impact of Early Intervention on Expressive and Receptive Language Development Among Young Children with Permanent Hearing Loss. *American Annals of the Deaf, 155*(5), 580-591.

Meisels, S. J., & Shonkoff, J. P. (2000). Early Childhood Intervention: A Continuing Evolution. In J. P. Shonkoff & S. J. Meisels (Eds.), *Handbook of Early Childhood Intervention* (2nd ed., pp. 3-35). New York: Cambridge University Press.

Mencher, G. T., & DeVoe, S. J. (2001). Universal Newborn Screening: A Dream realized or a Nightmare in the making? *Scandanavian Audiology, 30*(53), 15-21.

Meyer, M. E., & Swanepoel, D. (2011). Newborn Hearing Screening in the Private Health Care Sector- A national survey. *South African Medical Journal, 101*(9), 665-667.

Miles, J., & Banyard, P. (2007). *Understanding and Using Statistics in Psychology: A practical Introduction*. London: SAGE Publications.

MinnesotaDepartmentofHealth. (2014). Early Hearing Detection and Intervention: Guidelines for Otolaryngologists. Retrieved from http://www.improveehdi.org/mn/library/files/entguidelines.pdf

MiWORC. (2013). Labour Migration by numbers: South Africa's foreign and domestic migration data. Johannesburg African Centre for Migration & Society, University of the Witwatersrand.

Moeller, M. P., McCleary, E., Putman, C., Tyler-Kings, A., Hoover, B., & Stelmachowicz, P. (2010). Longitudinal Development of Phonology and Morhology in Children with Late-Identified Mild-Moderate Sensorineural Hearing Loss. *Ear and Hearing, 31*, 625-635.

Moodley, S., & Storbeck, C. (2012). The role of the neonatal nurse in early hearing detection and intervention in South Africa. *Professional Nursing Today, 16*(4), 28-31.

Moodley, S., & Storbeck, C. (2015). Narrative review of EHDI in South Africa. *South African Journal of Communication Disorders, 62*(1), 1-10.

Moore, J. M., Thompson, G., & Folsom, R. C. (1992). Auditory responsiveness of premature infants utilizing visual reinforcement audiometry (VRA). *Ear and Hearing, 13*, 187-194.

Mukherjee, S. S., Mukherjee, S., & Sarkar, K. D. (2013). Prevalence of Hearing loss in High Risk Infants of Mediocre Socio-Economic Background at Around One Year of Age and Their Correlation with Risk Factors. *Indian Journal of Otolaryngology and Head & Neck Surgery, 65*(Suppl 3), S598-S603.

Müller-Mazzotta, J., Zemlin, M., Berger, R., & Hanschmann, H. (2012). Influence of postconceptional age on universal newborn hearing screening in NICU-babies. *Audiology Research, 2*(e1), 1-3.

Naidoo, N., & Moodley, J. (2009). Rising rates of caesarean sections: an audit of caesarean sections in a specialist private practice. *South African Family Practice, 51*(3), 254-258.

Naidoo, S. (2012). The South African national health insurance: a revolution in health-care delivery! *Journal of Public Health, 34*(1), 149-150.

Neille, J., George, K., & Khoza-Shangase, K. (2014). A study investigating sound sources and noise levels in neonatal intensive care units. *South African Journal of Child Health, 8*(1), 6-10.

Ng, P. K., Hui, Y., Lam, B. C., Goh, W. H., & Yeung, C. Y. (2004). Feasibility of implementing a universal neonatal hearing screening programme using distortion product otoacoustic emission detection at a university hospital in Hong Kong. *Hong Kong Medical Journal, 10*(1), 6-13.

Nikolopoulos, T. P. (2014). Auditory dyssynchrony or auditory neuropathy: Understanding the pathophysiology and exploring methods of treatment. *International Journal of Pediatric Otorhinolaryngology, 78*(2), 171-173.

Nikolopoulos, T. P. (2015). Neonatal hearing screening: What we have achieved and what needs to be improved. *International Journal of Pediatric Otorhinolaryngology, 79*, 635-637.

No Author. (2011). Charlotte Maxeke Johannesburg Hospital, from http://www.johannesburghospital.org.za

Núñez-Batalla, F., Trinidad-Ramos, G., Sequí-Canet, J. M., De Aguilar, V. A., & Jáudenes-Casaubón, C. (2012). Risk Factors for Sensorineural Hearing Loss in Children. *Acta Otorrinolaringológica Española, 63*(5), 382-290.

Ohl, C., Dornier, L., Czajka, C., Chobaut, J., & Tavernier, L. (2009). Newborn hearing screening on infants at risk. *International Journal of Pediatric Otorhinolaryngology, 73*, 1691-1695.

Olusanya, B. O. (2009a). Follow-up default in a hospital-based universal newborn hearing screening programme in a low-income country. *Child: care, health and development, 35*(2), 190-198.

Olusanya, B. O. (2009b). Newborns at risk of sensorineural hearing loss in low-income countries. *Archives of Disease in Childhood, 94*, 227-229.

Olusanya, B. O. (2010). Ambient noise levels and infant screening programs in developing countries. *International Journal of Audiology, 49*, 535-541.

Olusanya, B. O. (2011a). Highlights of the new WHO Report on Newborn and Infant Hearing Screening and implications for developing countries. *International Journal of Pediatric Otorhinolaryngology, 75*(6), 745-748.

Olusanya, B. O. (2011b). Making targeted screening for infant hearing loss an effective option in less developed countries. *International Journal of Pediatric Otorhinolaryngology, 75*, 316-321.

Olusanya, B. O., & Akinyemi, O. O. (2009). Community-based infant hearing screening in a developing country:parental uptake and follow-up services. *BMC Public Health, 9*, 66.

Olusanya, B. O., & Bamigboye, B. A. (2010). Is discordance in TEOAE and AABR outcomes predictable in newborns? *International Journal of Pediatric Otorhinolaryngology, 74*, 1303-1309.

Olusanya, B. O., Emokpae, A., Renner, J. K., & Wirz, S. L. (2009). Costs and performance of early hearing detection programmes in Lagos, Nigeria. *Transactions of the Royal Society of Tropical Medicine and Hygeine, 103*, 179-186.

Olusanya, B. O., Imam, Z. O., Emokpae, A. A., & Iskander, I. F. (2016). Revisiting the Criteria for Exchange Transfusion for Severe Neonatal Hyperbilirubinemia in Resource-Limited Settings. *Neonatology, 109*, 97-104.

Olusanya, B. O., Luxon, L. M., & Wirz, S. L. (2004a). Benefits and challenges of newborn hearing screening for developing countries. *International Journal of Pediatric Otorhinolaryngology, 68*, 287-305.

Olusanya, B. O., Luxon, L. M., & Wirz, S. L. (2004b). Infant hearing screening: route to informed choice. *Archives of Disease in Childhood, 89*, 1039–1040.

Olusanya, B. O., Luxon, L. M., & Wirz, S. L. (2006). Ethical issues in screening for hearing impairment in newborns in developing countries. *Journal of Medical Ethics, 32*, 588-591.

Olusanya, B. O., & Newton, V. E. (2007). Global burden of childhood hearing impairment and disease control priorities in developing countries. *Lancet, 369*, 1314-1317.

Olusanya, B. O., Ruben, R. J., & Parving, A. (2006). Reducing the burden of communication disorders in the developing world: an opportunity for the Millenium Development Project. *The Journal of the American Medical Association, 296*, 441-444.

Olusanya, B. O., Somefun, A. O., & Swanepoel, D. (2008). The Need for Standardization of Methods for Worldwide Infant Hearing Screening: A Systematic Review. *The Laryngoscope, 118*, 1830-1836.

Olusanya, B. O., Swanepoel, D., Chapchap, M. J., Castillo, S., Habib, H., & Mukari, S. Z., et al. (2007). Progress towards early detection services for infants with hearing loss in developing countries. *BMC Health Services Research, 7*, 14-28.

Olusanya, B. O., Wirz, S. L., & Luxon, L. M. (2008). Hospital-based universal newborn hearing screening for early detection of permanent congenital hearing loss in Lagos, Nigeria. *International Journal of Pediatric Otorhinolaryngology, 72*, 991-1001.

Onoda, R. M., de Azevedo, M. F., Miyashiro, A., & dos Santos, A. M. N. (2011). Neonatal Hearing Screening: failures, hearing loss and risk indicators. *Brazilian Journal of Otorhinolaryngology, 77*(6), 775-783.

Paludetti, G., Conti, G., Di Nardo, W., De Corso, E., Rolesi, R., Picciotti, P. M., & Fetoni, A. R. (2012). Infant hearing loss: from diagnosis to therapy. *ACTA Otorhinolaryngologica Italica, 32*, 347-370.

Panacek, E. A. (2007). Performing Chart Review Studies. *Air Medical journal, 26*(5), 206-210.

Papacharalampous, G. X., Nikolopoulos, T. P., Davilis, D. L., Xenellis, I. E., & Korres, S. G. (2011). Universal newborn hearing screening, a revolutionary diagnosis of deafness: real benefits and limitations. *European Archives of Otorhinolaryngology, 268*, 1399-1406.

Parag, N., McKerrow, N. H., & Naby, F. (2014). Profile of babies born before arrival at hospital in a peri-urban setting. *South African Journal of Child Health, 8*(2), 45-49.

Patel, H., Feldman, M., CanadianPaediatricSociety, & CommunityPaediatricsCommittee. (2011). Universal newborn hearing screening. *Paediatric Child Health, 16*(5), 301-305.

Petrocchi-Bartal, L., & Khoza-Shangase, K. (2014). Hearing screening procedures and protocols in use at immunisation clinics in South Africa. *South African Journal of Communication Disorders, 61*(1), 1-9.

Pieper, C. H., Smith, J., Maree, D., & Pohl, F. C. (2003). Is nCPAP of value in extereme preterms with no access to neonatal intensive care? *Journal of Tropical Pediatrics, 49*, 148-152.

Pillay, Y., & Barron, P. (2014). Progress towards the Millenium Development Goals in SA. *South African Medical Journal, 104*(3 (Suppl 1)), 223.

Pimperton, H., & Kennedy, C. R. (2012). The impact of early identification of permanent childhood hearing impairment on speech and language outcomes. *Archives of Disease in Childhood, 97*, 648-653.

Pisacane, A., Auletta, G., Toscano, F., Errichiello, M., Barrier, F., Riccardi, P., . . . Marciano, E. (2013). Feasibility and effectiveness of a population-based newborn hearing screening in an economically deprived region of Italy. *International Journal of Pediatric Otorhinolaryngology, 77*, 329-333.

Prpic, I., Mahulja-Stamenkovic, V., Bilic, I., & Haller, H. (2007). Hearing loss assessed by universal newborn hearing screening- The new approach. *International Journal of Pediatric Otorhinolaryngology, 71*, 1757-1761.

Psarommatis, I., Florou, V., Fragkos, M., Douniadakis, E., & Konyrogiannis, A. (2011). Reversible auditory brainstem responses screening failures in high-risk neonates. *European Archives of Otorhinolaryngology, 268*, 189-196.

Rai, N., & Thakur, N. (2013). Universal screening of newborns to detect hearing impairment-Is it necessary? *International Journal of Pediatric Otorhinolaryngology, 77*, 1036-1041.

Ramkissoon, I., & Khan, F. (2003, Febrauary 18). Serving Multilingual Clients With Hearing Loss: How Linguistic Diversity Affects Audiologic Management. *The ASHA Leader*.

Rastogi, S., Mikhael, M., Filipov, P., & Rastogi, D. (2013). Effects of ventilation on hearing loss in preterm neonates: Nasal continuous positive pressure does not increase the risk of hearing loss in ventilated neonates. *International Journal of Pediatric Otorhinolaryngology, 77*(3), 402-406.

Rawool, V. W. (2010). Invisible Hearing Loss Among Obvious Multiple Disabilities, Part 1: Ensuring Auditory Care. *Hearing Review, 17*(1), 18-21.

Rifkin, E., & Bouwer, E. (2007). Cause and Effect vs. Risk Factors. In E. Rifkin & E. Bouwer (Eds.), *The Illusion of Certainty: Health Benefits and Risks* (pp. 15-31). Baltimore: Springer.

Roeser, R. J., Valente, M., & Hosford-Dunn, H. (2007). Diagnostic Procedures in Audiology. In R. J. Roeser, M. Valente & H. Hosford-Dunn (Eds.), *Audiology: Diagnosis* (2nd ed., pp. 1-16). New York: Thieme Medical Publishers.

Rossetti, L. M. (2001). Communication Intervention: Birth to Three. In L. M. Rossetti (Ed.), *Populations at risk for communication delay* (2nd ed., pp. 1-45). San Diego, CA: Singular Thomson Learning.

Russ, S. A., Hanna, D., DesGeorges, J., & Forsman, I. (2010). Improving Follow-up to Newborn Hearing Screening: A Learning-Collaborative Experience. *Pediatrics, 126*(Suppl 1), S59-S69.

Salina, H., Abdullah, A., Mukari, S. Z. M., & Azmi, M. T. (2010). Effects of background noise on recording of portable transient-evoked otoacoutic emission in newborn hearing screening. *European Archives of Otorhinolaryngology, 267*, 495-499.

SANC. (2011). SANC Geographical Distribution 2011: Geographical Distribution of the Population of South Africa versus Nursing Manpower from http://www.sanc.co.za/stats/stat2011/Distribution%202011xls.htm

Sanes, J., & Conlisk, E. (2005). Epidemiology_101, from https://www.google.co.za/url?sa=t&rct=j&q=&esrc=s&source=web&cd=6&cad=rja&uact=8&ved=0ahUKEwjb0d6Q5ajJAhWFHT4KHbPJCYUQFgg-MAU&url=http%3A%2F%2Fhelios.hampshire.edu%2F~cjgNS%2Fsputtbug%2F416

K%2FEnergy%2520Reg%2FEpidemiology_101_.doc&usg=AFQjCNGelpD1keXRcjhqD1kuKnQwsgzoKA&sig2=7aLcQQSt17M9cRWuMz-8zA

SASLHA. (2010). Guidelines for Neonatal Hearing Screening, from http://www.saslha.co.za/B_Ethics_Standards.asp

Say, L., & Raineb, R. (2007). A systematic review of inequalities in the use of maternal health care in developing countries: examining the scale of the problem and the importance of context. *Bulletin of the World Health Organization, 85*(10), 812-819.

Scheepers, L. J., Swanepoel, D., & le Roux, T. (2014). Why parents refuse newborn hearing screening and default on follow-up rescreening—A South African perspective. *International Journal of Pediatric Otorhinolaryngology, 78*, 652–658.

Schellack, N., Meyer, J. C., Gous, A. G. S., & Winters, C. (2011). Part II. Health and economic context. *South African Medical Journal, 101*(8), 558-561.

Schiavetti, N., & Metz, D. E. (2006). *Evaluating Research in Communicative Disorders* (5th ed.). Boston: Pearson Education.

Shahnaz, N., Miranda, T., & Polka, L. (2008). Multifrequency Tympanometry in Neonatal Intensive Care Unit and Well Babies. *Journal of the American Academy of Audiology, 19*, 392-418.

Shulman, S., Besculides, M., Saltzman, A., Ireys, H., White, K. R., & Forsman, I. (2010). Evaluation of the universal newborn hearing screening and intervention program. *Pediatrics, 126*(Suppl 1), S19-S27.

Sim, R. J., Mathew, S., Foley, R. J., & Robinson, P. J. (2009). Initial outcomes from universal newborn hearing screening in Avon. *Journal of Laryngology and Otology 123*, 982-989.

Sininger, Y. S., & Abdala, C. (1996). Hearing threshold as measured by auditory brain stem response in human neonates. *Ear and Hearing, 17*(5), 395–401.

Sininger, Y. S., Grimes, A., & Christensen, E. (2010). Auditory Development in Early Amplified Children: Factors Influencing Auditory-Based Communication Outcomes in Children with Hearing Loss. *Ear and Hearing, 31*(2), 166-185.

Sobhy, O. A., Asal, S., & Ragab, F. (2015). Study of reversibility of auditory brainstem abnormalities in infants with high risk for hearing loss. *Egyptian Journal of Ear, Nose, Throat and Allied Sciences, 16*, 75-79.

Sood, M., & Kaushal, R. K. (2009). Importance of Newborn Hearing Screening. *Indian Journal of Otolaryngology and Head & Neck Surgery, 61*, 157-159.

SouthAfricanGovernment. (2010). *Millenium Development Goals: Country Report 2010*. Pretoria: Government Press. Retrieved from http://www.statssa.gov.za/news_archive/Docs/MDGR_2010.pdf

SouthAfricanGovernmentInformation. (2011). Maternal and Women's Health, from http://www.info.gov.za/aboutsa/health.htm

Stach, B. A. (2010). *Clinial Audiology: An Introduction* (2nd ed.). New York: Delmar Cengage Learning.

Statistics South Africa. (2006). Provincial Profile 2004: Gauteng.

Statistics South Africa. (2013a). Gender statistics in South Africa, 2011.

Statistics South Africa. (2013b). Mid-year population estimates 2013.

Statistics South Africa. (2013c). Use of health facilities and levels of selected health conditions in South Africa: Findings from the General Household Survey, 2011.

Statistics South Africa. (2014). Mid-year population estimates 2014.

Statistics South Africa. (2015). Recorded live births 2013.

Stevens, G., Flaxman, S., Brunskil, E., Mascarenhas, M., Mathers, C. D., & Finucane, M. (2011). Global and regional hearing impairment prevalence: an analysis of 42 studies in 29 countries. *The European Journal of Public Health 23*(11), 146-152.

Storbeck, C. (2012). Childhood hearing loss in the developing world. *International Journal of Child Health and Nutrition, 1*, 59-65.

Storbeck, C., & Pittman, P. (2008). Early Intervention in South Africa: Moving beyond hearing screening. *International Journal of Audiology, 47*(Suppl. 1), S36-S43.

Suppiej, A., Rizzardi, E., Zandaro, V., Franzoi, M., Ermani, M., & Orzan, E. (2007). Reliability of hearing screening in high-risk neonates: Comparitive study of otoacoustic emission, automated and conventional auditory brainstem response. *Clinical Neurophysiology, 118*, 869-876.

Swanepoel, D. (2006). Audiology in South Africa. *International Journal of Audiology, 45*, 34-39.

Swanepoel, D. (2010). *The Global Epidemic of Infant Hearing Loss- Priorities for Prevention*. Paper presented at the Sound Foundation Through Early Amplification. Judith Gravel Lecture, Chicago. http://repository.up.ac.za/bitstream/handle/2263/19148/Swanepoel%28SoundFoundationConf2010%29_Final.pdf?sequence=1

Swanepoel, D., & Almec, N. (2008). Maternal views on infant hearing loss and early intervention in a South African community. *International Journal of Audiology, 47*((Suppl. 1)), S44-S48.

Swanepoel, D., Delport, S. D., & Swart, J. G. (2004). Universal newborn hearing screening in South Africa- A first-world dream? *South African Medical Journal, 94*(8), 634-635.

Swanepoel, D., Ebrahim, S., Joseph, A., & Friedland, P. L. (2007). Newborn hearing screening in a South African private health care hospital. *International Journal of Pediatric Otorhinolaryngology, 71*, 881-887.

Swanepoel, D., Hugo, R., & Louw, B. (2005). Infant hearing screening in the developing world. *Audiology Today, 17*(4), 16-19.

Swanepoel, D., Hugo, R., & Louw, B. (2006). Infant hearing screening at immunization clinics in South Africa. *International Journal of Pediatric Otorhinolaryngology, 70*(6), 1241-1249.

Swanepoel, D., Johl, L., & Pienaar, D. (2013). Childhood hearing loss and risk profile in a South African population. *International Journal of Pediatric Otorhinolaryngology, 77*, 394-398.

Swanepoel, D., Storbeck, C., & Friedland, P. (2009). Early hearing detection and intervention in South Africa. *International Journal of Pediatric Otorhinolaryngology, 73*(6), 783-786.

Swanepoel, D., Werner, S., Hugo, R., Louw, B., Owen, R., & Swanepoel, A. (2007). High frequency immittance for neonates: a normative study. *Acta Oto-Laryngologica, 127*, 49-56.

Swanepoel, D. C. D. (2009). Early Detection of Hearing Loss in South Africa. *South African Medical Journal, 99*(3), 158-159.

Swanepoel, D. C. D., & Storbeck, C. (2009). Early Hearing Detection and Intervention Services in South Africa, from http://www.ehdi.co.za/UserFiles/File/EARLY%20HEARING%202_final_pdf

Talaat, H. S., Kabel, A. H., Samy, H., & Elbadry, M. (2009). Prevalence of auditory neuropathy (AN) among infants and young children with severe to profound hearing loss. *International Journal of Pediatric Otorhinolaryngology, 73*, 937–939.

Tann, J., Wilson, W. J., Bradley, A. P., & Wanless, G. (2009). Progress Towards Universal Neonatal Hearing Screening: A World Review. *The Australian and New Zealand Journal of Audiology, 31*(1), 3-14.

Tatli, M. M., Serbetcioglu, M. B., Duman, N., Kumral, A., Kirkim, G., Ogun, B., & Ozkan, H. (2007). Feasibility of neonatal hearing screening program with two-stage transient otoacoustic emissions in Turkey. *Pediatrics International, 49*, 161-166.

Thandrayen, K., & Saloojee, H. (2010). Quality of care offered to children attending primary health clinics in Johannesburg. *South African Journal of Child Health, 4*(3), 73-77.

Tharpe, A. M. (2008). Unilateral and Mild Bilateral Hearing Loss in Children: Past and Current Perspectives. *Trends in Amplification, 12*(7), 7-15.

Thawala, M. D. (2007). *The Quality of Neonatal Inter-Facility Transport Systems within the Johannesburg Metropolitan Area*. Retrieved from http://wiredspace.wits.ac.za/bitstream/handle/10539/11031/Thesis__The_Quality_of_Neonatal_Inter_facility_Transport_System_within_Johannesburg_Metropolitan_region.pdf?sequence=3

The Consultative Group on Early Childhood Care and Development. (2012). Placing Early Childhood on the Global Agenda: Positioning Early Childhood Development in the Post-2015 Development Framework. Retrieved from http://www.ecdgroup.com/pdfs/Positioning_ECD_on_the_Post_2015_Devt_Agenda_CG_Background_Paper_August%202012.pdf

Theunissen, M., & Swanepoel, D. (2008). Early Hearing Detection and Intervention Services in the Public Health Care Sector in South Africa. *International Journal of Audiology, 47*, S23-29.

The World Bank. (2006). World Development Report 2006: Equity and Development.

The World Bank. (2015). World Bank list of economies (July 2015). http://www.google.co.za/url?sa=t&source=web&cd=1&rct=j&q=world%20bank%20list%20of%20economies%202014&ved=0ahUKEqjd5eqzpKrLAhWBJBoKHYl1BggQFggfMAA&url=http%3A%2F%2Fsiteresources.worldbank.org%2FDATASTATISTICS%2FResources%2FCLASS.XLS%usg=AFQjCNHWuLdkFELyg0PTXBHupLnCGsB91Q

Todd, N. W. (2006). Universal newborn hearing screening follow-up in two Georgia populations: newborn, mother and system correlates. *International Journal of Pediatric Otorhinolaryngology, 70*(5), 807-815.

Tsawe, M., Moto, A., Netshivhera, T., Ralesego, L., Nyathi, C., & Susuman, A. S. (2015). Factors influencing the use of maternal healthcare services and childhood immunization in Swaziland. *International Journal for Equity in Health, 14*(32), 1-11.

Tucci, D. L., Merson, M. H., & Wilson, B. S. (2010). A Summary of Literature in Global Hearing Impairment: Current Status and Priorities for Action. *Otology and Neurotology, 31*(1), 31-41.

van Dommelen, P., van Straaten, H. L. M., & Verkerk, P. H. (2011). Ten-year quality assurance of the nationwide hearing screening programme in Dutch neonatal intensive care units. *Acta Paediatrica, 100*(8), 1097-1103.

Van Dyk, M., Swanepoel, D., & Hall, J. W. (2015). Outcomes with OAE and AABR screening in the first 48h-Implications for newborn hearing screening in developing countries. *International Journal of Pediatric Otorhinolaryngology, 79*(7), 1034-1040.

van Rensburg, H. C. J. (2014). South Africa's protracted struggle for equal distribution and equitable access – still not there. *Human Resources for Health, 12*, 1-16.

Van Weel, C., & De Maesseneer, J. (2010). Now more than ever: World Health Assembly revisits primary health care. *Primary Health Care Research and Development, 11*, 1-3.

Velaphi, S., & Rhoda, N. (2012). Reducing neonatal deaths in South Africa – are we there yet, and what can be done? *South African Journal of Child Health, 6*, 67-71.

Verbeke, G., & Molenberghs, G. (2009). *Linear mixed models for longitudinal data*. New York: Springer Science and Business Media.

Vohr, B. R., Widen, B., Cone-Wesson, B., Sininger, Y. S., Gorga, M. P., Folsom, R. C., & Norton, S. J. (2000). Identification of neonatal hearing impairment: characteristics of infants in the neonatal intensive care unit and well-baby nursery. *Ear and Hearing, 21*(5), 373-382.

Vos, B., Lagasse, R., & Levêque, A. (2014). Main outcomes of a newborn hearing screening program in Belgium over six years. *International Journal of Pediatric Otorhinolaryngology, 78*, 1496-1502.

Wabiri, N., Chersich, M., Zuma, K., Blaauw, D., Goudge, J., & Dwane, N. (2013). Equity in Maternal Health in South Africa: Analysis of Health Service Access and Health Status in a National Household Survey. *PLOS ONE, 8*(9), 1-12.

Wake, M., Poulakis, Z., Hughes, E. K., Carey-Sargeant, C., & Rickards, F. W. (2005). Hearing impairment: a population study of age at diagnosis, severity, and langauge outcomes at 7-8 years. *Archives of Disease in Childhood, 90*, 238-244.

Wake, M., Tobin, S., Cone-Wesson, B., Dahl, H., Gillam, L., McCormick, L. Z., . . . Williams, J. (2006). Slight/Mild Sensorineural Hearing Loss in Children. *Pediatrics, 118*, 1842-1851.

Walker, E. A., Holte, L., Spratford, M., Oleson, J., Welhaven, A., & Harrison, M. (2014). Timeliness of Service Delivery for Children with Later-Identified Mild-to-Severe Hearing Loss. *American Journal of Audiology, 23*, 116-128.

Watkin, P., & Baldwin, M. (2012). The longitudinal follow-up of a universal neonatal hearing screen: The implications for confirming deafness in childhood. *International Journal of Audiology, 51*, 519-528.

White, K. R., Forsman, I., Eichwald, J., & Munoz, K. (2010). The Evolution of Early Hearing Detection and Intervention Programs in the United States. *Seminars in Perinatology, 34*, 170-179.

WHO. (1991). Report of the Informal Working Group on Prevention of Deafness and Hearing Impairment Programme Planning.

WHO. (2004). ICD-10: International Statistical Classification of Diseases and Related Health Problems Vol. 2. Retrieved from https://books.google.co.za/books?id=u3KSRLclIO0C&pg=PA136&lpg=PA136&dq=classification+manual+of+birth+weight&source=bl&ots=6wo18z0_RB&sig=8jkXgMC1yyWc-Q6Kz-3jr_IglO4&hl=en&sa=X&ved=0CCMQ6AEwAWoVChMIrfCi_NC4yAIVSW8UCh3bVwg3#v=onepage&q=classification%20manual%20of%20birth%20weight&f=false

WHO. (2007). *International Classification of Functioning, Disability and Health: Child and Youth Version*. Geneva: WHO Press.

WHO. (2010). Newborn and Infant Hearing Screening. Retrieved from http://www.who.int/blindness/publications/Newborn_and_Infant_Hearing_Screening_Report.pdf

WHO. (2011). South African General Health Statistical Profile 2011 (WHO), from http://www.health.gov.za/index.php/2014-03-17-09-09-38/2014-03-17-12-57-15/country-health-profile

WHO. (2012a). Early Childhood Development and Disability: A discussion paper. Retrieved from http://apps.who.int/iris/bitstream/10665/75355/1/9789241504065_eng.pdf?ua=1

WHO. (2012b). WHO global estimates on prevalence of hearing loss.

WHO. (2014). Deafness and hearing loss, from http://www.who.int/mediacentre/factsheets/fs300/en/

WHO. (2015). Care of the preterm and/or low-birth-weight newborn, from http://www.who.int/maternal_child_adolescent/topics/newborn/care_of_preterm/en/

Widen, J. E. (1990). Behavioral screening of high-risk infants using visual reinforcement audiometry. *Seminars in Hearing, 11*, 342-356.

Widen, J. E., Folsom, R. C., Cone-Wesson, B., Carty, L., Dunnell, J. J., Koebsell, K., . . . Norton, S. J. (2000). Identification of Neonatal Hearing Impairment: Hearing Status at 8 to 12 Months Corrected Age Using a Visual Reinforcement Audiometry Protocol. *Ear and Hearing, 21*, 471-487.

Wilber, L. A. (2002). Calibration: Puretone, Speech, and Noise Signals. In J. Kats (Ed.), *Handbook of Clinical Audiology* (5th ed., pp. 50-70). Baltimore: Lippincott Williams & Wilkins.

Wilson, S. L., & Cradock, M. M. (2004). Review: Accounting for Prematurity in Developmental Assessment and the Use of Age-Adjusted Scores. *Journal of Pediatric Psychology, 29*(8), 641-649.

WitsPaediatricFund. (2008). Rahima Moosa Mother and Child Hospital, from http://www.witspaediatricfund.org.za/who-we-serve/coronation

WMA. (2012). WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects, from http://www.wma.net/en/30publications/10policies/b3/

WMA. (2013). WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects, from http://www.wma.net/en/30publications/10policies/b3/index.html

Wolff, R., Hommerich, J., Riemsma, R., Antes, G., Lange, S., & Kleijnen, J. (2013). Hearing screening in newborns: systematic review of accuracy, effectiveness, and effects of interventions after screening. *Archives of Disease in Childhood, 95*, 130-135.

Wood, S. A., Davis, A. C., & Sutton, G. (2013). Effectiveness of targeted surveillance to identify moderate to profound permanent childhood hearing impairment in babies with risk factors who pass newborn screening. *International Journal of Audiology, 52*, 394-399.

Wood, S. A., Sutton, G., & Davis, A. C. (2015). Performance and characteristics of the Newborn Hearing Screening Programme in England: The first seven years. *International Journal of Audiology, 54*, 353-358.

Woodward, M. (2013). *Epidemiology: study design and data analysis* (3rd ed.). Florida: CRC Press.

Wrobel, M. J., Greczka, G., & Szyfter, W. (2014). The risk factor profile of children covered by the Polish universal neonatal hearing screening program and its impact of hearing loss incidence. *International Journal of Pediatric Otorhinolaryngology, 78*, 209-213.

Xu, Z., Cheng, W., & Yang, X. (2011). Performance of two hearing screening protocols in NICU in Shanghai. *International Journal of Pediatric Otorhinolaryngology, 75*, 1225-1229.

Yee, W., & Ross, S. (2006). Communicating with parents of high-risk infants in neonatal intensive care. *Paediatric Child Health, 11*(5), 291-294.

Yoon, P. J., Price, M., Gallagher, K., Fleisher, B. E., & Messner, A. H. (2003). The need for long-term audiologic follow-up of neonatal intensive care unit (NICU) graduates. *International Journal of Pediatric Otorhinolaryngology, 67*, 353-357.

Yoshinaga-Itano, C. (2004). Levels of evidence: Universal newborn hearing screening (UNHS) and early hearing detection and intervention systems (EHDI). *Journal of Communication Disorders, 37*, 451-465.

Yu, J. K. Y., Ng, I. N. H., Kam, A. C. S., Wong, T. K. C., Wong, E. C. M., Tong, M. C. F., . . . Yu, K. M. (2010). The Universal Neonatal Hearing Screening (UNHS) Program in Hong Kong: The Outcome of a Combined Otoacoustic Emissions and Automated Auditory Brainstem Response Screening Protocol. *Hong Kong Journal of Paediatrics, 15*, 2-11.

APPENDICES

Appendix A

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

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Ms Amisha Kanji

CLEARANCE CERTIFICATE	**M1211103**
PROJECT	Early Detection of Hearing Loss: Exploring Risk-Based Screening within a Developing Context
INVESTIGATORS	Ms Amisha Kanji.
DEPARTMENT	Speech Pathology & Audiology
DATE CONSIDERED	30/11/2012
DECISION OF THE COMMITTEE*	Approved unconditionally

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

DATE 01/02/2013 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Prof K Khoza-Shangase

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 B



GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

Office of the CEO
Enquiries:
Ms. L. Mngomezulu
(011): 488-3793
(011) 488-3753
25th January 2013

Ms. Amisha Kanji
Speech Pathology & Audiology
University of the Witwatersrand

Dear Ms. Kanji

RE: "Early detection of hearing loss: Exploring Risk-Based Screening within a Developing context"

Permission is granted for you to conduct the above research as described in your request provided:

1. Charlotte Maxeke Johannesburg Academic hospital will not in anyway incur or inherit costs as a result of the said study.
2. Your study shall not disrupt services at the study sites.
3. Strict confidentiality shall be observed at all times.
4. Informed consent shall be solicited from patients participating in your study.

Please liaise with the Head of Department and Unit Manager or Sister in Charge to agree on the dates and time that would suit all parties.

Kindly forward this office with the results of your study on completion of the research.

Yours sincerely

Dr. T.E. Selebano
Chief Executive Officer

Appendix C

SPEECH PATHOLOGY AND AUDIOLOGY

SCHOOL OF HUMAN & COMMUNITY DEVELOPMENT
FACULTY OF HUMANITIES
UNIVERSITY OF THE WITWATERSRAND

Private Bag 3, WITS, 2050
Tel: (011) 717 4577 Fax: (011) 717 4572

To whom it may concern,

Re: Permission to conduct audiology research on high-risk neonates

I am a qualified speech-language therapist and audiologist currently working at the University of the Witwatersrand and registered for a PhD (Audiology). I have previously worked as a speech-language therapist and audiologist at Charlotte Maxeke Johannesburg Academic Hospital and completed my Master's degree using data on very low birth weight neonates. Following the completion of my Master's degree, I reintroduced hearing screening services in the Kangaroo Mother Care ward at the hospital. Findings from my Master's research study indicated the need to conduct risk-based newborn hearing screening on all high-risk neonates.

I therefore request permission to conduct such a study in the neonatal wards, newborn clinic and audiology department (pending ethical clearance). Hearing screening will be conducted prior to discharge and at six weeks post discharge. Infants who do not pass the hearing screening will be referred for further, diagnostic audiological testing and those who pass the screening will be monitored at six months corrected age. If a hearing loss is detected, infants will be referred to the Audiology department for further management and intervention. Psychological counselling will also be provided to caregivers, and referral to HI HOPES (Home intervention Hearing and language opportunities Parent education services) will be ensured for home-based support.

Should you have any queries, please do not hesitate to contact me

Sincerely,

Amisha Kanji
(Speech-Language Therapist & Audiologist)

PROFESSOR P.A. COOPER
HEAD: DEPT OF PAEDIATRICS &
CHILD HEALTH

I, _____ (name), _____ (rank and department) hereby grant permission to Amisha Kanji to conduct her research study at Charlotte Maxeke Johannesburg Academic Hospital.

Name	Signature	Date
_____	_____	6/11/12

Appendix D

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

RAHIMA MOOSA MOTHER AND CHILD HOSPITAL

RAHIMA MOOSA MOTHER AND CHILD HOSPITAL
Enquiries: Mrs. S. Jordaan
Tel: (011) 470 – 9030/4
Fax: (011) 477 4117

Speech Pathology and Audiology
School of Human & Community Development
Faculty of Humanities
University of the Witwatersrand
JOHANNNESBURG
2001

Re: "Newborn hearing screening on all high -risk neonates"

Dear Ms Amisha Kanji,

Permission is granted for you to conduct the above stud y as indicated in your request:

1. The Rahima Moosa hospital will not in anyway incur or inherit costs as a result of the said study.
2. Your study shall not disrupt services at the study site.
3. Strict confidentiality shall be observed at all times.
4. Informed consent shall be solicited from patients participating in your study.
5. NO file should leave the records department and/or the hospital premises.

Arrangement will be made with recordkeeping clerks so that you could occupy space in their department.

Kindly forward this office with the results of your research on completion of it.

I, AMISHA KANJI accept the terms and conditions set-in this document

sign A Kanji date 19/9/2013

Yours sincerely,

Jordaan

CHIEF EXECUTIVE OFFICER
SJ/cj. 2013-09-19

Appendix E

SPEECH PATHOLOGY AND AUDIOLOGY

SCHOOL OF HUMAN & COMMUNITY DEVELOPMENT
FACULTY OF HUMANITIES
UNIVERSITY OF THE WITWATERSRAND

Private Bag 3, WITS, 2050
Tel: (011) 717 4577 Fax: (011) 717 4572

Ms. Aashiqa Ally/ Ms. Muazzama Pilodia
Head of Department of Speech Pathology and Audiology
Rahima Moosa Mother and Child Hospital

Dear Ms. Ally/ Ms. Pilodia,

Re: Permission to conduct audiology research on high-risk neonates

I am a qualified speech-language therapist and audiologist currently working at the University of the Witwatersrand and registered for a PhD (Audiology). I have previously worked as a speech-language therapist and audiologist at Charlotte Maxeke Johannesburg Academic Hospital and completed my Master's degree using data on very low birth weight neonates. Following the completion of my Master's degree, I reintroduced hearing screening services in the Kangaroo Mother Care ward at the hospital. Findings from my Master's research study indicated the need to conduct risk-based newborn hearing screening on all high-risk neonates.

I therefore request permission to conduct such a study in the neonatal wards, neonatal follow up clinic and audiology department at Rahima Moosa Mother and Child Hospital (pending ethical clearance for this research site). Hearing screening will be conducted prior to discharge (in wards 16b and 16c) and at six weeks post discharge (in alignment with the neonatal follow up clinic). I further request permission to conduct the six week post discharge follow-up screening in the Audiology department on Monday mornings. The proposed study is aligned with clinical practice. The babies who do pass will be monitored at 6 months corrected age through behavioural audiometry. Infants who do not pass the hearing screening will be referred for further, diagnostic audiological testing and those who pass the screening will be monitored at six months corrected age. If a hearing loss is detected, infants will be referred to the Audiology department for further management and intervention. Psychological counselling will also be provided to caregivers, and referral to HI HOPES (Home Intervention Hearing and language opportunities Parent education services) will be ensured for home-based support.

Should you have any queries, please do not hesitate to contact me

Sincerely,

Amisha Kanji
(Speech-Language Therapist & Audiologist)

Speech Therapy & Audiology Departments

I, Muazzama H. H. Pilodia (name), Speech Therapist & Audiologist (rank and department) hereby grant permission to Amisha Kanji to conduct her research study at Rahima Moosa Mother and Child Hospital.

Muazzama H. H. Pilodia
Name

Signature

11/09/2013
Date

NEONATAL HEARING SCREENING- INITIAL SCREENING

PATIENT/CAREGIVER INFORMATION

Ward_____ Hospital Number _____ Patient Name_____

D.O.B: _____ Date of Assessment:_____ Caregiver Name_____

Gender _____ Address:_____

Contact No.s.: _____ Maternal Age_____ Date of Admission to 177/16b/NICU: _____

Date of Transfer to 184/185/16c:_____ Date of Discharge: _____ Child No.: _____

Home Language: _____ Mother's Highest Level of Education:_____

BIRTH & MEDICAL HISTORY

Birth Weight:	_____g	**APGAR**			**Other Birth/Medical History**
ELBW: 999g or <		1 min	/10		e.g. other infections
VLBW: 1000-1499g		5min	/10		(septicaemia, meningitis)
LBW: 1500g-2499g		10min	/10		
		In-utero Infections			
Gestational Age	/40	Cytomegalovirus			
Length of NICU stay		Herpes			
Type of Delivery		Rubella			
C-section		Syphilis			
Vaginal		Toxoplasmosis			
Emergency C-section		Malaria			
Neonatal Jaundice		**RVD**			
Bilirubin levels		Exposed			
No. of days above 10md/dl		Postive			
EBT/PTT		Negative			
No. of EBT		Unknown			
Length of PTT		PCR Results			
					Family history of hearing loss

Medication		
Names	Dosage	Duration

Neurological		**Ventilation**		Duration	**Syndrome/Craniofacial Anomalies**
Birth Asphyxia		Mechanical/Assisted			
HIE Grade I / II / III		CPAP			
IVH I / II / III / IV		ECMO			

RESULTS

	DPOAE		**TEOAE**			**AABR 35dBnHL**
Frequency	**L**	**R**	**Left**			**Left**
	P/R/N	P/R/N	Pass			Pass
1000Hz			Refer			Refer
2000Hz			Noisy			**Right**
3000Hz			**Right**			Pass
4000Hz			Pass			Refer
5000Hz			Refer			**Sound Levels during testing**
6000Hz			Noisy			

Recommendation

Follow-up screening at 6 weeks post discharge

NNFU Date: _____

Appendix G

NEONATAL HEARING SCREENING- FOLLOW-UP SCREENING

PATIENT/CAREGIVER INFORMATION

Hospital Number _____ Patient Name_____

D.O.B: _____ Date of Assessment:_____ Caregiver Name_____

Gender _____ Gestational Age _____ Address_____

Contact No.: _____ Place of Assessment: _____ Maternal Age_____

ADDITIONAL CASE HISTORY INFORMATION

RESULTS

OTOSCOPIC EXAMINATION

	R	L
TM visible		
TM not visualised		
Perforration		
Bulging TM		
Retracted TM		
Soft cerumen		

TYMPANOMETRY (1000Hz)

R	
L	

Sound Levels During Testing

	DPOAE		TEOAE			AABR 35dBnHL
Frequency	L	R	Left			Left
	P/R/N	P/R/N	Pass			Pass
1000Hz			Refer			Refer
2000Hz			Noisy			Right
3000Hz			Right			Pass
4000Hz			Pass			Refer
5000Hz			Refer			
6000Hz			Noisy			

RECOMMENDATION

Middle Ear Management & Recheck	
Diagnostic ABR	
Behavioural audiometry at 6 months corrected age	

NEONATAL HEARING SCREENING- DIAGNOSTIC ASSESSMENT

PATIENT/CAREGIVER INFORMATION

Ward_____ Hospital Number _____ Patient Name_____

D.O.B: _____ Date of Assessment:_____ Caregiver Name_____

Gender _____ Gestational Age _____ Address_____

Contact No.: _____ Maternal Age_____

ADDITIONAL CASE HISTORY INFORMATION

RESULTS (DIAGNOSTIC ABR SESSION)

OTOSCOPIC EXAMINATION

	R	L
TM visible		
TM not visualised		
Perforration		
Bulging TM		
Retracted TM		
Soft cerumen		

TYMPANOMETRY (1000Hz)

	R	L
Positive Peak		
Negative Peak		

RECOMMENDATION

Hearing Aid Evaluation	
Middle Ear Management & Recheck	
Discharge	

DIAGNOSTIC ABR (attach results)

RESULTS (BEHAVIOURAL AUDIOMETRY SESSION AT 6 MONTHS CORRECTED AGE)

OTOSCOPIC EXAMINATION

	R	L
TM visible		
TM not visualised		
Perforration		
Bulging TM		
Retracted TM		
Soft cerumen		

TYMPANOMETRY (1000Hz)

R	
L	

VISUAL REINFORCEMENT AUDIOMETRY

	Inserts	Headphones	Freefield
Frequency	dB Level	dB Level	dB Level
500 Hz			
1000Hz			
2000Hz			
4000Hz			
SAT			

Notes:

RECOMMENDATION

Hearing Aid Evaluation	
Middle Ear Management & Recheck	
Discharge	

Appendix I

INFORMATION TO CAREGIVER/S OR LEGAL GUARDIAN OF PARTICIPANTS

Good day
My name is Amisha Kanji. I am a speech and hearing therapist and am studying toward my postgraduate degree through the University of the Witwatersrand. As part of my studies, I am conducting research on babies who were in the Neonatal Intensive Care Unit (NICU) and are now in Ward 177, 184 or 185 at Charlotte Maxeke Johannesburg Academic Hospital. Research is done when we want to learn the answer to a question. In this study I want to learn about the hearing of babies in wards 184 and 185 and if hearing screening and testing can be done on these babies. I would like to invite your baby to take part in my study. If you agree for your baby to participate in the study, I will ask you to sign a form that shows that you have given permission for your baby to take part in the study. I have included more information about the study below. You can ask questions at any time about any aspect of this study.

INFORMATION ON HEARING SCREENING

A hearing screening is done 24 hours after a baby is born and tells us if and when your baby's hearing has to be tested again. The tests used for the screening are quick, and painless. If your baby does not pass the hearing screening, we will inform you and he/she will be booked for another screening and/or for more testing if needed.

HOW WILL THE STUDY BE CONDUCTED

For this study, I will first look through your baby's hospital file with your permission and take down any important information. Your baby's hearing will then be screened using three different tests. The names of the screening tests are otoacoustic emissions (OAE), automated auditory brainstem testing (AABR) and tympanometry.

OAE: For this test, a small probe will be placed into your baby's ear which will present a beeping sound for about one minute. This will not be painful and will not cause your baby any harm.
AABR: Your baby's skin on the forehead and ears will be cleaned. Small, spongy earphones will be placed in your baby's ear and sounds will be presented. This will not be painful and will not cause harm to your baby.
Tympanometry: Like the OAE, a probe will be placed in your baby's ear and slight pressure will be felt. This will not be painful or cause any harm to your baby.

If you agree for your baby to take part in this study, these tests will be repeated again at 6 weeks after discharge when you bring him/her to the newborn clinic for a check-up. It will take about 20 minutes to do the hearing screening.

If your baby passes the hearing screening, he/she will be booked for an appointment when they are 6 months of age so that their hearing can be tested again to find out whether their hearing is fine or if there has been a change. The testing at 6 months of age will be different to the screening tests. Different types of sounds will be presented through speakers and your baby will need to turn to the sound if he/she hears it. Testing will take about 45 minutes.

If your baby does not pass the hearing screening, we will inform you and he/she will be booked for further testing. Sometimes, babies do not pass the first screening because of the fluid in the ear canal from birth. Screening results can also be affected if the baby is restless during testing or if there is a lot of noise in the environment in which the testing is being performed.

Further testing will involve a test called the **auditory brainstem response (ABR)** test and will be similar to the AABR. Your baby will have to be asleep and restful. This test will take about 1 ½ hours and will provide more information about your baby's hearing. If results of this test indicate that your baby has a hearing loss, you will be referred to the audiology department so that the hearing loss can be managed.

The results from the hearing screening and other hearing tests will be provided to you during the study.

CONFIDENTIALITY

Your baby's name or hospital number will not be used when writing up the study and will not be made available on any data published or made public.

REIMBURSEMENTS

You will be provided with R50 for transport if you bring your baby for testing at 6 months of age and if you need to bring your baby for further testing after the two screenings.

WHAT ARE YOUR RIGHTS AS A PARENT/LEGAL GUARDIAN

- You have the right to withdraw your baby from the study at any time, with immediate effect with no negative consequences to you or your baby's right to further treatment.
- You have the right to see the results of the study and be informed of the results of all the hearing screening tests performed on your baby.
- You have the right to contact me at any time with any queries or concerns.
- If you have any concerns or complaints about the study or me as the researcher, you have the right to contact the Human Research Ethics Committee (Medical) chairperson, Professor Cleaton-Jones or the Research Administrator, Ms. Anisa Keshav on 011 717 1234.

If you would like your baby to be part of this study, please fill in the consent form at the bottom of the page.

If you have any questions you need to ask me, my contact details are below.
Amisha (Work) 011 717 4551

Thank you for taking the time to read through the information.
Sincerely,
Amisha Kanji

CONSENT FORM

This is to certify that I, _____ parent/legal guardian of _____ (baby's name) hereby agree to volunteer my baby to participate in this study authorized by the University of the Witwatersrand and the Superintendent of the hospital. The study has been explained to me and I am aware of my rights as the parent/caregiver of the participant. I understand the information that was explained to me and understand that I can withdraw my baby from the study at any time.

_____ _____

Signature of parent/legal guardian of participant Date

I, the undersigned have fully explained the study to the parent/caregiver/legal guardian of the above participant. I have also answered all the questions raised by the parent/caregiver.

_____ _____

Audiologist Date

Appendix J

INFORMATION TO CAREGIVER/S OR LEGAL GUARDIAN OF PARTICIPANTS

Good day
My name is Amisha Kanji. I am a speech and hearing therapist and am studying toward my postgraduate degree through the University of the Witwatersrand. As part of my studies, I am conducting research on babies who were in wards 16b and 16c at Rahima Moosa Mother and Child Hospital. Research is done when we want to learn the answer to a question. In this study I want to learn about the hearing of babies in wards 16b and 16c and if hearing screening and testing can be done on these babies. I would like to invite your baby to take part in my study. If you agree for your baby to participate in the study, I will ask you to sign a form that shows that you have given permission for your baby to take part in the study. I have included more information about the study below. You can ask questions at any time about any aspect of this study.

INFORMATION ON HEARING SCREENING

A hearing screening is done 24 hours after a baby is born and tells us if and when your baby's hearing has to be tested again. The tests used for the screening are quick, and painless. If your baby does not pass the hearing screening, we will inform you and he/she will be booked for another screening and/or for more testing if needed.

HOW WILL THE STUDY BE CONDUCTED

For this study, I will first look through your baby's hospital file with your permission and take down any important information. Your baby's hearing will then be screened using three different tests. The names of the screening tests are otoacoustic emissions (OAE), automated auditory brainstem testing (AABR) and tympanometry.

OAE: For this test, a small probe will be placed into your baby's ear which will present a beeping sound for about one minute. This will not be painful and will not cause your baby any harm.
AABR: Your baby's skin on the forehead and ears will be cleaned. Small, spongy earphones will be placed in your baby's ear and sounds will be presented. This will not be painful and will not cause harm to your baby.
Tympanometry: Like the OAE, a probe will be placed in your baby's ear and slight pressure will be felt. This will not be painful or cause any harm to your baby.

If you agree for your baby to take part in this study, these tests will be repeated again at 6 weeks after discharge when you bring him/her to the newborn clinic for a check-up. It will take about 20 minutes to do the hearing screening.

If your baby passes the hearing screening, he/she will be booked for an appointment when they are 6 months of age so that their hearing can be tested again to find out whether their hearing is fine or if there has been a change. The testing at 6 months of age will be different to the screening tests. Different types of sounds will be presented through speakers and your baby will need to turn to the sound if he/she hears it. Testing will take about 45 minutes.

If your baby does not pass the hearing screening, we will inform you and he/she will be booked for further testing. Sometimes, babies do not pass the first screening because of the fluid in the ear canal from birth. Screening results can also be affected if the baby is restless during testing or if there is a lot of noise in the environment in which the testing is being performed.

Further testing will involve a test called the **auditory brainstem response (ABR)** test and will be similar to the AABR. Your baby will have to be asleep and restful. This test will take about 1 ½ hours and will provide more information about your baby's hearing. If results of this test indicate that your baby has a hearing loss, you will be referred to the audiology department so that the hearing loss can be managed.

The results from the hearing screening and other hearing tests will be provided to you during the study.

CONFIDENTIALITY

Your baby's name or hospital number will not be used when writing up the study and will not be made available on any data published or made public.

REIMBURSEMENTS

You will be provided with R50 for transport if you bring your baby for testing at 6 months of age and if you need to bring your baby for further testing after the two screenings.

WHAT ARE YOUR RIGHTS AS A PARENT/LEGAL GUARDIAN

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- You have the right to see the results of the study and be informed of the results of all the hearing screening tests performed on your baby.
- You have the right to contact me at any time with any queries or concerns.
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Signature of parent/legal guardian of participant Date

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_____ _____

Audiologist Date