HEARING SCREENING FOR INFANTS FROM A NEONATAL INTENSIVE CARE UNIT AT A STATE HOSPITAL

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ABSTRACT

Infant hearing screening (IHS) programs are not yet widespread in developing countries, such as South Africa. In order to ensure that the benefits of early hearing detection and intervention (EHDI) programs reach all infants, initial recommendations for the implementation of IHS programs in South Africa have been made by the Year 2002 Hearing Screening Position Statement by the Health Professions Council of South Africa. One of the platforms recommended for IHS in South Africa is the neonatal intensive care unit (NICU). South African NICU infants are at an increased risk for hearing loss, resultant of their high-risk birth histories, as well as the prevalence of context-specific environmental risk factors for hearing loss. There is currently a general scarcity of contextual data regarding the prevalence of risk indicators for hearing loss, and the prevalence of auditory impairment in the South African NICU population.

The objective of this study was to describe an IHS program for NICU infants at a secondary hospital in Gauteng, South Africa. A quantitative descriptive research design was used to report on a cohort of 129 NICU infants followed up during a 29 month period. The objective of the study was achieved by describing the sample of infants in terms of the presence of specific risk indicators for hearing loss, the efficiency of the IHS program, and the incidence of auditory pathologies. Infants received their initial hearing screening as part of their medical and developmental follow-up visit at the hospital at three months of age. Routine rescreening visits were scheduled three monthly, whilst infants who failed the hearing screening were requested to return after three weeks for a follow-up. A data collection sheet was used to collect biographical information and risk indicators for hearing loss. Immittance measurements were recorded in the form of high-frequency and low-frequency tympanometry. Distortion product otoacoustic emissions (DPOAE) and automated auditory brainstem responses (AABR) were recorded, as well as diagnostic auditory brainstem responses (ABR) in cases where infants referred the screening protocol.

Results revealed that environmental risk factors present in this sample included poor maternal education levels and prenatal HIV/AIDS exposure. At least 32% of mothers participating in this study did not complete high school. Prenatal HIV/AIDS exposure was present in at least 21% of the current sample of infants. The screening coverage rate fell short of the 95% benchmark set by the Joint Committee on Infant Hearing (JCIH, 2000). A 67% coverage rate was achieved with AABR screening, and an 88% coverage rate was achieved with DPOAE screening. 93% of infants had immittance screening performed on their initial visit to the IHS program. According to the Fisher's two-sided exact test and the logistic regression procedure, high frequency tympanometry proved to be more effective than low frequency tympanometry, when assessing the middle ear functioning of infants younger than seven months when compared with DPOAE results. Normative pressure and admittance data was compiled for the use of high frequency tympanometry in NICU infants. Poor follow-up rates were recorded for both routine and non-routine visits, but are expected to improve over time.

Furthermore, results indicated a high incidence of hearing impairment. Permanent congenital hearing loss was identified in 3% (n=4) of the sample. Half of these presented with sensorineural hearing loss, whilst the other half had auditory neuropathy. The incidence of auditory impairment is estimated to be 3.75% if the percentage of infants who did not return for follow-up is taken into account. A high incidence of middle ear pathology was recorded, with an incidence rate of 60.4%, including bilateral and unilateral middle ear pathology. The high prevalence of auditory impairment in South African NICU infants, and the lack of widespread IHS programs, indicates that many vulnerable infants are being the denied the benefits of early identification of and intervention for hearing loss. The implementation of widespread IHS programs in South Africa is therefore essential, in order to ensure that all South African infants receive the benefits of EHDI programs.

Keywords: Automated auditory brainstem responses (AABR), developed countries, developing countries, distortion product otoacoustic emissions (DPOAE), early hearing detection and intervention (EHDI), high frequency and low frequency immittance measures, infant hearing loss, infant hearing screening (IHS), neonatal intensive care unit (NICU).

OPSOMMING

Neonatale gehoorsiftingsprogramme is tans nog nie wyd versprei in ontwikkelende lande soos Suid Afrika nie. Om te verseker dat alle babas baatvind by die voordele van vroeë identifikasie en intervensie programme, is aanbevelings vir die implementering van neonatale gehoorsiftingsprogramme in Suid Afrika gemaak deur die Gehoorsiftingsverklaring Jaar 2002 van die Suid Afrikaanse Raad vir die Gesondheidsprofessies. Een van die platforms wat aanbeveel is vir neonatale gehoorsiftingsprogramme in Suid Afrika, is die neonatale intensiewe sorgeenheid. Suid Afrikaanse neonatale intensiewe sorgeenheid babas het ‘n hoë risiko vir gehoorverlies as gevolg van hulle hoë risiko geboorte geskiedenis, asook die prevalensie van konteks spesifieke omgewingsrisikofaktore. Daar is huidiglik 'n tekort aan kontekstuele data oor die prevalensie van risikofaktore vir gehoorverlies, en die prevalensie van ouditiewe patologie in die Suid Afrikaanse neonatale intensiewe sorgeenheid populasie.

Die doel van hierdie studie was om die eienskappe van ‘n neonatale gehoorsiftingsprogram vir babas in ‘n neonatale intensiewe sorgeenheid in ‘n sekondêre hospitaal in Gauteng, Suid Afrika, te beskryf. ‘n Kwantitatiewe beskrywende navorsingsontwerp is gebruik om ‘n groep van 129 neonatale intensiewe sorgeenheid babas, wat oor ‘n 29 maande periode opgevolg was, te beskryf. Die doel van die studie is bereik deur die steekproef van babas te beskryf in terme van die spesifieke risikofaktore vir gehoorverlies, die effektiwiteit van die neonatale gehoorsiftingsprogram, en die insidensie van ouditiewe patologie. Die babas het hulle inisiële gehoorsifting as deel van hulle mediese en ontwikkelings opvolg by die hospitaal ondergaan. Roetine her-siftingsbesoeke is vir elke drie maande geskeduleer, terwyl babas wat die gehoorsifting nie geslaag het nie versoek is om na drie weke vir opvolg terug te kom. ‘n Datainsamelingslys is gebruik om biografiese inligting en moontlike risikofaktore vir gehoorverlies in te samel. Hoë frekwensie en lae frekwensie immittansie metings is uitgevoer. Distorsie produk otoakoestiese emissies (DPOAE) en

outomatiese ouditiewe breinstam response (OOBR) is opgeneem, asook diagnostiese ouditiewe breinstam response (OBR) vir babas wat die gehoorsiftingsprotokol nie deurgekom het nie.

Resultate dui aan dat omgewingsrisikofaktore wat geidentifiseer is sluit ‘n lae opvoedkundige vlak van die ma, asook prenatale HIV/VIGS blootstelling in. ‘n Minimum van 32% van die ma’s wat aan die studie deelgeneem het, het nie hoërskool voltooi nie. Prenatale HIV/VIGS bloodstelling was in ‘n minimum van 21% van die huidige steekproef van babas teenwoordig. Die toetsdekking het effens kort geval van die voorgeskrewe 95% daargestel deur die Joint Committee on Infant Hearing (JCIH). ‘n 67% toetsdekking is bereik met OOBR sifting en ‘n 88% toetsdekking is bereik met DPOAE sifting. 93% van die babas het immittansie sifting gehad tydens hulle inisiële besoek aan die neonatale gehoorsiftingsprogram. Volgens Fisher se eksakte tweekantige toets en die logistiese regressie prosedure, was hoë frekwensie timpanometrie meer effektief as lae frekwensie timpanometrie om middeloor funksionering van babas jonger as sewe maande te evalueer wanneer dit vergelyk word met DPOAE metings. Normatiewe druk en admittansie data is saamgestel vir die gebruik van hoë frekwensie timpanometrie vir baba van neonatale intensiewe sorgeenhede. Swak opvolgsyfers is verkry vir beide roetine en nie-roetine besoeke, maar daar word verwag dat opvolg beskoeke met tyd sal verbeter.

Verder dui resultate op ‘n hoë insidensie van ouditiewe patologie. Permanente kongenitale gehoorverlies is geïdentifiseer in 3% (n=4) van die steekproef. Die helfte van babas met permanente kongenitale gehoorverlies het gepresenteer met sensoriesneurale gehoorverlies en die ander helfte met ouditiewe neuropatie. Die insidensie van ouditiewe patologie word beraam om 3.75% te wees as die persentasie babas wat nie teruggekom het vir opvolg nie in ag geneem word. ‘n Hoë insidensie van middeloor patologie het voorgekom met ‘n insidensie van 60.4%, wat bilaterale en unilaterale middeloor patologie insluit. Die hoë prevalensie van ouditiewe patologie in Suid Afrikaanse neonatale

intensiewe sorgeenheid babas en die gebrek aan wydverspreide neonatale gehoorsiftingsprogramme dui daarop dat ‘n groot getal babas die voordele van vroeë gehoorsifting en gehoorintervensie verbeur. Die implementering van wydverspreide neonatale gehoorsiftings programme in Suid Afrika is daarom noodsaaklik om te verseker dat alle Suid Afrikaanse babas kan baatvind by die voordele van vroeë gehoorsifting en identifikasie programme.

Sleutelwoorde: Distorsie produk otoakoestiese emissies (DPOAE), hoë frekwensie en lae frekwensie immittansie metings, neonatale gehoorsifting, neonatale gehoorverlies, neonatale intensiewe sorgeenheid, outomatiese ouditiewe breinstam response (OOBR), vroeë identifikasie en intervensie van gehoorverlies,

CHAPTER 1

INTRODUCTION AND ORIENTATION

AIM: To present the background of the problem addressed by this study, to provide the rationale for conducting this research, to define terminology used, and to provide an overview of the chapters included in the dissertation.

1.1 INTRODUCTION

Early detection of hearing loss has been a long-standing priority in the field of audiology. Hearing screening tests have been used for the last 60 years to identify children of school going age who require further audiological evaluation, and ultimately to identify those children who require further audiological and educational intervention (White, 2003:79). However, owing to the fact that hearing loss is an invisible disability, it may often go undetected until school age, especially in children with no additional disabilities. The identification of hearing loss in developing countries is often passive, and poor reactions of a child to acoustic stimuli are ignored or only identified following an underlying disease, such as suppurative Otitis Media (Olusanya, Luxon & Wirz, 2004:295; Olusanya, 2001:142). This late identification of hearing loss leads to delays in speech, language, reading and writing, academic achievement, and personal and social development (Yoshinaga-Itano & Gravel, 2001:62).

The last 35 years have therefore seen the implementation and development of infant hearing screening (IHS) programs in order to identify hearing loss as early in life as possible. If hearing loss is identified early, early intervention services can be provided, in order to prevent developmental delays in children with hearing loss (Yoshinaga-Itano, 2004:454). IHS programs have evolved from early behavioural observation techniques to sophisticated, screening technologies

relying on physiologic measurements, such as oto-acoustic emissions (OAEs) and automated auditory brainstem responses (AABRs) (Diefendorf, 2002:469; Northern & Downs, 2002:259).

1.2 BACKGROUND

The expense of using physiologic hearing screening technologies on all infants is justified by the following three facts: Hearing loss occurs twice as frequently as any other congenital abnormality screened for in newborns (Mehl & Thomson, 1998:2; Olusanya, Luxon & Wirz, 2004:288). In addition to this there are serious negative consequences associated with undetected hearing loss, such as speech, language and cognitive delays, poor social adjustment, poor educational achievement, as well as a subsequent economic disadvantage (Yoshinaga-Itano & Gravel, 2001:62; Kennedy, 1999:73; Parving, 1999:69). Lastly, early identification of hearing loss is justified by the dramatic benefits associated with early identification and intervention for infants and young children with hearing loss. Infants with hearing loss and no additional disabilities, whose hearing loss is identified early and who are provided with early intervention services before the age of six months, are able to develop language and communication skills equivalent to their normal hearing peers (Yoshinago-Itano, 2004:455). This results in tremendous benefits for the affected individuals, their families, and society at large (Yoshinaga-Itano, 2004:454).

In response to the great benefits of early detection of and intervention for infants with hearing loss, various developed countries have implemented widespread infant hearing screening as part of routine medical care, whereby each infant undergoes hearing screening before hospital discharge. This is true for countries such as the United States of America (USA), the United Kingdom (UK), and countries in Europe (Davis & Hind, 2003:S194; Olusanya, McPherson, Swanepoel et al., 2006:294; Van Straaten, 1999:77).

Thirty-nine states in the USA have passed legislation, which mandates the implementation of universal newborn hearing screening (UNHS), and the uptake in IHS is well over 90% in most voluntary states (Olusanya & Roberts, 2006:1). This results in 95% of infants receiving hearing screening before hospital discharge (Olusanya & Roberts, 2006:1; Keren, Helfand, Homer et al., 2002:856). Systematic implementation of IHS is ongoing in the UK. The UK commissioned a national program of newborn hearing screening (NHS) by the Department of Health in 2001, which aims to identify 100% of newborns with hearing loss by 24 weeks of age by means of AABR and OAE screening, and to provide early intervention services as soon as identification has taken place (Olusanya, Luxon & Wirz, 2005:117; Davis & Hind, 2001:S194). Australia implemented its first large-scale infant hearing screening program in 2000 (Coates, 2003:82). Similar advances are evident in European countries, such as the Netherlands (Van Straaten, 1999:77).

Following the implementation of UNHS, the average age of identification of infant hearing loss has been reduced to six to nine months in these developed countries (Vohr, Oh, Stewart, Bentkover, Gabbard, Lemons, Papile & Pye, 2001:238; Keren, Helfand, Homer, McPhillips & Lieu, 2002:856; Van Straaten, 1999:77). Despite these advances in IHS experienced by the developed world, such as the move from targeted newborn hearing screening (TNHS) to UNHS, many obstacles in establishing and maintaining effective early hearing detection and intervention (EHDI) programs remain (White, 2003:79-83). These obstacles consist mainly of program management issues, rather than obstacles regarding the techniques and technology used for IHS. Challenges pertaining to the management of IHS programs in developed countries include: a shortage of pediatric audiologists to provide diagnostic follow-up services and early intervention for infants who fail the hearing screening; physicians lacking the knowledge required to make referrals for hearing screening; and inadequate data systems to track failed IHS cases (Nemes, 2006:21-22).

If developed countries are still facing challenges towards IHS (Nemes, 2006:21-22), it only serves to reason that developing countries with limited financial and skilled human resources, are facing far greater challenges to IHS. IHS is thus currently a practice reserved mainly for the developed world, and the benefits of early intervention are not available to infants in developing countries (Swanepoel, Hugo & Louw, 2006:1242). Developing countries are only in the beginning stages of implementing EHDI programs. Most developing countries do not have any structured IHS programs in place, and only recently have isolated pilot programs begun to emerge (Olusanya, Swanepoel, Chapchap et al., 2007:6). A myriad of challenges currently still exists at every step of the EHDI process. Despite challenges to IHS, the importance of IHS in developing countries cannot be overlooked, as 90% of infants with hearing loss are born in developing countries (Olusanya et al., 2004:287, 291). Hearing loss is furthermore associated with poor socio-economic status (Kubba, Mcandie, Ritchie et al., 2004:123), thereby justifying the great need for IHS programs in developing countries, where the majority of infants are born into circumstances placing them at an environmental risk. IHS programs in developing countries have, however, received more attention in recent years, with pilot programs being implemented in countries such as Brazil, Mexico, India, the Middle East, Kenya, Nigeria, and South Africa (Olusanya et al., 2007:10).

South Africa is a developing country located in Sub-Saharan Africa, where two thirds of the least developed nations reside (McPherson & Swart, 1997:2). South Africa is classified collectively as a developing nation, although the South African population consists of pockets of both developed and developing contexts (Swanepoel et al., 2006:1242). Compared to other developing countries, South Africa has a well developed healthcare system (McPherson & Swart, 1997:6). South Africa is the only country in Sub-Saharan Africa with tertiary and professional training in audiological services (Swanepoel, 2006:265). Despite this, the South African audiological profession faces challenges, as it is culturally

and linguistically underrepresented (Swanepoel, 2006:265). Furthermore, audiological services are unevenly distributed between private and public healthcare sectors (Swanepoel, 2006:265).

In addition to challenges of the South African audiological profession, South Africa faces many challenges with regards to the implementation of IHS. Competing for strained health care resources is one of these challenges (Keren et al., 2002:860; Olusanya, 2001:142). The healthcare system is pressurized by the enormous burden of infectious diseases but especially HIV/AIDS (Olusanya et al., 2007:5; Swanepoel, Hugo & Louw 2006:1242; Department of Health, 2006:10-11). Developing countries, such as South Africa, therefore face the moral dilemma of overlooking non life-threatening conditions such as hearing loss, and allocating their limited resources to life threatening diseases, thereby trading quality of life for quantity of life (Alberti, 1999:S3-S4). The overwhelming burden of infectious diseases skews healthcare priorities towards saving lives rather than improving quality of life for infants with hearing loss (Olusanya et al., 2007:5; Swanepoel, Hugo & Louw, 2006:1242).

Further challenges to implementing IHS programs in South Africa are cultural beliefs and attitudes of various communities that are not conducive to IHS. A fatalistic outlook to disabilities, evident in many African families, may result in a passive attitude towards hearing loss identification and management (Swanepoel, Hugo & Louw, 2005:14; Olusanya, Luxon & Wirz, 2004:288; Olusanya, 2001:142). Limited research has however, been done to determine the actual perceptions of disabilities in African families. Furthermore, there is a great dearth of accurate epidemiological data regarding childhood hearing loss in the developing world. The extent of the problem of childhood hearing loss has therefore not yet been established, making accurate planning of IHS services difficult (Swanepoel, Hugo & Louw, 2005:76). Platforms for IHS that are appropriate in developed countries are furthermore, not always viable in developing countries. Many infants in developing countries are born outside large

hospitals, resulting in large hospitals not always being an ideal platform for IHS (Olusanya, Luxon & Wirz, 2004:299).

Another challenge to IHS programs is the fact that benchmarks and quality indicators are still lacking in developing countries, such as South Africa. Benchmarks for IHS programs include infant coverage rate, the referral rate for diagnostic audiological evaluation, and the follow-up of infants who did not pass the hearing screening (JCIH, 2000:6). Contextually relevant benchmarks for IHS programs need to be established in developing countries, in order to guide the implementation of IHS programs, and to evaluate the effectiveness of such programs. Assessment of real cost and efficiency of IHS programs in South Africa, using pilot studies, needs to be conducted in order to ensure a relevant course of action (HPCSA, 2002:7; Swanepoel, Delport & Swart, 2004:635).

Swanepoel, Hugo & Louw (2006:1242) also state that there is currently a great lack of contextual data regarding the prevalence, as well as the etiology of hearing loss in South Africa. Contextual research pertaining to the prevalence and epidemiology of infant hearing loss is especially necessary for unique populations such as prenatally HIV/AIDS infected or exposed infants (Swanepoel, Delport & Swart, 2004:635). Various pilot studies need to be conducted in order to address this dearth of contextual data regarding the epidemiology of hearing loss in the South African infant population. Such pilot studies should also serve to provide contextual guidelines for IHS programs. This will aid in advocating for legislative support and political encouragement for IHS programs in South Africa.

Contextually relevant research on the South African infant population is particularly relevant, as these infants are exposed to a unique set of environmental risk indicators for hearing loss. Poor socio-economic conditions, as evident in South Africa, have been shown to place infants at an increased risk for congenital auditory impairment (Kubba et al., 2004:123). Poor maternal

education levels and a high incidence of infectious diseases have also been reported to be environmental risk factors for hearing loss (Swanepoel, Hugo & Louw, 2005:79). Infectious diseases, such as HIV/AIDS are prevalent in South Africa and are associated with an increased risk for auditory impairment (Goldstein, Pretorius & Stuart, 2003:15; Swanepoel et al, Hugo & Louw, 2005:80). According to the National HIV and Syphilis Antenatal Sero-Prevalence Survey conducted in 2005, South Africa has a 30.2% incidence rate of HIV/AIDS in pregnant women (Department of Health, 2006:10). Infants with prenatal maternal HIV/AIDS exposure are a unique population, which has not yet before been studied in terms of the risk for auditory impairment resultant of prenatal HIV/AIDS exposure. The above discussed environmental risk indicators for hearing loss in South Africa necessitate the initiation of various pilot programs, in order to gain an accurate representation of risk indicators for hearing loss, and the incidence of auditory impairment evident in this unique group of infants.

A recent study evaluating the effectiveness of infant hearing screening at maternal child health (MCH) clinics in Hammanskraal, South Africa, reported some of the first results for IHS in South Africa (Swanepoel, Hugo & Louw, 2005c:76). MCH clinics include six-week immunization clinics, which is one of the platforms proposed for IHS by the Hearing Screening Position Statement (HPCSA, 2002:2). Results of this study revealed that MCH clinics hold promise as a suitable context for IHS, and may serve as a valuable platform to achieve widespread screening coverage in South Africa, alongside neonatal intensive care units (NICUs) and well-baby nurseries.

Despite MCH clinics being identified as a suitable context for IHS, various obstacles towards IHS at MCH clinics were identified. These included contextual barriers characteristic of primary healthcare clinics in South Africa and significant degrees of socio-economic depravity evident in infants and their caregivers, leading to increased risk for hearing loss and poor follow-up rates of infants enrolled in the study (Swanepoel, Hugo & Louw, 2006:1247; Swanepoel, Hugo &

Louw, 2005:18). Swanepoel (2004:298) recommends that pilot studies in NICUs and well-baby nurseries are necessary, as hardly any research reports regarding these contexts are documented. Such pilot studies should determine the incidence of risk factors for hearing loss in South Africa, the prevalence of hearing loss, as well as the best practice in screening, tracking of infants, and follow-up (Swanepoel, 2004:298).

Despite the challenges towards implementing IHS programs in South Africa, and the challenges faced by the audiological profession, IHS is gaining momentum in South Africa. The Health Professions Council of South Africa conceptualized a Hearing Screening Position Statement (HSPS) in the Year 2002, based on the Joint Committee of Infant Hearing Screening Year 2000 Position Statement. The HSPS Year 2002 advocates early detection and intervention for infants with hearing loss, and proposes targeted newborn hearing screening (TNHS), using objective physiologic screening techniques (HPCSA, 2002:1-2), as an intermediate step to universal newborn hearing screening (UNHS). The target set by the Professional Board for Speech, Language and Hearing Professions is to grant 98% of infants born in South Africa access to IHS by the year 2010 (HPCSA, 2002:1-2; Swanepoel, Delport & Swart, 2004:364). Three platforms for IHS are recommended, namely the well-baby nursery, at discharge from the neonatal intensive care unit (NICU), and at six-week immunization clinics (HPCSA, 2002:5). Since 2002 there has been an increase in awareness of IHS in South Africa, resultant of published reports on IHS programs emerging for the first time. The South African HSPS is currently being revised, as pilot studies on IHS have reported that reconsideration of first world models is necessary if the implementation of IHS programs in South Africa is to be successful (Swanepoel, 2006:265).

In addition to the strong advocacy for early identification of hearing loss by the HPCSA, South African health policies recognize the importance of early identification of and intervention for infants with hearing loss. This is evidenced in

the White Paper on an Integrated National Disability Strategy which advocates prevention of disability as a cornerstone of the disability policy, and calls for "early identification of impairment and disabilities" followed by "early intervention" (White Paper on an Integrated National Disability Strategy, 1997). The White Paper furthermore advocates "free health care for all children with disabilities under six, including free access to assistive devices and rehabilitation services" (White Paper on an Integrated National Disability Strategy, 1997). It is therefore clear that the necessary policies to implement early hearing detection and intervention (EHDI) programs in South Africa are in place, and it is only the implementation of EHDI programs in South Africa that still needs to be addressed (Swanepoel, Delport & Swart, 2006:5).

1.3 RATIONALE

One of the platforms for IHS recommended by the South African HSPS is the NICU (HPCSA, 2002:2). Infants admitted to the NICU are at an increased risk for hearing loss when compared to infants in the well-baby nursery, as they display an array of risk factors, such as low APGAR scores, a low birth weight (LBW), possible hyperbilirubenemia, mechanical ventilation for more than four to five days, severe respiratory failure, in utero or perinatal infections, and frequently administered ototoxic medications (Yoon, Price, Gallagher, Fleisher & Messner, 2003:354; Yoshikawa, Ikeda, Kudo & Kobayashi, 2004:362). This is coupled with the fact that infants in developing countries, such as South Africa, already display increased risk factors for hearing loss, due to poor socio-economic conditions and a high incidence of prenatal HIV/AIDS exposure (Swanepoel, Hugo & Louw, 2005:80; Swanepoel, Hugo & Louw, 2005:18). The prevalence of hearing loss in the NICU population is reported by various authors to be between 10 to 20 times higher than in the general population of newborns (Yoon et al., 2003:356). This higher prevalence argues the fact that screening NICU graduates is cost-

effective compared to UNHS in well baby nurseries, since the yield of identified infants is higher per 1000 screened.

Given NICU infants' increased risk for hearing loss, coupled with environmental risk indicators for hearing loss evident in South African infants, it is of utmost importance to initiate IHS programs for NICU infants in South Africa. The initiation of IHS programs is necessary in order to address the existing inequalities for infants with hearing loss in developing countries, who are currently not being afforded the linguistic, cognitive, social, and economic benefits of early identification of and intervention for hearing loss. Such inequalities exist in terms of quality of life indicators between infants in developed countries who are afforded EHDI services and those in developing countries who are not afforded EHDI services (Swanepoel, Delport & Swart, 2006:5). Infants with hearing loss, who are afforded EHDI services, are able to develop language and communication skills equivalent to their normal hearing peers (Yoshinago-Itano, 2004:455). Infants with hearing loss, who are not afforded EHDI services have language, cognitive, and social delays, resulting in poor educational achievement. These adverse effects of late identified hearing loss result in limited job opportunities for the individual and subsequent economic disadvantage in terms of loss of income (Olusanya, Luxon & Wirz, 2004:288; Kennedy, 1999:73; Parving, 1999:69). Ethical and moral dilemmas are therefore created if infants in developing countries are not afforded EHDI services, as disparities in healthcare between infants with hearing loss in developed and developing countries are avoidable by means of EHDI programs.

In order to bring about more equal opportunities for infants with hearing loss in terms of language, cognitive, social, and educational development across developed and developing countries, it is essential that developing nations begin to invest in their children's health by means of early childhood development initiatives, such as EHDI programs (World Bank, 2006:11). EHDI programs have the potential to result in great economic returns later in life and is able to

contribute towards the economic state of developing countries, as infants with hearing loss will have the opportunity to become active participants and contributing members of their community (World Bank, 2006:11).

The onus lies on South African audiologists to find innovate, culturally acceptable ways of implementing IHS programs, if the benefits of EHDI programs are to reach the country's infants (Swanepoel, Hugo & Louw, 2006:1242-1243). Establishing such IHS programs in South Africa will necessitate the initiation of pilot studies at various sites, in order to determine the best platforms for IHS, the most suitable protocol for IHS in South Africa, and the target disorders to be screened for (Swanepoel, Hugo & Louw, 2006:1243).

1.4 PROBLEM STATEMENT AND RESEARCH QUESTION

Few published studies worldwide have reported the results of large-scale targeted hearing screening programs (Keren et al., 2002:856). To date, no published studies could be traced that report IHS in NICUs in South Africa. However, it is important that pilot IHS programs in NICUs in South Africa be conducted and investigated, as not only do these infants display increased risk factors for hearing loss, but NICUs are one of the three platforms proposed by the Hearing Screening Position Statement for TNHS in South Africa (HPCSA, 2002:5). This study therefore aims to address the scarcity of empirical data in the NICU. The research question arising is:

What are the characteristics of an infant hearing screening (IHS) program in a neonatal intensive care unit (NICU) at a secondary state hospital in Gauteng, South Africa?

1.5 DEFINITION OF TERMINOLOGY

Screening

According to Northern & Downs (2002:259), screening involves the application of tests, examinations and procedures to a large number of individuals, in order to make a differentiation between individuals who have a high probability of having a certain disorder, and those who have a low probability of having a certain disorder. It involves a cut-off point, below or above which the disorder being investigated is suspected. Screening is not a diagnostic procedure, and individuals who fail the screening process are therefore referred for diagnostic testing (Northern & Downs, 2002:259).

Newborn Hearing Screening (NHS)

Newborn hearing screening (NHS) involves the screening of auditory abilities of newborns. A newborn is any infant in its first four days of life. The goal of NHS is to identify newborns with a substantial hearing loss, so that treatment and early intervention can be implemented by the age of six months. Two commonly used techniques for NHS are the automated auditory brainstem response (AABR) and the measurement of otoacoustic emissions (OAEs). These two techniques are regarded as the only acceptable tests for NHS according to the South African Hearing Screening Position Statement Year 2002 (HPCSA, 2002:1-2). The application of AABRs and OAEs does not require active participation of the participant, and is thus ideal for hearing screening of newborns. Newborns who fail the hearing screening procedure are referred for further diagnostic evaluation (HPCSA, 2002:4; Stach, 1998:188-189).

Infant Hearing Screening (IHS)

Infant hearing screening (IHS), like NHS refers to application of techniques, such as AABRs and OAEs, in order to differentiate between children requiring further diagnostic hearing testing, and those with normal hearing. Unlike NHS, IHS refers to hearing screening of all newborns as well as young children up to the

age of 12 months. In the current study, participants enrolled in the IHS program at a secondary hospital, range between the ages of zero and 12 months upon entering the program. The term IHS is thus more appropriate than the term NHS for purposes of this study.

Universal Newborn Hearing Screening (UNHS)

UNHS denotes hearing screening provided for all newborns and infants in a healthcare facility. The principles of UNHS are that all infants have access to hearing screening, using a physiologic measure, such as OAEs or AABRs. This should be achieved in the following way. Newborns who receive standard routine care should have access to hearing screening during their hospital stay at birth admission. Newborns born outside of a large hospital should be referred for hearing screening before the age of one month. And lastly, all newborns in the NICU must receive hearing screening before being discharged from the hospital (Northern & Downs, 2002:268, 270).

Targeted Newborn Hearing Screening (TNHS)

The HSPS Year 2002 recommends targeted newborn hearing screening (TNHS) in South Africa (HPCSA, 2002:1-2). TNHS refers to risk-based NHS. Only infants who display risk factors for hearing loss receive hearing screening (HPCSA, 2002:1). Risk factors for hearing loss are defined by the Joint Committee on Infant Hearing (JCIH) Position Statement Year 2000 (JCIH, 2000:19). TNHS is a more cost-effective way of NHS, as only 10% of infants display risk factors for hearing loss. It however, also has the disadvantage of not identifying a large number of infants with hearing loss, as 50% of infants with hearing loss display no risk factors (Olusanya, Luxon & Wirz, 2004:288).

Early Hearing Detection and Intervention (EHDI)

Early hearing detection and intervention (EHDI) services for infants with hearing loss is endorsed by the JCIH Year 2000 Position Statement (JCIH, 2000:3). The goal of EHDI is to ensure maximal communicative and literacy development for

children with hearing loss. EHDI comprises the following: All infants should be screened for hearing loss prior to hospital discharge, using objective or physiological tests, such as OAEs and AABRs. Confirmation of an infant's hearing loss should take place by the age of three months, and appropriate family-centered intervention should commence by the age of six months. Furthermore, infants who display risk factors for late onset or progressive hearing loss should receive ongoing audiologic monitoring for three years, at appropriate intervals (JCIH, 2000:3; Northern & Downs, 2002:269). In the current study, the term EHDI embodies the above concepts, although the age limits for hearing screening, confirmation of hearing loss, and early intervention, as specified by the JCIH are not at all times adhered to. Hearing screening in the current study takes place on infants between the ages of zero and 18 months. Diagnostic confirmation of hearing loss and early intervention services may thus only commence at a later age than suggested by the JCIH.

High Risk Register

High risk newborns are targeted for hearing screening before or shortly after hospital discharge. Infants are considered at risk for hearing loss, if they display one or more of the following risk factors, belonging to the high risk register for hearing loss: a stay in the NICU for 48 hours or longer; stigmata or other findings associated with a syndrome known to include hearing loss; craniofacial anomalies; in utero infections, such as cytomegalovirus, herpes, toxoplasmosis or rubella. These are risk factors as defined by the JCIH (2000). The term high risk register, as used in the current study, also includes risk factors, such as a birth weight less than 1500g, hyperbilirubenemia requiring exchange transfusion, exposure to ototoxic medication and mechanical ventilation for more than five days (Northern & Downs, 2002:272; Olusanya, Luxon & Wirz, 2004:288; Parving, 1999:69). Infants belonging to the high risk register subsequently receive TNHS or risk-based hearing screening.

Developed Countries

Developed countries are those countries that experience a high standard of living. This is derived through an industrialized and diversified economy, and is measured in terms of gross domestic product (GDP), under five mortality rates, immunization uptake, and education (World Bank, 2006:29-34). Developed countries have a high gross domestic product (GDP) per capita. They are also said to have a high human development index (HDI), which is a statistical measure that gauges a country's level of human development. Although the term 'developed countries' usually refers to high levels of *economic* development, it is also closely associated with high levels of *social* development. High levels of social development can be described in terms of education, healthcare and life expectancy (World Bank, 2006:2-6). In the current study the term 'developed countries' refers to high levels of both economic and social development. In order to be classified as a developed country, countries need to have a certain GDP per capita. Countries, like South Africa, which consist of both developed and developing sections, but that do not have the GDP per capita of a developed country, are placed into the category of a developing country (McPherson & Swart, 1997:2).

Developing Countries

According to the World Trade Organisation (WTO) approximately two thirds of the WTO's 150 members are developing countries (World Trade Organisation, 2006). Developing countries experience a low standard of living, with an undeveloped industrial base, and a moderate-low human development index (HDI). As with developed countries, the term 'developing countries' does not only refer to levels of economic development, but also to levels of social development. Developing countries experience low levels of both economic development and social development, in terms of education, healthcare and life expectancy (World Bank, 2006:2-6).

1.6 OUTLINE OF CHAPTERS INCLUDED IN THE DISSERTATION

Table 1.1 provides an outline of the chapters included in the dissertation, with a short description of the content and objective of each.

Table 1.1 Outline of chapters included in the dissertation

CHAPTERS	CONTENT AND OBJECTIVE
Chapter one Introduction and Orientation	Chapter one provides and introduction and orientation to the study. It sketches the scenarios in which the problem addressed by this study originated, and provides the rationale for conducting this research. Terminology is defined and an overview of the content of chapters in the dissertation is given. The objective of this chapter is to orientate the reader to the research process.
Chapter two Risk-based screening in developing countries: realizing early identification of hearing loss	Chapter two comprises the theoretical component of the dissertation. It is a critical review of existing theoretical knowledge about the field of IHS. The objective of this chapter is to assist both the researcher and the reader in obtaining knowledge necessary for understanding this research project, the methodology and the interpretation of findings.
Chapter three Methodology	Chapter three describes the research methodology, in terms of the aims of this study, the research design used, the research sample, material and apparatus used to conduct this study, as well as procedures for collecting, recording and analyzing data. Ethical considerations and validity and reliability of this study are discussed. The objective of this chapter is to describe the research methodology in such a way that the reader will be able to duplicate the research exactly.
Chapter four Results and Discussion	Chapter four presents results of all collected and processed data in graphic form, followed by a discussion of these results. Results are presented in accordance with the sub-aims of the study. The objective of this chapter is to answer the research question, and present new meaning as a contribution to the field of newborn and infant hearing screening.

Table 1.1 Outline of chapters included in the dissertation

CHAPTERS	CONTENT AND OBJECTIVE
Chapter five Conclusions and Recommendations	Chapter five draws conclusions about the research question and discusses implications of the findings. A critical evaluation of this research project is provided, and recommendations for further research are made. The objective of this chapter is to finalize the research project, and create a platform for further research.

1.7 SUMMARY

This chapter discussed the importance of IHS, placing emphasis on the importance of IHS in South Africa and in the NICU population in particular. The need for research regarding the effectiveness of IHS programs for NICU infants in a developing country, such as South Africa, was argued. A research question was formulated to describe the characteristics of an IHS program in a NICU at a state hospital in South Africa. A list of terminology was presented and defined in terms of how it would be used in the current study. This was followed by an outline of chapters included in the dissertation.

CHAPTER 2

RISK-BASED SCREENING IN DEVELOPING COUNTRIES: REALIZING EARLY IDENTIFICATION OF HEARING LOSS

AIM: This chapter will provide a critical review of the rationale for infant hearing screening for high risk infants in both developed and developing countries, as well as an argument for infant hearing screening of high-risk neonatal intensive care unit infants in South Africa.

2.1 INTRODUCTION

The field of pediatric audiology has seen great advances in the development of infant hearing screening (IHS) for infants over the past four decades (Northern & Downs, 2002:259). These advances have been in response to staggering benefits of early identification of and intervention for infants with hearing loss, as well as serious negative consequences associated with late identification of hearing loss, emerging from the growing body of literature (Yoshinago-Itano, 2004:455; Kennedy, 1999:73; Parving, 1999:69). Subsequently, in the developed world, the practice of IHS is becoming part of standard medical care. This holds true for the USA, UK and Europe (Northern & Downs, 2002:268). Despite the widespread implementation of IHS in developed nations, implementation of IHS programs faces various challenges in developing countries (Swanepoel, Hugo & Louw, 2006:1242). A lack of IHS programs in developing countries is in part attributed to a lack of resources, unfavorable cultural beliefs and attitudes towards IHS, as well as a dearth of contextually relevant research (Olusanya, Luxon & Wirz, 2004:288; Swanepoel, Hugo & Louw, 2005a:14; Swanepoel, Hugo & Louw, 2005b:76). These challenges need to be considered before the benefits

of early identification and intervention are able to reach the wider infant population in developing countries.

Existing literature reports few studies on targeted newborn hearing screening (TNHS) of high-risk neonatal intensive care unit (NICU) infants in the developing world. The NICU population is at a greatly increased risk for hearing loss, with a reported ten to 20 times greater incidence of hearing loss when compared to the general newborn population, justifying the increased importance of providing IHS for these high-risk infants (Yoon, Price, Gallagher et al., 2003:355; Yoshinaga-Itano, 2004:462). It is therefore the aim of this chapter to provide a critical review of the development of IHS, and to discuss challenges to IHS in developing countries. Increased risk for hearing loss evident in NICU infants will be justified, followed by a discussion of studies reporting TNHS for high-risk NICU infants in both developed and developing countries. Lastly an argument for IHS for high-risk NICU infants in South Africa, where infants are exposed to additional environmental risk factors, will be provided (Swanepoel, Hugo & Louw, 2005c:78).

2.2 RATIONALE FOR INFANT HEARING SCREENING WORLDWIDE

The field of pediatric audiology has seen the development of hearing screening programs for infants over the past four decades, with the advent of universal newborn hearing screening (UNHS) in developed countries, and the use of electrophysiological measures for hearing screening (Northern & Downs, 2002:259). IHS programs aim to identify those infants with a high probability of having a hearing loss so that habilitative measures can be implemented as early as possible in order to minimize the negative consequences of undetected hearing loss and maximize the child's linguistic, cognitive, social and educational development (Northern & Downs, 2002:259). Objective electrophysiological measures of hearing screening have become the only acceptable tests endorsed

for IHS (HPCSA, 2002:4). These currently include the automated auditory brainstem response (AABR) and otoacoustic emission (OAE) testing. Both of these screening techniques are easily conducted and are well established as having high sensitivity and specificity rates in the identification of hearing loss in newborns (Meier, Narabayashi, Probst et al., 2004:932; Van Straaten, 1999:77). The development of IHS programs and the urgency for early identification of and intervention for hearing loss in infants has been in response to three main facts emerging from current literature.

Firstly, hearing loss occurs at least twice as frequently as other congenital abnormalities screened for in newborns, such as congenital hypothyroidism, sickle cell disease, phenylketonuria, and galactosemia combined, making it the most common congenital abnormality in newborns (Mehl & Thomson, 1998:2; Olusanya, Luxon & Wirz, 2004:288). Northern & Downs (2002:267) further substantiate that hearing loss occurs more frequently than any other birth defect, and estimate the prevalence of infant hearing loss at 1.5-6.0/1000 births. Screening for sensorineural hearing loss is reported to identify 260 infants per 100000 infants screened in comparison to 50 infants per 100000 infants screened for congenital hypothyroidism, which is currently the most common congenital condition screened for in the USA (Mehl & Thomson, 1998:2; Swanepoel, Delport & Swart, 2004:634). These figures can be estimated to be even higher, when late onset and progressive hearing loss are taken into account.

Early identification of hearing loss is further justified by the serious negative consequences that undetected hearing loss has on a young child's development. Hearing loss places a child at high risk for speech, language and cognitive delays, poor social adjustment, insufficient educational achievement, as well as at an economic disadvantage (Kennedy, 1999:73; Parving, 1999:69). Normal hearing forms the foundation for speech and language development. An infant or young child with hearing loss experiences sensory deprivation, which in turn

leads to failure to develop communication skills. Undetected hearing loss has a cascading effect, in that poor communication skills lead to learning problems, which lead to subsequent poor educational achievement. Poor communication abilities furthermore lead to social and emotional developmental problems (Kennedy, 1999:73; Parving, 1999:69; Van Straaten, 1999:77).

A review article by Yoshinaga-Itano & Gravel (2001:62) reported that children with bilateral severe to profound hearing loss who are identified after the age of 12 months, leave the educational system at 18 years of age with a reading level equivalent to that of an average middle third to middle fourth grader, and language abilities that are equivalent to that of a nine to ten year old. Even children with mild degrees of hearing loss, such as unilateral or high frequency hearing loss, are more likely to experience academic difficulties, as well as difficulties interacting socially, when compared to their normal hearing peers. These children are also more likely to have a poor self-esteem as a result of language delays and academic difficulties.

In the USA a deaf individual's income after school is 30% less than that of a normal hearing individual. Furthermore, special education and loss of productivity amounts on average to more than one million dollars over the individual's lifetime (Mohr, Feldman & Dunbar, 2000:1). Loss of productivity not only places an economic burden on families, but also on the government. The viability of IHS programs in terms of costs per infant identified with hearing loss therefore needs to be investigated within the framework of each country's healthcare budget.

Costs of IHS vary greatly in the literature, depending on the type of protocol used for IHS, as well as the equipment used. Yoshinaga-Itano & Gravel (2001:64) report the cost of bilateral identification of hearing loss to be 12600 dollars per infant. They do not however, specify the protocol used for screening. Keren et al. (2002:860) report IHS to amount to approximately 16000 dollars per infant diagnosed with hearing loss by six months of age through TNHS, and 44000

dollars per infant diagnosed with hearing loss through UNHS. Despite variations in cost estimates for the identification of infant hearing loss, it is undeniable that early identification of hearing loss is expensive. Costs of early identification of hearing loss are however, in no way comparable to the total cost of special education and the loss of income to a deaf individual as a result of limited job opportunities (Keren et al., 2002:860). Cost savings of 10000 dollars annually are estimated for each child that does not require special education, and an annual saving of 50000 dollars per child requiring a less intensive education program (Yoshinaga-Itano & Gravel, 2001:64). South Africa, as a developing country, where financial and skilled human resources are scarce, cannot afford the economic burden that is placed on the government by late identified hearing loss, and subsequent loss of employment opportunities. It is therefore essential that IHS programs begin to be introduced in South Africa, in order to avoid the economic burden of late identified hearing loss.

The serious negative consequences of late identified hearing loss on a child's development and on society at large, are preventable by early identification of and intervention for hearing loss. Dramatic benefits associated with early identification and intervention for infants and young children with hearing loss have been documented (Olusanya, Luxon & Wirz, 2004:288). These have been substantiated greatly by various research studies evaluating the benefits associated with early identification of and intervention for hearing loss. Various authors report a "sensitive period" for language development in the first six months of infancy (Kennedy, 1999:73; Lin, Huang, Lin et al., 2004:185; Olusanya, Luxon & Wirz, 2004:288). Children with hearing loss and no additional disabilities, who are identified early and provided with early intervention services before the age of six months are therefore able to develop language and communication skills within the range of the normal distribution of their normal hearing peers (Yoshinaga-Itano, Sedey, Coulter et al., 1998:1170).

Results of a study conducted by Moeller (2000:4-5), investigating age of enrollment for hearing impaired children in early intervention programs and its relationship to language performance at five years of age revealed the following: Firstly, age of enrollment in early intervention services is associated with significantly better language abilities at the age of five years. Earliest enrolled individuals, when compared with normal hearing five year olds, performed in the average range of vocabulary measure, regardless of their degree of hearing loss. These children furthermore demonstrated verbal reasoning skills in the low average range of their normal hearing peers.

Thompson, McPhillips, Davis et al. (2001) conducted a literature search on controlled trials published in accredited journals and investigated whether identification and treatment of hearing loss prior to six months improves language and communication skills. Five studies reported on the speech and language abilities of children with hearing loss, who were identified early and enrolled in a home intervention program. These studies were conducted by Holt (1993), Apuzzo & Yoshinaga-Itano (1995), Yoshinaga-Itano, Sedey, Coulter et al. (1998), Yoshinaga-Itano & Apuzzo (1998) and Mayne, Yoshinaga-Itano, Sedey et al. (2000).

Results of these studies revealed that children with hearing loss, identified before six months of age, and provided with early intervention services, achieved language scores at or near their cognitive test scores. Children with hearing loss identified after six months of age scored on average 20 points lower on language scores than on cognitive scores (Thompson et al., 2001:107-108). Yoshinaga-Itano (2004:454) emphasizes the point that early identification of hearing loss alone does not result in improved language abilities. Early identification of hearing loss needs to be followed by prompt early intervention services in order to ensure improved language and developmental outcomes (Yoshinaga-Itano, 2004:454). Furthermore, parents of children who have better language development are reported to have lower levels of parental stress, resulting in

better personal-social development of their child (Yoshinaga-Itano & Gravel, 2001: 63-64).

It is evident therefore that even a six month delay in diagnosis and early intervention for hearing loss can determine whether a child receives inclusive or special education. Children who do not require special education save as much as 348000 dollars during a 12 year education (White Paper Addressing the Societal Costs of Hearing Loss and Issues in Third Party Reimbursement, 2004). This is particularly relevant for the South African context, where not only financial resources are limited, but skilled human resources too. It is exceptionally difficult for children to gain access to special schools in a country where learners have difficulty gaining access to an education, let alone to special schools.

The advantages of early identification of and intervention for childhood hearing loss, including the possibility of inclusive education for children whose hearing loss was identified early, have lead to the urgent need for IHS programs to be implemented. The developed world has begun to implement IHS as part of standard medical care. This is true for countries such as the USA, the UK, and Europe (Swanepoel, Hugo & Louw, 2005c:75; Van Straaten, 1999:77). The decade of the 1990s saw the initiation of UNHS in the developed world (Northern & Downs, 2002:268). Thirty-nine states in the USA have passed legislation, which mandates the implementation of UNHS. The uptake in IHS is furthermore well over 90% in most voluntary states (Olusanya & Roberts, 2006:1). Subsequently 95% of infants undergo hearing screening before hospital discharge (Olusanya & Roberts, 2006:1; Keren et al., 2002:856).

Systematic implementation of IHS is ongoing in the UK, and the UK has advanced from using a distraction test that could only be performed when infants were as old as seven to eight months, to commissioning a national program of NHS by the Department of Health in 2001. This program aims to identify 100% of newborns with hearing loss by 24 weeks of age by means of AABR and OAEs,

and to provide early intervention services as soon as identification has taken place (Olusanya, Luxon & Wirz, 2005:117; Davis & Hind, 2001:S194). Australia also implemented its first large-scale infant hearing screening program in 2000, whereby all babies born at five of the major birthing hospitals in Perth receive hearing screening before hospital discharge (Coates, 2003:82). Implementation of UNHS in other states of Australia has also recently commenced (Coates, 2003:82). Similar advances are evident in European countries, such as the Netherlands (Van Straaten, 1999:77).

Despite the recent growth of IHS, it remains a practice predominantly only conducted in the developed world, and the benefits of early intervention are not yet available to infants in developing countries owing to multifaceted challenges (Swanepoel, Hugo & Louw, 2006:1242). No comparative data for developing countries is available, resulting from a lack of systematic and routine IHS programs (Olusanya, 2001:142). In keeping with the current developments in IHS however, the Professional Board for Speech, Language and Hearing Professions of the Health Professions Council of South Africa developed a Hearing Screening Position Statement (HPCSA, 2002).

The South African HSPS accepts the JCIH Year 2000 Positions Statement as its definitive document. The South African HSPS advocates targeted (risk based) IHS, using objective physiologic measures, as an interim step to UNHS in a developing South African context. Three platforms for IHS in South Africa are recommended by the HSPS, namely the well-baby nursery, at discharge from the NICU, and at six-week immunization clinics (HPCSA, 2002:5). Nevertheless, benchmarks and quality indicators are still lacking, and need to be established, in order to evaluate the effectiveness of IHS programs at these three platforms. Assessment of real cost and efficiency of IHS programs, using pilot studies, needs to be conducted to ensure a relevant course of action (HPCSA, 2002:7; Swanepoel, Delport & Swart, 2004:635). The challenges to IHS in developing countries like South Africa are however, multifaceted, resultant of limited financial

and human resources, as well as environmental risk factors for hearing loss (Olusanya, 2001:142; Swanepoel, Hugo & Louw, 2005c:78).

2.3 CHALLENGES TO INFANT HEARING SCREENING IN THE DEVELOPING WORLD

The developing world can be classified into 164 countries, comprising six major regions, and a total of approximately five billion people spread over the six regions (Olusanya, Luxon & Wirz, 2004:289). Countries comprising the six major regions are displayed graphically below in table 2.1

TABLE 2.1 The six major regions of the developing world

The six major regions of the developing world
1. Sub Saharan Africa – 46 countries
2. Middle East and North Africa – 21 countries
3. East Asia and the Pacific – 29 countries
4. South Asia – 8 countries
5. Latin America and the Caribbean – 33 countries
6. Central / Eastern Europe and the Baltic States – 27 countries

(Olusanya et al., 2004:289)

Although the above described regions are all classified as the developing world, the per capita income, immunization up-take and the under-five mortality rate show significant differences across the regions, as well as individual countries. The average per capita income for the developing world is a little over 1000 dollars, and as low as 110 dollars in the least developed countries. Comparatively, the average per capita income in developed countries is 20000 dollars (Olusanya, 2001:142). This implies that all developing countries are classified as either low income or lower middle income according to their gross

national income per capita. Nevertheless, there are marked variations of gross national income per capita amongst various developing countries, with individual countries even showing marked variations in per capita income within their own individual populations (Olusanya, Luxon & Wirz, 2004:289). These significant differences in per capita income have resulted in the ability of some developing countries to begin initiating IHS, and other developing countries not being able to do so yet.

Existing literature contains very few reports documenting IHS and the incidence of congenital hearing loss in the developing world. This is due to a lack of widespread IHS programs in these countries and a subsequent lack of representative epidemiological data on hearing disorders (Olusanya, Luxon & Wirz, 2004:289). IHS programs in developing countries have, however, received more attention in recent years. Pilot programs have been implemented in countries such as Brazil, Mexico, India, the Middle East, Kenya, Nigeria, and South Africa (Olusanya et al., 2007:10). Further research and data on IHS programs in developing countries is however, vital, if the problem of childhood hearing loss is to be appropriately addressed.

In 2001 WHO estimated 250 million people worldwide to be living with hearing loss, of which two thirds reside in the developing world. Between 126000 and 500000 infants are born each year with a significant hearing loss. Ninety percent of these infants are estimated to be born in developing countries (Olusanya, Luxon & Wirz, 2004:287, 291; Prasanuk, 2000:207). It thus becomes evident that, although prevalence figures for hearing loss are largely still unknown in the developing world, infant hearing loss is more prevalent in developing than developed countries, and is therefore associated with poor socio-economic conditions (Kubba et al., 2004:123). Countries with the fewest resources for IHS are therefore also those with the highest incidence of hearing loss, making widespread implementation of IHS programs all the more challenging.

Challenges to IHS in the developing world are multifaceted, and are discussed below.

2.3.1 Limited financial and human resources for IHS programs in developing countries

Developing countries have limited financial resources and therefore struggle to bear the financial burden of implementing IHS programs (Madriz, 2001:85; Olusanya, 2001:142). Olusanya (2001:142) estimates the cost of using AABR and OAE screening to be 35 dollars per infant, and over 35000 dollars to detect a child with hearing loss. This is over and above the estimated 4000 dollars cost of AABR and OAE screening equipment (Olusanya, 2001:142). These cost estimates are based on the general newborn population, and the cost of identifying an infant with hearing loss in the high-risk population will therefore be somewhat less. Keren et al. (2002:860) report the average cost of identifying an infant with hearing loss to be 16000 dollars, using TNHS, and 44000 dollars, using UNHS.

This is a high price to pay when the average per capita income in developing countries is 1000 dollars. The small percentage (13%) of the global healthcare funds that is allocated to developing countries, where 80% of the global population resides, is not able to cover the financial implications of widespread IHS. The limited available resources in developing countries are therefore allocated to life-threatening conditions, few of which involve otorhinolaryngology or even hearing loss (Alberti, 1999:S3-S4; Swanepoel, Hugo & Louw, 2005a:14). These limited available healthcare funds allocated to developing countries, however, necessitate the investigation of alternative ways for the implementation of IHS. Developing countries should look towards making use of volunteers, community workers, and existing infrastructures to begin implementing widespread IHS.

IHS in developing countries and subsequent early identification of and intervention for hearing loss has the potential to result in long-term savings, in terms of educational needs of the child and employment opportunities. Children who do not require special education save as much as 348000 dollars during a 12 year education in the United States of America (White Paper Addressing the Societal Costs of Hearing Loss and Issues in Third Party Reimbursement, 2004). Although IHS is costly, it can be argued that the expenses of identifying a child with hearing loss do not nearly compare to the total savings over a lifetime of an individual with early identified hearing loss.

2.3.2 Increased incidence of risk indicators for childhood hearing loss in developing countries

A further challenge to IHS in developing countries is the increased incidence of risk factors for hearing loss, resultant of poor socio-economic conditions and exposure to environmental risk indicators (Kubba et al., 2004:123; Swanepoel, Hugo & Louw, 2005c:79). Developing countries face the moral dilemma of overlooking non life-threatening conditions such as hearing loss, and allocating their limited resources to life threatening diseases, thereby trading quality of life for quantity of life. Although lives are saved by allocating funds to conditions such as meningitis, measles, mumps, cytomegalovirus and acute respiratory infections, in doing so, the incidence of hearing loss is further increased in developing countries, as the above are risk factors for hearing loss (Olusanya, Luxon & Wirz, 2004:295-296; Alberti, 1999:S3-S4). Socio-economic depravity has also been shown to place an infant at increased risk for congenital hearing loss (Kubba et al., 2004:123). All risk factors for hearing loss as indicated by the JCIH Year 2000 Position statement have been shown to be prevalent in developing countries. However, maternal rubella, high fever, birth trauma and neonatal sepsis have been documented as additional prevalent risk factors for hearing loss in at least three of the world developing regions (Olusanya, Luxon & Wirz, 2004:293-294).

The increased incidence of risk factors for hearing loss, and advances in medical care in the developing world also have an influence on the increased rate of progressive or late onset childhood hearing loss in many of these countries. This may be ascribed to the high incidence of measles, mumps, meningitis, and the high rate of administration of ototoxic drugs used to treat these diseases (Olusanya, Luxon & Wirz, 2004:295-296). The NICU population is at particularly high risk for late-onset or progressive hearing loss, resultant of their medical conditions as well as medical treatments provided in the NICU. Risk factors for late-onset or progressive hearing loss in NICU infants include severe respiratory failure, persistent pulmonary hypertension, and subsequent mechanical ventilation (Robertson, Tyebkhan, Hagler et al, 2002:355; Olusanya, Luxon & Wirz, 2004:296). This necessitates hearing screening programs with ongoing audiological monitoring and follow-up of infants and young children in developing countries, in order for late-onset or progressive hearing loss to be identified as early as possible.

2.3.3 Attitudes of caregivers, healthcare workers and communities towards IHS programs in developing countries

The implementation of widespread IHS programs is further challenged by caregivers, healthcare workers and communities at large with attitudes that are not always conducive to IHS. The lack of awareness towards the importance of early identification of and intervention for hearing loss in developing countries, leads to passive identification of hearing loss. Further complicating the problem of passive identification of hearing loss, are cultural beliefs and attitudes of various communities towards IHS. A fatalistic outlook towards disabilities, evident in many African families, coupled with customs and superstitious beliefs, serves to greatly challenge the implementation of IHS programs in developing countries (Olusanya, Luxon & Wirz, 2004:288; Olusanya, 2001:142; Swanepoel, Hugo & Louw, 2005a:14).

Hearing loss is an invisible disability, which cannot be passively identified until the child fails to develop speech and language (Yoshinaga-Itano, 2004:456). Even when parents report abnormal reactions of their child to acoustic stimuli, the attitudes and awareness of the importance of early identification of and intervention for hearing loss among healthcare workers often lead to delays in diagnosis. Parents and healthcare workers may believe that the child will outgrow the hearing loss, leading to failure to investigate the suspected hearing loss (Swanepoel, Hugo & Louw, 2005a:12). Alternatively, the identification of a hearing loss may follow an underlying disease, such as suppurative otitis media, but would not have otherwise been investigated (Olusanya, Luxon & Wirz, 2004:295; Olusanya, 2001:142). A lack of awareness of the importance of early identification of and intervention for hearing loss amongst healthcare workers and communities at large results in IHS not gaining the necessary advocacy for widespread implementation.

More recently however, some reports have demonstrated promise in maternal views on IHS in developing countries. A study conducted by Olusanya, Luxon & Wirz (2005) investigated maternal views of infant hearing loss in Nigeria, a developing country. This study was conducted in response to reports documenting a lack of public awareness of childhood hearing loss and unfavorable superstitious beliefs and customs evident in many cultures. Interestingly, results of this study revealed that 92% of mothers displayed a positive attitude towards IHS, and 84% showed high acceptance of the use of hearing aids if their child were found to have a hearing loss (Olusanya, Luxon & Wirz, 2006:621). These important results are indicative of maternal readiness for the introduction of IHS in developing countries, and can be viewed as a positive step in the quest for more widespread implementation of IHS programs.

2.3.4 Establishing appropriate platforms for IHS programs in developing countries

Introducing IHS programs to developing countries poses a further challenge to be considered. This concerns the question as to whether platforms for IHS used in the developed world are relevant for the developing world. Traditionally, the developed world has largely made use of hospital based IHS programs. In most developing countries, a large number of births occur outside large hospitals (Olusanya, Luxon & Wirz, 2005:117). A hospital based platform for IHS may therefore not be appropriate. A hospital based IHS study conducted in Malaysia revealed a follow-up rate of only 57% (Mukari, Tan & Abdullah, 2005:4-5). Reasons for these poor follow-up rates were investigated, and it was found that geographical distance and transport problems were some of the main reasons for poor follow-up rates (Mukari, Tan & Abdullah, 2005:6).

However, the JCIH recommends a 95% coverage rate of infants within six months of initiating an IHS program (Mukari, Tan & Abdullah, 2005:2). Relying on only hospital based IHS in developing countries would result in the coverage rate of infants falling far short of this target. These results emphasize that hospitals are not always an appropriate platform for IHS programs in developing countries. A study conducted by Prince, Miyashiro, Weirather et al. (2003:1203) investigated the epidemiology of early hearing loss detection in Hawaii. It was found that infants born in community hospitals were less likely to follow-up for IHS than those infants born in large medical centres. A lack of appropriate platforms for IHS, and poor follow-up rates of infants enrolled in IHS programs, result in major barriers to the implementation of widespread IHS programs in developing countries.

Developing countries need to make use of existing infrastructure to determine suitable and culturally acceptable platforms for IHS programs, as platforms for IHS used in developed countries are not always appropriate in developing countries. It is essential that alternative platforms for IHS programs be

investigated in each country, in order to gain the necessary advocacy for IHS in developing countries. This view is supported by Swanepoel, Hugo & Louw (2005b:17) and Olusanya, Luxon & Wirz (2005:118), who also recommend that pilot sites of IHS programs should serve as examples for future large scale program implementation, thereby providing time to develop the requisite support services. Swanepoel, Hugo & Louw (2005b:18) conducted an IHS project at two immunization clinics in South Africa, and made use of existing infrastructure for IHS programs. Results of this study showed immunization clinics to be suitable as IHS platforms, despite challenges related to the nature of these clinics (Swanepoel et al., 2005:18). Furthermore it was found that comprehensive coverage of infants was achievable at immunization clinics (Swanepoel, Hugo & Louw, 2005a:12). These results support the need to investigate alternative platforms for IHS programs in developing countries that are contextually relevant. Such platforms should take the unique socio-economic, demographic and healthcare infrastructures of each country and regions within countries into account (Mencher & de Voe, 2001:18; Olusanya, 2001:146).

2.3.5 Limited prevalence data and contextual research for childhood hearing loss in developing countries

There is a great dearth of accurate epidemiological data regarding childhood hearing loss in developing countries, which serves to pose a further complication to the implementation of large scale IHS programs. The extent of the problem of childhood hearing loss has not yet been accurately established. Not only is there a lack of prevalence data regarding infant and childhood hearing loss, but the developing world also lacks data regarding the prevalence of risk factors for hearing loss (Swanepoel, Hugo & Louw, 2005c:76). Although the relationship between poor socio-economic conditions and an increased incidence of childhood hearing loss has been established, there are many other risk factors to consider. An example of such a risk factor is the overwhelming burden of infectious diseases, such as HIV/AIDS, which are rife in developing countries (Swanepoel, Hugo & Louw, 2005c:75). In developing countries there is thus a

lack of basic data to plan hearing screening initiatives, pointing towards a need for comprehensive contextual research initiatives, if the necessary implementation of widespread IHS is to be achieved (Swanepoel, Hugo & Louw, 2005a:15).

There is a dire need for contextual research, which should investigate the epidemiology and prevalence of childhood hearing loss in developing countries. Individual risk factors for hearing loss may vary across different communities, and the investigation of risk factors specific to each community should form part of such research efforts. This view is supported by Swanepoel, Delport & Swart (2004:635), who also emphasize that the high incidence of HIV/AIDS in developing countries has a great effect on the prevalence of hearing loss, as HIV/AIDS is a known risk factor for chronic Otitis Media. Contextual empirical data from pilot studies is furthermore necessary to demonstrate the widespread importance of IHS, as limited resources and poor motivation is currently hindering the initiation of epidemiological research for hearing loss (Swanepoel, Hugo & Louw, 2005b:17; Madriz, 2001:85). Without such research, the necessary legislative support in implementing widespread IHS cannot be attained (Swanepoel, 2006:265).

In 2001 the World Health Organization recognized the problem of childhood hearing loss by taking crucial steps in preventing and controlling hearing loss over the last decade. Such crucial steps include collecting epidemiological data on the prevalence and profile of hearing loss. The United Nations Children's Fund (UNICEF, 2002) also recognized the importance of early identification of and intervention for childhood hearing loss, and subsequently has introduced an opportunity for EHDI programs. EHDI programs should form part of early childhood development programs, which aim to give every child the best start in life (Olusanya, McPherson, Swanepoel et al., 2006:294).

2.3.6 Target disorder for IHS programs in developing countries

Lastly, it is essential to address the issue as to whether the target disorder of IHS programs in developing countries needs to be shifted from permanent sensorineural hearing loss to long-term conductive hearing loss, as suggested by Mencher & De Voe (2001:17). Acute respiratory infections leading to Otitis Media are a global problem in children under the age of five years (Alberti, 1999:S4). However, the incidence of middle ear pathology is reported to be considerably higher in developing countries than in developed ones (Olusanya, Luxon & Wirz, 2004:296). A study conducted by Olusanya (2001:143) in Nigeria investigated the prevalence and pattern of hearing loss in school entrants. Of those children identified as having a hearing loss, 36% of them were found to have a conductive hearing loss, resultant of middle ear pathology. The reported prevalence in this study is representative of the current state in most developing countries (Olusanya, 2001:143; 146).

Apart from socio-economic factors, HIV/AIDS is a leading causative factor of Otitis Media in infants and young children in the developing world. The high incidence of HIV/AIDS in developing countries results in an increased vulnerability in infants and young children for acquiring infections such as Otitis Media (Swanepoel, Hugo & Louw, 2005c:80; Bankaitis & Keith, 1995:353). Chronic Otitis Media has become a public health problem for which prevalence data needs to be collected in order to determine the exact nature of this problem (Alberti, 1999:S5). This is justified by the irreversible damage to the auditory pathway that can be caused by intermittent Otitis Media (Boone, Bower & Martin, 2006:395).

In developing countries, where resources are limited, and where unfavorable cultural beliefs and attitudes towards hearing loss exist, the issue of prevention of hearing loss as the main goal of IHS programs naturally arises (Olusanya, Luxon & Wirz, 2004:288). Prasanuk (2000:207) reports that over 50% of hearing loss is preventable if detected early and managed appropriately. If healthcare

professionals are aware of the dire consequences of middle ear pathology in infants and young children, it is of essence that these infants receive the opportunity for early diagnosis by IHS programs. This not only implies a shift in the target disorder screened for, but also necessitates regular follow-up of all infants. The inclusion of conductive pathology as a target disorder for IHS programs is a vital and necessary step in the management of hearing loss in developing countries.

2.3.7 Summary of challenges to IHS in developing countries

The above discussed challenges to IHS result in barriers to the implementation of IHS programs in developing countries. These challenges are also reasons for poor advocacy of early identification of and intervention for hearing loss in developing countries. A summary of the challenges to IHS in developing countries, as discussed above, is presented in table 2.2.

TABLE 2.2 Challenges to the implementation of IHS programs in developing countries

CHALLENGES TO IHS	DESCRIPTION OF CHALLENGES
Limited financial and human resources	- *Lack of funding for IHS programs* - *Shortage of trained pediatric audiologists*
Increased incidence of risk factors for hearing loss	– *Socio-economic depravity is associated with increased incidence of hearing loss* – *Increased incidence of diseases known to cause hearing loss* – *Increased administration of ototoxic drugs in response to diseases*
Increased incidence of progressive or late onset childhood hearing loss	– *Administration of ototoxic drugs* – *Medical conditions and medical treatments of NICU infants*
Unfavourable attitudes of caregivers and healthcare workers towards the implementation of IHS programs	– *Passive attitudes of caregivers and healthcare workers in the identification of childhood hearing loss* – *Lack of awareness of the importance of early identification of and intervention for hearing loss*

TABLE 2.2 Challenges to the implementation of IHS programs in developing countries

Cultural beliefs of communities towards IHS	– *Fatalistic outlook towards disabilities evident in many communities* – *Superstitious beliefs not conducive towards IHS programs*
Platforms for IHS used in developed countries not always appropriate in developing countries	– *Many infants born outside large hospitals, making hospital-based IHS programs difficult* – *Suitable and culturally acceptable platforms for IHS need to be determined*
Dearth of accurate epidemiological data on childhood hearing loss	– *Lack of prevalence data on childhood hearing loss and risk factors for hearing loss, resultant of IHS programs not being widespread*
High incidence of middle ear pathology	– *HIV/AIDS increases vulnerability to acquiring infections such as Otitis Media* – *Higher prevalence of Otitis Media reported in developing countries* – *Target disorder of IHS programs may need to be shifted from sensorineural hearing loss to long-term conductive hearing loss.*

Table 2.2 and the above discussion highlighted the important challenges to IHS evident in developing countries. Despite these challenges, screening for infant hearing loss remains a priority in developing countries, if the benefits of EHDI programs are to be made universally available to infants with hearing loss.

2.4 A CASE FOR INFANT HEARING SCREENING IN DEVELOPING COUNTRIES

Infant hearing loss is not a life-threatening condition, and the significance of childhood hearing loss is thus often overlooked (Swanepoel, Delport & Swart, 2006:4; Olusanya, 2006:1089). Despite the fact that infant hearing loss is not a life-threatening condition, failure to intervene in time for infants with hearing loss is a severe threat to quality of life indicators, such as language, social, and cognitive development, also places these individuals at an economic

disadvantage in terms of limited job opportunities (Swanepoel, Delport & Swart, 2006:4; Kennedy, 1999:73; Parving, 1999:69). The WHO's definition of health is not merely the absence of disease, but the complete physical, mental and social wellbeing of an individual. According to the WHO definition, true health for infants with hearing loss can therefore only be achieved through early identification and intervention of infant hearing loss (Swanepoel, Delport & Swart, 2006:5). Investing in children's health during early childhood development initiatives, such as EHDI programs, is central to more equal opportunities across developed and developing countries, and can result in great economic returns later in the child's life (World Bank, 2006:11).

As discussed previously, financial constraints in developing countries limit the implementation of IHS programs in these countries. Unfortunately, WHO and the World Bank measure burden of disease and subsequent allocation of funds in terms of mortality, rather than the consequences of disease on individuals and society at large (Olusanya, 2006:5). Millennium Development Goals (MDGs) currently constitute the United Nation's main agenda for mobilizing resources to the developing world between 2000 and 2015 (UNICEF, 2006:2). These include eradicating extreme poverty and hunger in developing countries, as well as providing universal primary education, amongst others (UNICEF, 2006:2; Olusanya, 2006:1089). Olusanya (2006:1) points out that neither of these two MDGs are however, achievable, if disabilities are not appropriately addressed. It is not possible to eradicate extreme poverty and hunger without a program to rehabilitate individuals with disabilities. Similarly, universal primary education cannot be achieved without a program to address communication disorders in early childhood (Olusanya, 2006:1089). In order to achieve the above discussed MDGs it is therefore essential to initiate widespread implementation of IHS programs in developing countries, in order to ensure that the benefits of early identification of and intervention for hearing loss are universally received by all infants.

In order to begin to implement IHS programs in developing countries, alternative means of funding need to be investigated, as governments are not always able to bear the financial burden of diverse healthcare needs within their limited budget (Olusanya, 2006:8). This has lead to a growing trend towards public-private partnerships for healthcare delivery in developing countries. Such partnerships include non-governmental organizations (NGOs), whose effectiveness in service delivery has been demonstrated in various developing countries such as Nigeria, South Africa, Brazil and Poland (Olusanya, 2006:9). It is essential to extend public-private partnerships for IHS in developing countries, in order to decrease the health inequalities between rich and poor nations of the world, whereby infants in developed countries are being afforded access to EHDI programs and infants in developing countries are not (Olusanya, 2006:9).

Screening high-risk or NICU infants for hearing loss may be a viable starting point for IHS in developing countries, given the limited financial and skilled human resources of these countries. Targeted high-risk IHS provides a high yield of infants identified with hearing loss by screening a relatively small percentage of the general newborn population (Swanepoel, Delport & Swart, 2004:634). This should however, merely be an intermediate step towards UNHS in developing countries, and not a long-term alternative. Infants with the best prognosis for EHDI programs are often those in the well-baby nursery, as they do not display concomitant risk factors for developmental delays. Nevertheless, TNHS of high-risk NICU infants provides a viable starting point for developing countries where widespread IHS has previously been absent.

2.5 UNIQUE CHARACTERISTICS OF AND RISK FACTORS FOR HEARING LOSS IN NICU INFANTS

Targeted IHS for high-risk NICU infants, as a starting point to widespread IHS in developing countries was suggested, as it is a more cost-effective starting point

to IHS than UNHS. In keeping with the three platforms recommended for IHS in South Africa by the South African HSPS (HPCSA, 2002:5), and in light of the above argument, the viability of IHS in the NICU population will be investigated and discussed.

NICU infants are a subset of the general newborn population. They display a characteristically high incidence of risk factors for hearing loss, and can therefore be classified as a subgroup of infants at highest risk for hearing loss. These infants require specialized medical care, resultant of premature birth, congenital infections, or complications during the birth process, amongst others. Over the past 25 years the number of NICU infants surviving at the limits of viability has steadily increased (Roizen, 1999:50; Yoshikawa, Ikeda, Kudo, et al., 2004:362). Advances in medical care, including the use of surfactant cells, high frequency ventilation, and a decreased morbidity associated with congenital rubella, have lead to the increased survival rate of NICU infants (Yoshikawa et al., 2004:362). These infants are therefore exposed to the possible effects that the above combined factors may have on their auditory system. In addition to the above, infants in the NICU often have complex neurologic and other health problems, not associated with, but compounded by hearing loss (Roizen, 1999:50).

In light of NICU infants' increased risk for hearing loss, it is not surprising that these infants have been reported to have a ten to 20 times higher risk for sensorineural hearing loss than the general newborn population, given their reasons for hospitalization and the treatments which they receive (Yoon et al., 2003:355; Yoshinaga-Itano, 2004:462). A study by Meyer, Witte, Hildmann et al. (1999:900) reports the prevalence of neonatal hearing disorders in the NICU population to be even ten to 50 times greater than that of the general newborn population. The risk factors prevalent in this population for congenital and neonatal hearing loss include: low birth weight, hyperbilirubenemia, in utero or perinatal infections, craniofacial anomalies, and exposure to ototoxic medications (Yoon et al., 2003:354). There is even some evidence of studies pointing towards

the increased susceptibility to ototoxic medication in preterm infants (Yoon et al., 2003:354). The above described risk factors are all included in the list of risk factors provided by the JCIH (2000:19-20), providing further evidence for the greatly increased risk of hearing loss in the NICU population.

The NICU population also displays risk indicators for late-onset or progressive hearing loss. This view is supported by Yoon et al. (2003:356) who report late-onset sensorineural hearing loss to be present in 20-50% of infants with previous persistent pulmonary hypertension. Yoon et al. (2003:354) describes the risk for late-onset hearing loss in NICU graduates to be resultant of cytomegalovirus, severe respiratory failure, and high frequency ventilation.

A multi-center trial conducted by Robertson et al. (2002:353) on 122 neonates in Canada aimed to determine the prevalence of sensorineural hearing loss at four years of age in survivors of severe neonatal respiratory failure, as well as to document the occurrence of late-onset or progressive sensorineural hearing loss. Results of this study revealed that 42% of survivors of severe respiratory failure had a sensorineural hearing loss by four years of age, double the number at two years of age (Robertson et al., 2002:355). Multifactorial causes for this delayed onset or progressive hearing loss in children following severe respiratory failure are suggested. These include: high frequency ventilation, diuretics, general intensive care, and ototoxic drugs. However, the exact etiology of progressive or late onset sensorineural hearing loss remains largely unknown (Robertson et al., 2002:355). These results agree with those documented by Yoon et al. (2003:354), but place more emphasis on severe neonatal respiratory failure being the leading cause of late onset hearing loss, although the exact etiology of this hearing loss requires further research (Robertson, 2002:355).

The important point that is highlighted by the studies of Robertson et al. (2002:356) and Yoon et al. (2003:356) is the fact that continued ongoing audiologic monitoring of infants with severe respiratory failure and persistent

pulmonary hypertension in particular is needed. As the above described risk factors for late-onset or progressive hearing loss are primarily evident in the NICU population, providing ongoing audiologic monitoring of this high-risk population will serve to ensure that cases of late-onset or progressive hearing loss do not go undetected.

In addition to having an increased risk for both congenital and late-onset hearing loss, NICU infants also have an increased risk for auditory neuropathy. Auditory neuropathy is characterized by normal outer hair cell function with dys-synchronous neural responses (Hood, Berlin, Morlet et al., 2002:201). A child with auditory neuropathy will therefore have normal OAE results, but abnormal ABR results (Sininger, 2002:198). Although the prevalence of auditory neuropathy is still largely unknown, owing to a scarcity of large scale studies with adequate sampling and test protocols, studies have estimated the prevalence to be approximately 2.3 per 1000 infants with risk factors for auditory neuropathy (Sininger, 2002:195-196).

Risk factors for auditory neuropathy include high-risk neonatal histories, hyperbilirubenemia at levels requiring exchange transfusion, and a family history of auditory neuropathy. Additional risk factors that have been reported in children with auditory neuropathy include prematurity, low birth weight, exposure to aminoglycosides or ototoxic medication, hypoxia, metabolic and mitochondrial disorders (D'Agostino & Austin, 2004:347; Berg, Spitzer, Towers et al., 2005:933; Sininger, 2002:195). The majority of these risk factors for auditory neuropathy are present in the NICU population, justifying the increased risk thereof for these infants.

The JCIH Year 2000 Position Statement specifically excludes auditory neuropathy as a target disorder for IHS programs, and calls for further research regarding the exact nature and prevalence of the disorder (JCIH, 2000:6; Sininger, 2002:197). The majority of IHS programs are using either OAE or

AABR screening protocols. A poll on IHS programs in the USA found that approximately 70% of hospitals are using IHS protocols in which an OAE pass result is sufficient to rule out hearing loss (Sininger, 2002:197). Such protocols are however, not adequate to identify infants with auditory neuropathy, as the diagnosis of auditory neuropathy necessitates a combined OAE and AABR protocol (Sininger, 2002:198). Given the high prevalence rate of auditory neuropathy, especially among the high-risk NICU population, it is important for screening programs to include auditory neuropathy as a target disorder. It is therefore essential that IHS programs for NICU infants make use of a combined OAE and AABR screening protocol, in order to ensure that those infants with auditory neuropathy are identified early and provided with EHDI services.

The above discussion highlights some of the pertinent characteristics placing the NICU population at an increased risk for congenital and late-onset hearing loss, as well as auditory neuropathy. Increased risk factors for hearing loss in the NICU population justify the great need for IHS in NICU infants, if they are to receive the full benefits of EHDI programs.

2.6 TARGETED INFANT HEARING SCREENING FOR NICU INFANTS IN DEVELOPING COUNTRIES

Recent advances in IHS in the developed world have lead to IHS becoming part of standard medical care in developed countries, such as the USA, UK, and most European countries (Davis & Hind, 2003:S194; Olusanya et al., 2006:2). These parts of the world have subsequently initiated widespread UNHS, with the result that almost all infants in developed countries have access to some form of IHS (Northern & Downs, 2002:268; Olusanya, McPherson, Swanepoel et al., 2006:294). Nevertheless, the discussion that follows will focus on TNHS in high-risk NICU infants, as this is the focus of the current study. Various authors report results of IHS programs in NICU infants in developed countries. Findings

reported from IHS programs in high-risk NICU infants in developed countries will be discussed, followed by a critical review of the few reports documenting IHS for high-risk NICU infants in developing countries.

2.6.1 Risk indicators for hearing loss in NICU infants

Meyer et al. (1999:901) investigated incidence, risk factors and follow-up rates of hearing disorders in at risk infants. The objective of the study was to obtain data on the actual incidence of and risk factors for hearing loss, in light of improved medical outcomes for high-risk neonates. 777 high-risk infants from five pediatric hospitals in Germany were followed over a two year period (Meyer et al., 1999:901). Results of the study revealed that 18 out of 770 infants were found to have permanent hearing loss, of which 13 had a sensorineural hearing loss, and 5 infants had a mixed hearing loss. These findings are consistent with current literature, which reports that the incidence of permanent congenital hearing loss in the NICU population is ten to 20 times higher than in the general newborn population (Meyer et al., 1999:903; Yoshinaga-Itano, 2004:462). This correlation in incidence of hearing loss in the NICU population between the current study and literature reports may be expected and is not surprising, as this study too was conducted in a developed country. Infants in developed countries are not exposed to additional environmental factors present in many developing countries, which may increase their risk of hearing loss.

It may even be argued that risk factors for hearing loss in developed countries are actually being decreased as advances in medical care take place. This conclusion is drawn from the following results: Meyer et al. (1999:902) reported birth weight less than 1500 g and oxygen dependency not to be directly associated with abnormal AABR results, and therefore not to be directly related to hearing loss (Meyer et al., 1999:902). It may be speculated that advances in medical care in a country such as Germany, has lead to low birth weight and oxygen dependency no longer being a direct causative factor of hearing loss.

Infants found to have permanent congenital hearing loss in this study did however, display the following risk factors: craniofacial anomalies; a family history of congenital hearing loss; sepsis and/or meningitis; very low birth weight in conjunction with mechanical ventilation for more than five days; congenital rubella; postnatal asphyxia; and Down's syndrome (Meyer et al., 1999:902). The above discussed risk factors are all contained in the list of risk indicators for hearing loss as documented by the JCIH (2000:19-20).

In accordance with the findings of Meyer et al. (1999:902), results of a study by Hess, Finckh-Kraemer, Bartsch et al. (1998:81) also revealed that birth weight between 1000 g and 1500 g was not a predictive factor of hearing loss. Hess et al. (1998:81) furthermore reported that gestational age between 29 weeks and 31 weeks was also no predictive factor of hearing loss. The authors of this study reason that improved NICU medical care may reduce the probability of hearing loss resulting from low birth weight and a low gestational age (Hess et al., 1998:81), and are therefore in agreement with Meyer et al. (1999:902).

Yoshikawa et al. (2004:362) investigated the effects of documented risk factors for hearing loss on actual neonatal hearing loss. The authors conducted hearing screening on 102 NICU infants and 124 infants from the well-baby nursery at Tohoku University in Japan. Findings of this study substantiate the results of the study by Meyer et al. (1999:902) who report low birth weight and oxygen dependency not to be directly related to hearing loss. This study found no statistical differences between NICU infants who passed and referred AABR screening with regards to: birth weight less than 2200 g; gestational age; APGAR scores; ototoxic drug exposure; respiratory distress syndrome; muconium aspiration syndrome; and persistent pulmonary hypertension (Yoshikawa et al., 2004:365-366).

Additional risk factors for hearing loss identified in the study by Yoshikawa et al. (2004:364), not documented by the JCIH (2000), were found to be hypoxia and

asphyxia. These were said to play a definitive role in cochlear damage in this study. Such results highlight the need to continue to investigate additional risk factors for hearing loss. In doing so, TNHS would become more effective, as an increased number of infants with risk factors would be screened, and a greater percentage of the total population of infants with hearing loss would subsequently be identified. This is particularly relevant for developing countries, where an increased yield to TNHS enables more infants to have access to the benefits of early identification of hearing loss, which would have not otherwise been the case.

2.6.2 The incidence of childhood hearing loss in NICU infants

Van Straaten, Hille, Kok et al. (2003:333) documented results of a large scale NICU hearing screening program in the Netherlands. Seven NICUs across the country participated in the study, with a total of 2488 infants. The incidence of unilateral permanent congenital hearing loss was found to be 15 out of 2484 (0,6%) infants, with 48 out of 2484 (1,9%) of infants having bilateral hearing loss. Of the infants found to have permanent congenital hearing loss, two had auditory neuropathy, whilst the rest had sensorineural hearing loss (Van Straaten et al., 2003:334-335). Incidence rates of permanent congenital hearing loss in the NICU population, as described in this study are in accordance with the reported incidence rates among NICU infants (Yoshinaga-Itano, 2004:462; Yoon et al., 2003:355).

Yoon et al. (2003:355) conducted a study on 82 NICU graduates in the USA. This study aimed to justify the need for long-term audiologic follow-up of NICU graduates. Bilateral sensorineural hearing loss was found in 2% of infants participating in the study. This incidence, along with the incidence reported in the above discussed studies, is in accordance with current reported incidence rates of permanent congenital hearing loss in the NICU population (Yoshinaga-Itano, 2004:462). Furthermore, Yoon et al. (2003:355) report a high percentage of abnormal tympanometry in this group of NICU graduates. 29% of infants had

bilateral abnormal tympanometry results, whilst 8% were reported to have unilateral abnormal tympanometry results. These results point towards an increased incidence of conductive hearing loss in NICU infants (Yoon et al., 2003:355-356).

From the above results it therefore becomes clear that not only do NICU infants display an increased incidence of risk factors for permanent sensorineural and late-onset hearing loss, but they also display an increased incidence of conductive pathology. The need for routine audiologic follow-up of all NICU infants is therefore evident, and a single stage screening protocol as used in UNHS in many developed countries may not be adequate for the NICU population (Yoon et al., 2003:356). If NICU infants in developed countries display an increased incidence of conductive pathology, it only leaves to reason that the expected incidence of conductive pathology in NICU infants in developing countries will be even higher, resultant of environmental risk factors that these infants are exposed to (Swanepoel, Hugo & Louw, 2005c:76). Further research investigating this concept is vital, if the full benefits of early identification of all types of hearing loss are to reach infants in developing countries.

The above discussion highlights several important facts. The incidence of permanent congenital hearing loss, as reported in the above discussed studies, is in accordance with reported incidence rates in the current body of available literature (Meyer et al., 1999:903; Yoon et al., 2003:355; Yoshinaga-Itano, 2004:462). These findings are to be expected, as incidence rates described in the current literature are largely from results of studies conducted in developed countries. Furthermore, the above discussed studies highlight the fact that advances in medical care of NICU infants have resulted in risk factors such as low birth weight, no longer always being independent, direct causative factors of hearing loss in this high-risk population (Meyer et al., 1999:902). Lastly, an increased incidence of conductive pathology in NICU graduates has been reported. This invariably necessitates long-term audiologic follow-up of all NICU

infants, if the full benefits of early identification of and intervention for hearing loss are to be available to the entire infant population (Yoon et al., 2003:355-356).

2.6.3 Follow-up rates of infants enrolled in IHS programs

In the study conducted by Van Straaten et al. (2003:334-335) of a large scale NICU hearing screening program in the Netherlands, 23 infants (1%) were lost to follow-up during the study period, indicating a 99% follow-up rate. This IHS program, when described in terms of follow-up, can therefore be said to be highly efficient. The standards set by the JCIH (2000:10) require that at an IHS program should achieve a follow-up rate of at least 70%, whilst this one has a 99% follow-up rate.

Hess et al. (1998:81) investigated prevalence of hearing loss in an at-risk NICU population in Germany. 942 high-risk NICU infants were screened using AABR and TEOAE testing over a seven year period. During this study, 1,9% of participating infants were lost to follow-up (Hess et al., 1998:81). This is a slightly higher rate of infants lost to follow-up when compared with the study conducted by Van Straaten et al. (2003:334). However, the standards set by the JCIH (2000:10) require that at an IHS program should achieve a follow-up rate of at least 70%. These standards were met by both the above discussed studies (Hess et al., 1998:81; Van Straaten et al., 2003:334).

Another study conducted by Prince et al. (2003:1202) in Hawaii investigated the epidemiological profile of infants who did not return for follow-up hearing screening. Results of the study brought several interesting facts to light. There were no significant differences in age or marital status between mothers of infants who returned for follow-up screening and those who did not. Young single mothers have the highest risk for adverse parenting outcomes, and follow-up for IHS is heavily reliant on caregiver involvement (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:78-79). However, what this study did reveal

was that maternal education levels, rather than maternal age, were directly related to follow-up for IHS. Significantly lower follow-up rates were noted for infants of mothers with lower educational levels, such as a lack of high-school education (Prince et al., 2003:1204).

Furthermore, the study by Prince et al. (2003:1203-1204) revealed that infants weighing less than 2500 g were less likely to return for follow-up than infants weighing more than 2500 g, despite the possible increased risk for hearing loss in the low birth weight group (Yoshikawa et al., 2004:366). The poorer follow-up rates of infants weighing less than 2500 g may possibly be ascribed to the fact that these infants were medically more fragile and were unable to complete the screening process (Prince et al., 2003:1205). It could also be reasoned that parents of low birth weight infants have greater medical concerns regarding their infants, and hearing screening does not rank as highly as their other concerns. Further research would be necessary to investigate this concept. If found to be true, the great need for raising parental awareness on the importance of early identification of and intervention for hearing loss would urgently need to be addressed.

2.6.4 Justifying targeted infant hearing screening in developing countries

Although TNHS is largely being replaced by UNHS in developed countries, the JCIH (2000:18-19) still recommends TNHS for developing countries where a lack of human and financial resources limit the development of UNHS. TNHS is a more cost-effective and time-efficient means of IHS, as only approximately 10% of infants display risk factors for hearing loss (Swanepoel, Delport & Swart, 2004:635). UNHS has the potential for long-term cost saving when compared to TNHS, as a 50% increased yield in identifying infants with hearing loss permits an increased number of infants to receive the benefits of early identification of hearing loss. Nevertheless, the current financial status of developing countries needs to be taken into account. TNHS may therefore be more viable financially in these countries, even if it is only an interim step to eventual UNHS (Keren et al.,

2002:862; Swanepoel, Delport & Swart, 2004:634; Olusanya, Luxon & Wirz, 2004:299). Targeting NICU infants is ideal, as all infants belong to the high risk register (Van Straaten, 1999:78). Despite the above facts, there are very few reported studies documenting TNHS for high-risk NICU infants in developing countries. IHS programs in developing countries are still uncommon (Olusanya & Roberts, 2006:1). A discussion of available results from studies reporting TNHS in NICU infants in the developing world is presented in the following section.

Despite a lack of widespread implementation of IHS programs in developing countries, the benefits and challenges of EHDI programs in these countries have been identified. Pilot programs are therefore currently being implemented in various developing countries, such as Brazil, Mexico, South Africa, India and the Middle East (Olusanya, McPherson, Swanepoel et al., 2006:294). Pilot programs in Nigeria, South Africa, Malaysia, Brazil & Poland have furthermore demonstrated the effectiveness of public-private partnerships in service delivery for infants with hearing loss, in order to compensate for the financial limitations of these developing countries (Olusanya, 2006: 9).

A study conducted by Olusanya, Luxon & Wirz (2005:116) reported that parental suspicion prompted by a child's inappropriate response to sound is currently still the primary mode of detection of childhood hearing loss in Nigeria. This passive detection takes place at a mean age of 22 months, falling far short of the target of early identification before the age of six months (Olusanya, Luxon & Wirz, 2005:116). Enrollment in schools for the deaf is currently therefore the only means of intervention for young children identified with hearing loss (Olusanya, Luxon & Wirz, 2005:117).

Madriz (2001:88) investigated audiological services in Latin America regarding resources available and services delivered. This survey found that Latin America has very few early identification programs for children with hearing loss (Madriz, 2001:88). Panama and Cuba were found to be the only two Latin American

countries that provide some form of IHS for high-risk infants. Panama is reported to use the 'Burian test', which tests two intensities (40 dB and 70 dB). Initial assessment and follow-up of high-risk infants using the Burian test is ensured in Panama (Madriz, 2001:88). Cuba has developed an electrophysiological instrument that tests four frequencies in both ears simultaneously. Their healthcare system too, ensures that all high-risk infants undergo such hearing screening (Madriz, 2001:88). The above described methods for IHS, as used in Panama and Cuba, do not meet the standards set out by the JCIH (2000:9), which advocate that OAE and AABR electrophysiological procedures are the only acceptable tests for IHS.

The above discussion highlights the fact that IHS reports in developing countries remain scarce. However, failure to identify hearing loss early remains a severe threat to hearing impaired infants' quality of life. It therefore becomes a moral and ethical obligation to initiate pilot programs at various sites in developing countries, in order to identify suitable approaches to IHS at different levels of healthcare delivery in these countries, and to ensure that the benefits of EHDI programs reach infants of all socio-economic status (Olusanya, Luxon & Wirz, 2005:117; Swanepoel, 2006:3). The WHO acknowledges that screening interventions aimed at developed countries should also be made available to developing countries where these conditions have emerged as important health problems (Olusanya, 2006:9). Infant hearing loss is even more prevalent in developing countries than developed countries. Pilot IHS programs are therefore necessary at various sites in developing countries, in order to provide evidence towards the above argument, and in turn gain the necessary research funding and political advocacy for widespread IHS in developing countries (Swanepoel, Delport & Swart, 2004:634-635).

2.7 IMPLEMENTATION OF INFANT HEARING SCREENING IN SOUTH AFRICA

In response to a global growing awareness of the importance of early identification of and intervention for hearing loss, the Health Professions Council of South Africa (HPCSA) conceptualized a Hearing Screening Position Statement (HSPS) in 2002. The HSPS accepts the JCIH Year 2000 Position Statement as its definitive document, and proposes TNHS as an intermediate step to UNHS in South Africa. The target set by the HSPS aims to grant access to hearing screening to 98% of infants born in South Africa by the year 2010 (HPCSA, 2002:1-2). The HSPS recommends three platforms for hearing screening in South Africa, namely: immunization clinics; at discharge from the NICU; and in the well baby nursery (HPCSA, 2002:5).

South Africa is a culturally and linguistically diverse country located on the tip of the African continent. It forms part of Southern Africa, which together with Eastern Africa, Middle Africa and Western Africa, form sub-Saharan Africa (McPherson & Swart, 1997:2). Although two-thirds of the world's least developed nations are in sub-Saharan Africa, South Africa has a relatively well developed healthcare system. South Africa has an interesting structure when compared to that of other developing countries, as it is made up of pockets of both developed and developing contexts. Despite a relatively well developed healthcare system and pockets of developed and developing contexts, South Africa is classified collectively as a developing nation (Swanepoel, Hugo & Louw, 2006:1242; McPherson & Swart, 1997:2).

2.7.1 The current state of IHS in South Africa

Despite a growing global awareness on the importance of early identification of infant hearing loss, IHS programs are far from widespread in South Africa, and are not meeting the needs of the South African population. Very little contextual research on IHS is reported to date (Swanepoel, Hugo & Louw, 2006:1242). If the full benefits of EHDI programs are, however, to be made available to the South African population at large, it is imperative that the recommendations

made by the HSPS be assessed critically within the South African context and the existing South African infrastructure (Swanepoel, Hugo & Louw, 2006:1242). Literature currently reports no prevalence studies on infant hearing loss in South Africa. Isolated IHS programs are in place, but these are not systematic and widespread. The few studies that have been conducted are limited to small samples, and are therefore not representative of the South African population at large. Such contextual research is vitally important, in order to gain the necessary legislative support needed to initiate large-scale IHS programs in South Africa (Swanepoel, 2006:265). Widespread TNHS can furthermore only be implemented in South Africa, following reports documenting risk factors for hearing loss, specific to South African communities (Swanepoel, Hugo & Louw 2005c:76).

In response to the dearth of research on IHS programs in South Africa, and in accordance with the platforms recommended for hearing screening by the HSPS, Swanepoel, Hugo & Louw (2005b:18) conducted an IHS program at two immunization clinics in Hammanskraal. These immunization clinics formed part of maternal child health (MCH) clinics. Results of this study revealed various interesting outcomes. MCH clinics proved to be a suitable context for IHS programs, despite the contextual barriers, characteristic of primary healthcare clinics in South Africa. The importance of IHS at such clinics was further emphasized by the significant degrees of socio-economic depravity displayed by mothers and their infants. Socio-economic depravity has been associated with an increased risk for congenital hearing loss, thereby placing South African infants from developing contexts, such as Hammanskraal, at an increased risk for hearing loss (Swanepoel, Hugo & Louw 2005c:79; Swanepoel, Hugo & Louw 2005b:18).

Based on this study conducted in Hammanskraal, the recommendation for the implementation of large-scale longitudinal studies at various pilot sites in South Africa was made. Such pilot studies should make use of existing South African

infrastructure, in order to gather the necessary data on incidence figures and risk factors for hearing loss (Swanepoel, Hugo & Louw 2005b:18). In order to address the scarcity of research regarding prevalence figures and population specific risk factors for hearing loss, it is essential that the viability and effectiveness of IHS at the other two platforms recommended by the HSPS be investigated.

2.7.2 A case for risk based IHS in the South African NICU population

The NICU population, with an increased incidence of risk factors for hearing loss, is one of the platforms recommended by the HSPS for the implementation of IHS (HPCSA, 2002:5). Based on the discussion of the importance of IHS in the NICU population, and their increased risk for hearing loss, it is essential to therefore investigate the viability of IHS programs in the South African NICU population. Applying TNHS to high-risk NICU infants will provide a large yield of infants identified with hearing loss when compared to the number of infants that are being screened. Approximately 10% of the newborn population displays risk factors for hearing loss. However, screening this 10% of infants serves to identify approximately 50% of all infants born with hearing loss. (Swanepoel, Delport & Swart, 2004:634).

TNHS in NICU infants may therefore be a viable option for implementing IHS programs in South Africa, given the country's limited financial and human resources, and the fact that Audiology is a culturally and linguistically underrepresented profession (Swanepoel, 2006:265). NICU infants in South Africa are exposed to both increased risk factors for hearing loss resultant of their medical condition and treatment, as well as additional environmental risk factors for hearing loss evident in South Africa.

2.7.3 Environmental risk indicators for hearing loss in South Africa

South African infants are exposed to a variety of environmental risk factors for hearing loss and for the success of EHDI programs, not always evident in other

countries. There are a high percentage of single mothers in South Africa. Previous reports indicate that 42% of children under the age of seven years live with only one parent (Swanepoel, Hugo & Louw, 2005c:78). A study conducted by Swanepoel, Hugo & Louw (2005c:78) in a community in Hammanskraal, found the percentage of young children living with only a single parent to be almost double that. This may be attributed to a large number of children being born outside formal partnerships, as well as a number of African men establishing dual households (Swanepoel, Hugo & Louw, 2005c:79). The high number of single mothers in South Africa has a significant impact on the implementation and development of IHS programs, as these are heavily reliant on parental or caregiver involvement. Furthermore, single mothers face economic strain, with the result that infants are exposed to an increased risk for developmental delays or disabilities, such as hearing loss (Swanepoel, Hugo & Louw, 2005c:79).

The high percentage of single mothers in South Africa is of particular relevance in the NICU population. Mothers of NICU infants not only bear the financial burden of being a single parent, but they also have to deal with the complex medical conditions and associated treatments of their infants alone. Economic and emotional strains on single mothers of NICU infants need to be taken into consideration when implementing IHS programs for high-risk NICU infants, as these may have negative effects on program compliance and the follow-up IHS process. Subsequently, raising parental awareness of the importance of early identification and intervention for hearing loss, and ensuring active caregiver involvement in IHS programs is reasoned to be an integral part of future IHS programs for NICU infants in South Africa.

The need for raising caregiver awareness regarding the importance of IHS is further substantiated by the high incidence of teenage pregnancies in South Africa. 41% of the South African teenage population is said to be sexually active (Swanepoel, Hugo & Louw, 2005c:79). The youngest mothers are at the highest

risk for adverse parenting outcomes. Young mothers furthermore are at an increased risk for having low birth weight infants, implying that a large percentage of teenage mothers in South Africa will parent NICU infants (Swanepoel, Hugo & Louw, 2005c:79; Yoon et al., 2003:354). Further contextual research in South Africa is therefore necessary to determine levels of maternal awareness of the importance of IHS. Ensuring maternal awareness of the importance of IHS, as well as ensuring active maternal involvement in the screening process, is an integral part to successfully implementing IHS programs in the NICU population in South Africa.

Furthermore, parents in developing sections of South Africa display poor educational levels. Although there has been a steady increase in educational levels among the African population over the last decade, there is still a large percentage of the population that does not have a Grade 12 education (Swanepoel, Hugo & Louw, 2005c:79). Parents who did not complete high school are less likely to complete the hearing screening follow-up process than those who are more educated (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:79). Poor follow-up rates of infants and their caregivers enrolled in IHS programs have particularly adverse effects on the high-risk NICU population. As the NICU population is at a greatly increased risk, not only for congenital hearing loss (Yoshikawa et al., 2004:361-362), but also for late onset or progressive hearing loss (Robertson et al., 2002:355), poor follow-up rates will have dire consequences on the quest for ensuring that the benefits of early identification and intervention of hearing loss are available to this high-risk population.

Environmental risk factors evident in the South African infant population serve to emphasize the great need for EHDI programs in the high-risk NICU population in South Africa. Infants born in a developing South African context are furthermore exposed to the overwhelming burden of infectious diseases. Infectious diseases, such as HIV/AIDS increase an infant's risk for hearing loss. Exposure to HIV/AIDS subjects infants and young children to a variety of risk factors for

hearing loss, including: increased risk for low birth weight; increased vulnerability for acquiring infections, such as Otitis Media, meningitis, or cytomegalovirus (Swanepoel, Hugo & Louw, 2005c:80). The above mentioned risk factors are already prevalent in the NICU population. Coupled with the increased risk factors for hearing loss resultant of HIV/AIDS, it stands to reason that the South African NICU population is at an even higher risk for hearing loss than the NICU population in more developed countries.

South African HIV/AIDS prevalence rates are alarmingly high when compared to that of the rest of the world. By the end of 2002 South Africa had a total of 5.3 million people infected with HIV/AIDS, the highest of any country in the world (Swanepoel, Hugo & Louw 2006:1242; Goldstein, Pretorius & Stuart, 2003:15). These numbers have subsequently risen. According to the National HIV and Syphilis Antenatal Sero-Prevalence Survey conducted in 2005, 30.2% of pregnant women were estimated to be HIV positive in South Africa, with an estimated prevalence rate of 32.4% in childbearing women in the province of Gauteng (Department of Health, 2006:10-11).These are shocking statistics, which provide further justification for the great need to provide high-risk NICU infants with early identification of and intervention for hearing loss in South Africa.

In light of NICU infants' increased risk for hearing loss, as well as the fact that South African infants are exposed to an array of additional environmental risk factors for hearing loss, it is essential that the effectiveness of an IHS program for high-risk NICU infants be researched in South Africa. This should contribute to the current need for relevant contextual research regarding the incidence of hearing loss in NICU infants, follow-up rates of NICU infants enrolled in an IHS program, as well as to determine risk factors for hearing loss, specific to the South African population.

Such research is essential in order to provide a starting point for implementing more widespread IHS programs for South African infants, if the benefits of EHDI

programs are to reach all infants. A lack of contextual research regarding IHS in developing countries, such as South Africa, needs to be addressed urgently, as failure to intervene for infants with hearing loss is a severe threat to their quality of life indicators in terms of language and cognitive development, as well as job opportunities (Swanepoel, Delport & Swart, 2006:4; Kennedy, 1999:73; Parving, 1999:69). Awareness of the benefits of EHDI programs to infants with hearing loss results in a moral obligation to begin narrowing the quality of life disparities between infants in developed countries, who are provided with EHDI services, and those in developing countries, who do not yet have widespread access to EHDI, by beginning to implement pilot IHS programs in developing countries.

2.8 CONCLUSION

The development of objective electrophysiological hearing screening techniques, together with the growing body of literature emphasizing the importance of early identification of and intervention for childhood hearing loss, has lead to the widespread implementation of IHS programs in the developed world over the past 40 years (Northern & Downs, 2002:259; Yoshinaga-Itano, 2004:455). Despite this growth of IHS programs in the developed world, multifaceted challenges are currently preventing the benefits of EHDI programs from being available to infants in developing countries (Swanepoel, Hugo & Louw 2006:1242). A lack of contextually relevant research, increased risk factors, coupled with limited resources and unfavourable cultural beliefs pose some of the challenges to IHS in the developing world (Olusanya, 2001:142; Swanepoel, Hugo & Louw, 2005b:18; Oulsanya, Luxon & Wirz, 2004:288).

Despite these challenges to IHS in developing countries, the need for implementing more widespread IHS programs is becoming increasingly clear. Not implementing IHS for infants in developing countries, such as South Africa, based on challenges to IHS, raises moral and ethical issues in light of the

benefits of EHDI programs on childhood development. Alternative means of financial support for IHS, such as non-governmental organizations, need to be sourced, in order for the benefits of EHDI programs to reach infants all over the world.

The need for implementing IHS programs in South Africa is recognized by the formulation of the HSPS Year 2002, which advocates targeted IHS as a viable starting point to more widespread implementation of IHS in South Africa (HPCSA, 2002:5). South Africa needs to initiate feasible steps towards implementing pilot IHS programs at various sites. Such pilot programs should serve to address the need for contextually limited research on IHS in South Africa, including environmental risk indicators for hearing loss unique to the South African population. Implementing IHS in the high-risk NICU population as a starting point to eventual UNHS in South Africa, where limited EHDI services for infants with hearing loss currently exist, may prove to be a viable starting point.

Few IHS programs in South Africa have been documented to date, with no available reported studies on IHS programs for high-risk NICU infants in South Africa. This chapter therefore served to identify a need for contextually relevant research on IHS in high-risk NICU infants in South Africa. The remaining chapters of this study aim to describe an IHS program for high-risk NICU infants in a secondary hospital in Gauteng, South Africa.

2.9 SUMMARY

This chapter discussed theoretical perspectives on the current state of IHS for high-risk NICU infants. A rationale for IHS was provided, including the importance of early identification of and intervention for childhood hearing loss.

Challenges to IHS specific to the developing world were discussed. It was emphasized that undetected infant hearing loss, resultant of a lack of IHS programs in developing countries, poses a moral dilemma in terms of inequalities of quality of life indicators between infants in developed countries and those in developing countries. Targeted IHS in the high-risk NICU population was put forward as a starting point for IHS in developing countries. This was followed by a discussion of unique characteristics and risk factors for hearing loss in the NICU population, thereby justifying why TNHS in high-risk NICU infants is a viable population in which to initiate IHS programs in countries where none previously existed. A description of various IHS programs for high-risk NICU infants in developed countries was provided, in terms of risk factors for hearing loss, follow-up rates of infants, and the incidence of auditory impairment in these countries. The limited research reports documenting IHS in developing countries followed, highlighting the scarcity of widespread IHS programs in the developing world. Lastly, the implementation of IHS in South Africa was discussed in terms of South Africa's increased incidence of environmental risk factors for hearing loss, as well as what has been done up until now. This provided an argument for the implementation of IHS programs for NICU infants in a developing South African context.

CHAPTER 3

METHODOLOGY

AIM: To provide a detailed description of the research design, the sample, the material and apparatus, and the procedures followed in this study.

3.1 INTRODUCTION

According to Leedy & Ormrod (2005:3) research is "a carefully planned attack, a search-and-discover mission explicitly outlined in advance". A research question cannot be accurately answered without the careful planning of designs and methods that will be appropriate for the particular study. The current study's research design and methods were therefore carefully planned in a purposeful way in order to acquire data relevant to the specific research question (Leedy & Ormrod, 2005:3).

This chapter discusses the research design that was selected for this study. The research design defines material and apparatus used for recording and analyzing the data, in order to answer the research question posed: ***What are the characteristics of an IHS program for infants discharged from a NICU in a state hospital in Gauteng, South Africa?*** The participant sample, as well as ethical aspects pertaining to this study, is also discussed.

3.2 RESEARCH AIMS

The main aim of this study was to describe the characteristics of an infant hearing screening (IHS) program for NICU infants in a secondary hospital over a 29 month period.

The following sub-aims were formulated in order to achieve the main aim:

- To describe risk indicators for hearing loss in the population of infants enrolled in the screening program over the 29 month period.
- To describe aspects of effectiveness and efficiency of the IHS program for the population of infants screened over the 29 month period.
- To determine the incidence of auditory impairment in the population of infants screened over the 29 month period.

3.3 RESEARCH DESIGN

A *developmental descriptive* research design using *quantitative* methods was followed in order to address the aims of this study (Leedy & Ormrod, 2005:179). The study was *retrospective* in nature, as data of an IHS program collected between January 2004 and May 2006 was analyzed. An overall organization of the study was conceptualized in the research design displayed below in Figure 3.1. This was done in order for the researcher to be able to follow appropriate procedures and to be able to collect necessary data for answering the research question (Leedy & Ormrod, 2005:85).

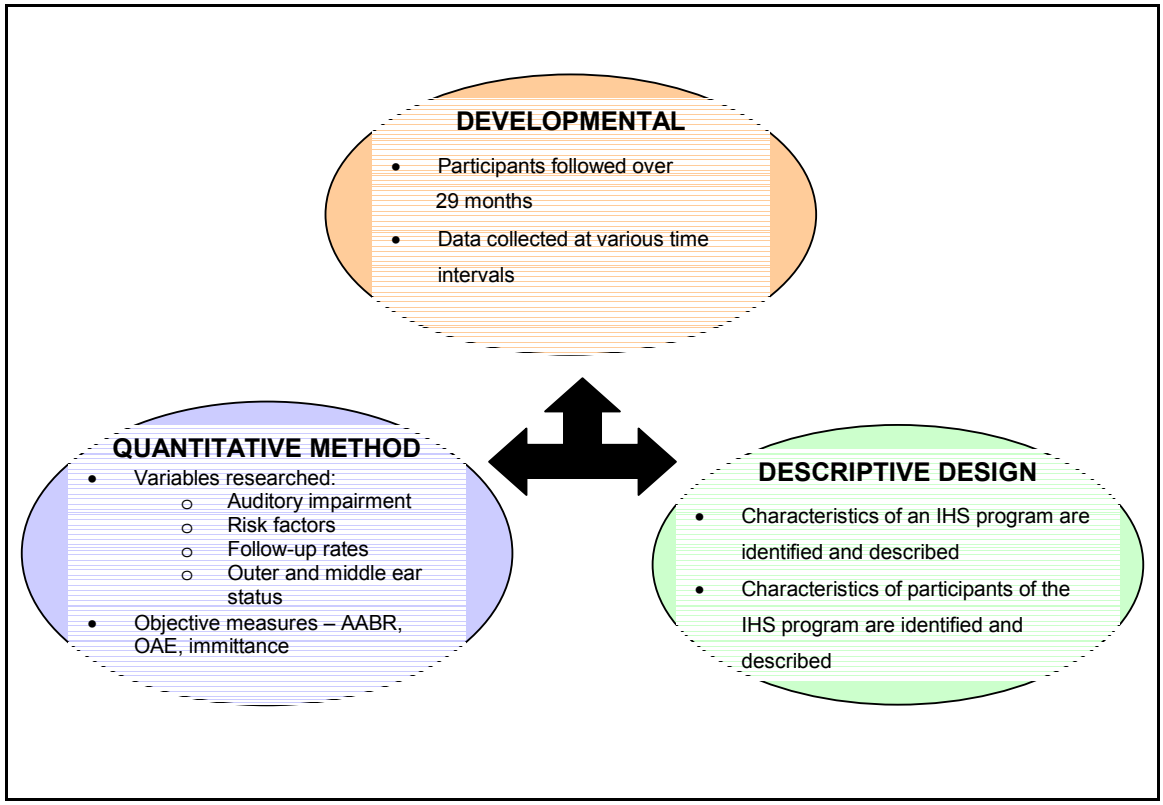

FIGURE 3.1 Graphic representation of the research design

The research design used in this study was both developmental and descriptive in nature, using quantitative methods. The *developmental* component of the research design can be justified in the following manner: In a developmental study, longitudinal data is collected by following participants over a determined period of time. Data related to characteristics under investigation are collected at various time intervals (Leedy & Ormrod, 2005:183). In the current study participants of the IHS program at a secondary hospital were followed over a 29 month period. Hearing screening was conducted on the participants at intervals of three months, in order to obtain data relevant to addressing the sub-aims of this study. One disadvantage of a developmental research design is that participants may be lost to the program over time (Leedy & Ormrod, 2005:183). However, the research question posed by this study necessitated the collection of longitudinal data, in order to be answered effectively. Follow-up rates of

participants of the IHS program was in fact one of the characteristics of the program under investigation, and forms part of one of the sub-aims of the study. Although participants lost to follow-up of routine visits are a disadvantage of this study, this was monitored and documented. However, participants lost to follow-up when they were scheduled for diagnostic hearing testing is a disadvantage to the efficiency of the screening program.

The research design was furthermore *descriptive* in nature, as this study identified characteristics of an observed phenomenon, namely an IHS program at a secondary hospital. The aim of the study was not to modify the IHS program, or to determine cause-and-effect relationships, but merely to *describe* various characteristic of the IHS program in order to determine aspects of the effectiveness of the program (Leedy & Ormrod, 2005:179). Characteristics of the IHS program at a secondary hospital were identified, and subsequently described, in terms of the following: the presence of risk indicators for hearing loss; coverage rates achieved by the IHS program; follow-up rates of participants enrolled in the IHS program; and the incidence of auditory pathologies in participants. By describing the above mentioned characteristics of the IHS program, the researcher was able to obtain valid and reliable data relevant to answering the research question of the study.

The research design utilized *quantitative methods* in order to collect valid data, necessary for answering the research question posed. During quantitative research, methods utilized allowed the researcher to objectively measure variables of interest. One or more variables that the researcher seeked to study were identified and data were subsequently collected relating specifically to the identified variables (Leedy & Ormrod, 2005:95). Variables under investigation in the current study included the following: the presence of risk indicators for hearing loss; coverage rates achieved by the IHS program; follow-up rates of participants enrolled in the IHS program; and the incidence of auditory pathologies in participants. By investigating these variables, the researcher was

able to describe the characteristics of the IHS program at a secondary hospital. Data were collected relating specifically to these identified variables, using objective measures. Objective measures included the identification of predetermined risk factors for hearing loss; the recording of coverage rates and follow-up rates of participants; and the use of objective auditory evaluations. Furthermore, objective methods of research seek explanations and predictions that can be generalized to other persons and places (Leedy & Ormrod, 2005:95). The justification for conducting this study was to determine the characteristics of the IHS program at a secondary hospital, so that broader guidelines could be drawn to other IHS programs, in order to improve service delivery of infant hearing screening programs in South Africa in general.

3.4 ETHICAL CONSIDERATIONS

"A researcher's personal moral code is the strongest defense against unethical behaviour" (Neuman, 1997:443). The researcher strived to uphold high ethical standards in all aspects of this research project, as it is of utmost importance that participants' rights be respected at all times during research (Leedy & Ormrod, 2005:101). Various ethical principles were adhered to during this study. These are discussed below.

3.4.1 Respect for Persons

Informed consent

Informed consent was obtained from each caregiver on behalf of their infant, before entering the infant into the IHS program at a secondary hospital (Appendix D). Caregivers of research participants were provided with letters of informed consent. These were explained to them by a research assistant of the IHS program in their mother tongue, in order to ensure caregivers' full understanding of letters of informed consent. The research assistant is competent in English,

Afrikaans, and a variety of African languages. Caregivers of research participants were informed of the following: the purpose of the IHS research project; a description of procedures carried out in the IHS program; the fact that there are no risks or discomfort associated with participating in the IHS program; benefits of participation are explained in terms of early identification of hearing loss and subsequent early intervention. Furthermore, letters of informed consent assured caregivers that participation in the study is strictly voluntary and that they may withdraw their infant from the IHS program at any time, and that confidentiality would be maintained at all times (Leedy & Ormrod, 2005:101; Neuman, 1997:450). Assent could not be obtained from participants themselves, as their ages ranged between zero and 18 months.

Withdrawal of participants

As participants of the IHS program at a secondary hospital were between the ages of zero and 18 months, it could not be explained to them that they may withdraw from the study at any time. However, if infants became restless and cried excessively upon carrying out hearing screening procedures, the test personnel did not insist on continuing with the test. It was made clear to all caregivers of participants that they may withdraw their infant from the study at any given time (Leedy & Ormrod, 2005:102).

Confidentiality

Upon explaining letters of informed consent to caregivers of participants, they were assured that confidentiality would be maintained at all times (Leedy & Ormrod, 2005:102). This was made possible by holding participants' information in confidence (Neuman, 1997:453).

Inducement of participation

Participants and their caregivers were induced for participating in the IHS program by providing them with hearing screening free of charge, as well as with a diagnostic audiological evaluation for infants who failed the hearing screening.

Inducement of participation was however, in no way undue, and caregivers were therefore not convinced to provide consent for their infants to participate in the study against their better judgement (Neuman, 1997:451).

3.4.2 Beneficence and Non-malfeasance

Good research design

This study utilized a developmental descriptive research design, and was retrospective in nature (Leedy & Ormrod, 2005:179-183). Participants in an IHS program at a secondary hospital underwent routine audiological screening at various time intervals. The researcher described auditory and other characteristics documented in participants' IHS records. Participants were not required to participate in any experiments, and no ethical issues surrounding the research design of this study therefore arose.

Favorable risk-benefit balance

This study is said to have had a favourable risk-benefit balance for participants. There were no physical, psychological, social, or any other risks involved in participating in the IHS program at a secondary hospital (Leedy & Ormrod, 2005:101). Furthermore, there were no aspects of the research project about which the caregivers were not informed, and thus there was no deception of participants. Benefits of participating in the study included the following: Participants were provided with hearing screening free of charge. This allowed for early identification of hearing loss. Infants who failed the hearing screening were provided with a diagnostic hearing assessment free of charge. This had the advantage that early intervention for infants diagnosed with hearing loss could commence as soon as possible. The participants therefore had a subsequently improved prognosis for normal speech and language development (Yoshinaga-Itano, 2004:455). Benefits of participating in this study therefore far outweighed any risks, without undue inducement of participation.

Relevance of research

This research project has high relevance in a country such as South Africa. IHS programs for NICU infants are not yet widespread in South Africa, owing to a lack of financial and human resources, as well as a scarcity of contextually relevant research in this matter (Keren et al., 2002:860; Olusanya, 2001:142). However, widespread implementation of NHS is justified as a result of dramatic benefits associated with early identification of hearing loss, serious negative consequences associated with late identification of hearing loss (Yoshinago-Itano, 2004:455), as well as by the HSPS Year 2002, which advocates TNHS for 98% of infants in South Africa by the Year 2010 (HPCSA, 2002:1). The above justifies the relevance of this research project, and it can therefore be said to be ethical to conduct this project.

Safeguards for vulnerable populations

Assent could not be obtained from participants, as their ages ranged between zero and 18 months. However, if infants became restless and cried excessively upon carrying out hearing screening procedures, the test personnel did not insist on continuing with the test. Furthermore, no test procedures that were carried out were in any way harmful to participants (Neuman, 1997:446-448).

3.4.3 Distributive Justice

Inclusion and exclusion criteria

All infants who participated in the IHS program at a secondary hospital between January 2004 and May 2006 were included in this study, provided they met the participant selection criteria. Participant selection criteria required infants to be between the ages of zero and 12 months upon entering the IHS program, to be graduates of the NICU at a secondary hospital, and for IHS records to be complete. These selection criteria are just, and no infants were therefore unjustly included or excluded from this study.

Fair distribution of benefits

Distribution of benefits in this study was in all ways fair. All participants received hearing screening free of charge. All participants who failed the hearing screening received a diagnostic audiological evaluation free of charge.

3.5 RESEARCH CONTEXT

The context selected for collecting research data for the current study was Kalafong hospital. Kalafong hospital is a secondary hospital located in Atteridgeville in the city of Tshwane. Atteridgeville is one of three districts in the city of Tshwane, where the most households reside (Tshwane 2020 Plan, 2006:19). The Atteridgeville district, selected as a research context for the current study, is representative of a large percentage of the city of Tshwane. The majority of households in the city of Tshwane have a lower per capita income than the national average (Tshwane 2020 Plan, 2006:20). Participants enrolled in the current study therefore reside in socio-economic conditions, where poverty, unemployment and poor levels of education are apparent (Tshwane 2020 Plan, 2006:19-22).

3.6 SAMPLE

Characteristics of the sample that was chosen for this study are discussed below in terms of the population from which the sample was selected, the sampling design that was used, the participant selection criteria, the participant selection procedure, and the sample size.

3.6.1 Population

The population from which the sample for this study was selected needs to be viewed in light of the main aim of the study. The main aim of the study was to

describe the characteristics of an IHS program for NICU infants at a secondary hospital over a 29 month period. The population from which the sample was selected therefore included all NICU infants enrolled in an IHS program between January 2004 and May 2006.

3.6.2 Participant Selection Criteria

Participants enrolled in the IHS program at a secondary hospital were required to meet the following selection criteria, in order to form part of the current study:

Age

Ages of participants enrolled in the IHS ranged between zero and 18 months. However, participants were required to be between the ages of zero and 12 months upon *entering* the IHS program, as the current screening program is defined as an infant hearing screening program, and not a newborn hearing screening program.

NICU graduates

In order to be entered into the IHS program, infants were required to be NICU graduates of the secondary hospital, as NICU infants are classified as a sub-group of infants at highest risk for hearing loss (Yoon et al., 2003:355; Yoshinaga-Itano, 2004:462).

Time of enrollment in the IHS program

Owing to the fact that this was a retrospective research study, research participants were required to be enrolled in the IHS program at a secondary hospital between January 2004, when the IHS program was initiated, and May 2006, when data was entered into a Microsoft access data base. This allowed for 29 months of data to be analyzed and reported on.

IHS program records

Records of all infants enrolled in the IHS program at a secondary hospital between January 2004 and May 2006 were required to be complete for each visit to the IHS program, in order for participants to be entered into the current research project. Records were considered complete if they contained demographic information pertaining to the infant and his/her caregiver; auditory tests conducted and their results; risk factors for hearing loss; and number of visits to the IHS program.

3.6.3 Participant Selection Procedure

A description of the participant selection procedure is provided below:

- This study was retrospective in nature, and a meeting therefore took place with both the head of the NICU at the secondary hospital, who is the primary investigator of the IHS program, as well as the project leader, in order to discuss the purpose of this research project. Both the primary investigator and the project leader agreed to allow data collected during the IHS program at the secondary hospital between January 2004 and May 2006 to be analyzed by the researcher, and for the results of the research project to be recorded and published in scientific journals with appropriate acknowledgment (Appendix A).
- The IHS program at the secondary hospital had been running since January 2004 and was already registered as a research project at the time of initiating this study. Ethical clearance had been obtained from the Research Ethics Committee of the Faculty of Health Sciences, University of Pretoria (Appendix B). Ethical clearance was obtained from the Ethics Committee of the Faculty of Humanities, University of Pretoria, upon initiation of this study (Appendix C). Upon entering the IHS program, caregivers were provided with a letter explaining the purpose of the research project, and confidentiality of participation was ensured (Appendix D). This letter was furthermore explained to them by a research assistant involved in the IHS program, who is

competent in English, Afrikaans, and a variety of African languages. Letters of informed consent were thereafter signed by the caregiver (Appendix D), and were included in participants' records. The researcher only selected infants for participation in the current study if letters of informed consent were included in participants' records.

- Data collected from the IHS program between January 2004 and May 2006 was accessed by the researcher, in order to select participants. Participants' records were required to be complete, and to meet the participant selection criteria in order for participants to be entered into this research project.

3.6.4 Description of the Sample

129 infants and their caregivers enrolled in the IHS program between January 2004 and May 2006 at a secondary hospital were selected for participation in the study, based on participants meeting the predetermined participant selection criteria discussed in 3.6.2. Infants received their initial hearing screening at approximately three months of age. Routine follow-up visits were scheduled three monthly, in order to enable the identification of late-onset or progressive hearing loss, as well as middle ear pathology. Infants who failed the hearing screening were required to follow-up in two to four weeks time, if they failed the hearing screening due to suspected middle ear pathology. If infants failed the hearing screening due to reasons other than suspected middle ear pathology, they were requested to return in three months time. Follow-up visits for infants participating in the IHS program were scheduled until infants reached 18 months of age. All 129 infants were graduates of the NICU at a secondary hospital. Records of visits to the IHS program were complete for all 129 infants, in terms of demographic information for each infant and their caregiver; auditory tests conducted and their results; risk factors for hearing loss; and number of visits to the IHS program. The researcher was not able to ensure equal gender distribution, as this study was retrospective in nature. Ensuring equal gender distribution would have required the researcher to unnecessarily discard participants' records that were complete and met the selection criteria. 68 of the

129 participants (53%) were therefore male and 61 participants (47%) were female. Table 3.1 provides a description of the sample for each of the participants' first three visits to the IHS program.

TABLE 3.1 Description of the sample for participants' first three visits to the IHS program

	VISIT 1	VISIT 2	VISIT 3
Number of infants	129	75	49
Mean age	14 weeks	27 weeks	42 weeks
Standard deviation	7	10	13
Age range	1-37 weeks	3 -64 weeks	20-83 weeks

129 infants had an initial hearing screening done, 75 infants had a second hearing screening done, and 49 infants attended a third hearing screening. Ages of infants increased with visit numbers. The age distribution of infants on their initial three visits to the IHS program is displayed graphically in figure 3.2 below.

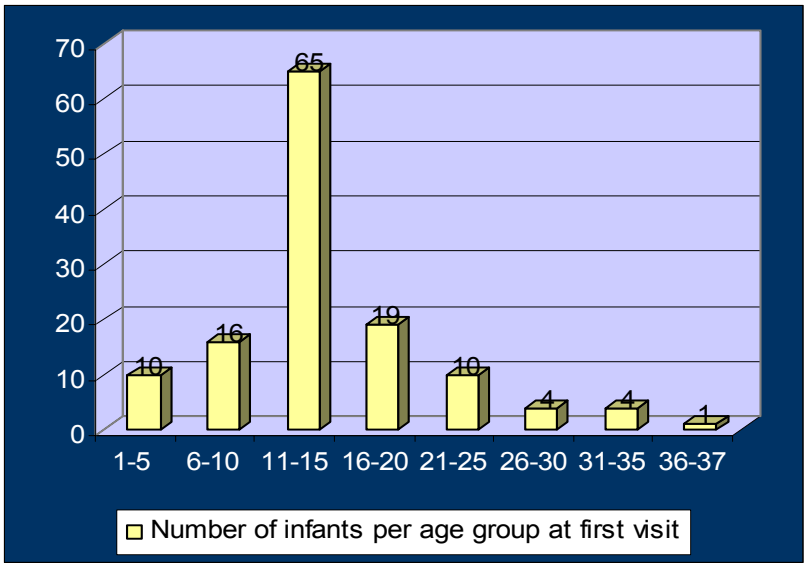

FIGURE 3.2 Age distribution (weeks) of infants at their initial IHS visit (n=129)

Figure 3.2 displays the fact that 50% of infants (n=65) had their initial hearing screening conducted between the ages of 11 and 15 weeks. This is to be expected, as the average age of enrollment into the IHS program was three months (12 weeks) of age. 20% of infants (n=26) were screened between the ages of one and ten weeks. This is accounted for by the fact that infants were initially screened whilst still in the NICU in the first few months of initiating the IHS program. 22% of infants (n=29) received their initial hearing screening between the age of 16 and 25 weeks. Figure 3.3 below displays the age distribution of infants on their second visit to the IHS program.

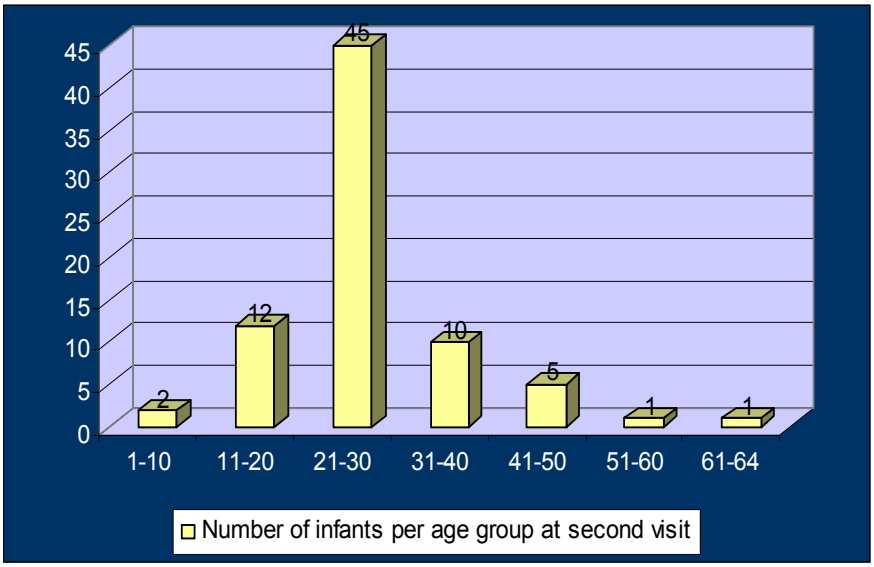

FIGURE 3.3 Age distribution (weeks) of infants at their second IHS visit (n=75)

Figure 3.3 displays the fact that 60% of infants (n=45) were between the ages of 21 and 30 weeks upon returning for their second IHS visit. This is explained by the fact that if infants failed their initial hearing screening, due to reasons unrelated to suspected middle ear pathology, they were requested to follow-up in three months time. If infants were approximately 12 weeks at their initial hearing

screening, they would be expected to be approximately 24 weeks old at their next follow-up hearing screening. This phenomenon is evidenced in the above figure. 16% of infants (n=12) returned for follow-up between the ages of 11 and 20 weeks. This group of infants comprised those who were requested to return two to four weeks after failing their initial hearing screening, if they failed the hearing screening due to suspected middle ear pathology. Figure 3.4 displays the age distribution of infants on their third visit to the IHS program.

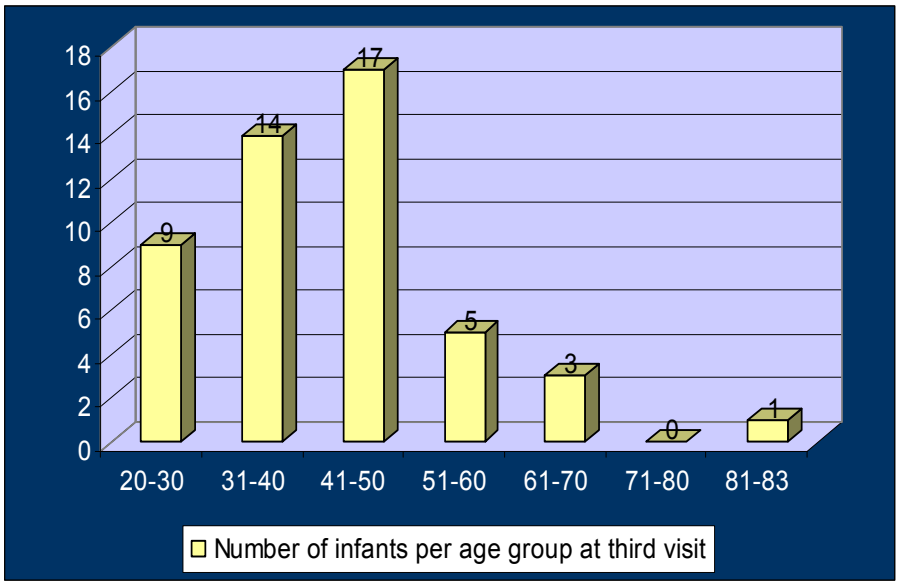

FIGURE 3.4 Age distribution (weeks) of infants at their third IHS visit (n=49)

Figure 3.4 shows that 63% of infants (n=31) returned for their third IHS visit between the ages of 31 and 50 weeks. This group of infants comprised those who again failed the hearing screening on their second visit to the IHS program, and were subsequently requested to follow-up again in three months time. According to the protocol used in this study, infants were required to fail the hearing screening process twice, before being referred for diagnostic audiologic testing once middle ear pathology had been ruled out.

A limitation of the current study was the fact that it was longitudinal in nature. Infants enrolled in the IHS program at the end of the 29 month study period could not return for follow-up IHS visits, whilst those enrolled in the first year of the study could repeatedly return. This limitation of the study has an influence on the above displayed discrepancies, in terms of when in time infants returned for their third IHS visit.

3.7 MATERIAL AND APPARATUS

Material and apparatus for the collection of data, recording of data, and data analysis that were used in this research project are described below.

3.7.1 Material and Apparatus for the Collection of Data

Data collection material consisted of evaluation techniques to assess the middle ear, cochlea, auditory nerve, and the lower brainstem. These were only screening techniques, and should an infant fail the hearing screening protocol, he/she was referred for diagnostic hearing assessments. Biographical information of participants and their risk factors for hearing loss were obtained from their hospital files. Material and apparatus used for the collection of data in this study are discussed below.

3.7.1.1 Biographical information and risk factors for hearing loss

A data collection sheet that was used to record biographical information and risk factors for hearing loss was compiled (Appendix E). A list of risk factors for hearing loss, as used in this study, was compiled from the Joint Committee of Infant Hearing (JCIH) Year 1994 and 2000 Position Statements (JCIH, 1994; 2000). Although the JCIH Year 2000 Position Statement does not include it as a risk factor for hearing loss, exposure to HIV/AIDS was included as a risk factor in this study. The central nervous system is particularly affected by HIV/AIDS. An estimated 71% of manifestations of HIV/AIDS involve the head and neck.

Furthermore, 20% to 50% of the HIV-infected population will develop varying degrees of hearing loss (Bankaitis & Keith, 1995:353). Frequent otologic manifestations of HIV infection include otitis externa, otitis media, sensorineural hearing loss, conductive hearing loss, mastoiditis and tympanic membrane perforations (Gold & Tami, 1998:165).

Furthermore, South Africa has the highest number of individuals in the world affected by HIV/AIDS (Goldstein, Pretorius & Stuart, 2003:15). According to the National HIV and Syphilis Antenatal Sero-Prevalence Survey conducted in 2005, 30.2% of pregnant women were estimated to be HIV positive in South Africa (Department of Health, 2006:10). The estimated prevalence rate of HIV/AIDS in childbearing women in the province of Gauteng is 32.4% (Department of Health, 2006:11). It is for the above reasons that exposure to HIV/AIDS was included as a risk factor for auditory impairment in the current study. A list of risk indicators for hearing loss used in the study can be found on the data recording sheet in Appendix E.

3.7.1.2 Assessment of auditory functioning

Screening tools used for the assessment of auditory functioning in the IHS program at a secondary hospital consisted of the following:

Middle-ear analyzer

The Interacoustics Impedance Audiometer AT235h was used to record immittance measures in this study. Immittance measures included Y-admittance tympanograms and acoustic reflexes. In order to elicit Y-admittance tympanograms, a 226 Hz probe tone as well as a 1000 Hz probe tone was used. Evaluation of middle ear functioning using a 226 Hz probe tone has been demonstrated to be unreliable in accurately assessing the middle ear status in infants younger than seven months (Swanepoel et al., 2007:50). The use of low frequency probe tones to record tympanometry in young infants leads to a high false negative rate, with subsequent poor sensitivity in detecting middle ear

pathology. The reason for this is that a young infant's middle ear is mass-dominated, whilst that of an adult is stiffness-dominated. However, the use of a 1000 Hz high frequency probe tone has been suggested to be a more reliable means of assessing a mass-dominated middle ear system. However, further normative studies investigating the use of a 1000 Hz probe tone in young infants are necessary in order to determine normative values for 1000 Hz tympanometry (Swanepoel et al., 2007:50). It is for this reason that both 226 Hz and 1000 Hz probe tones were used to evaluate middle ear functioning of participants in this study, in order to compare these two. The middle-ear analyzer was calibrated yearly, in order to ensure reliability of data being collected. A criterion for normative values of tympanometric measures was not applied in this study, as tympanometric results were compiled in order to gain a profile of normative tympanometric data in this group of infants. Ipsilateral acoustic reflexes were elicited at 1000 Hz using a 226 Hz probe tone. The middle-ear analyzer automatically calculated the presence of acoustic reflexes.

OAE screener

The handheld Biologic AuDX was used to record Distortion Product Oto-Acoustic Emissions (DPOAE). According to Northern & Downs (2002:287) screening programs usually require response levels to be 3 dB or greater above the noise level in order to be acceptable. In the current study four frequencies were assessed for each ear. A pass criterion was based on an infant passing at least three out of the four frequencies assessed. Parameters of DPOAE screening used in the current study are displayed in table 3.2 below.

TABLE 3.2 Parameters of DPOAE screening

Stimulus parameters	
L1	65 dB SPL
L2	55 dB SPL
F2/F1 Ratio	1.2
Minimum # samples	40
Sample size	1024 points (20 msec sample)
Pass/Refer criteria	
Minimum DP amplitude	-8 dB
Minimum DP-NF amplitude	6 dB
Frequencies used for screening	2, 3, 4 & 5 KHz
Number of frequencies for pass	3

AABR and OAE screener

The AbaerCub was used to record OAEs as well as AABRs. DPOAE and click evoked AABR measurements were recorded with this device. Parameters for DPOAEs are as discussed above. AABR screening has high sensitivity and specificity rates, and is not influenced by ambient noise. A predetermined pass criterion was used in this study, which required a repeatable response from both ears at 35 dBnHL or lower. Parameters of AABR screening are displayed in table 3.3 below.

TABLE 3.3 Parameters of AABR screening

Stimulus type	100 microsecond click
Stimulus polarity	Alternating
Stimulus rate	37.1
Stimulus intensity	35 dBnHL
Analysis Window	21.33 msec
High pass filter	1500 Hz
Low pass filter	100 Hz
Amplifier gain	30 000
Channels	1
Montage	High forehead (active or non-inverting) Test ear (reference or inverting) Non-test ear (ground)
Minimum sweeps	1536
Maximum sweeps	12 228 (in two separate trials of 6144 sweeps each)

Diagnostic ABR

The Biologic Navigator Pro was used to record diagnostic auditory brainstem responses (ABR). ABR recordings were elicited using a broadband click stimulus set at 2000 sweeps presented through EAR 3A insert earphones. Both rarefaction and condensation clicks were used in order to monitor for cochlear microphonics, as these give an indication of auditory neuropathy. If more than 10% of the responses were rejected per recording owing to muscle artifacts, the entire recording was repeated. Electrode discs of Ag/AgCI were fixed with electrolytic paste to the scalp at Fz (non-inverting), to the mastoid, ipsilateral to the stimulated ear (inverting), and to the Fpz (ground). Interelectrode impedance values were kept below 5 Kohms. Bioelectric activity was amplified with a gain of 150 000. The click ABR was analogue filtered between 100 Hz and 3000 Hz. A minimum of 1200 recordings were averaged per trial depending on the signal-to-noise ratio. A 10 dB up and 5 dB down threshold-seeking procedure was used.

Replications were made near and at minimum response levels, which were taken as the lowest intensity at which a repeatable wave V was determined. An absent ABR was only accepted after three trials at the maximum intensity (90 dB nHL) where no repeatable peak was indicated. The above discussed parameters of diagnostic ABR testing are graphically displayed in figure 3.4 below.

TABLE 3.4 Parameters of diagnostic ABR testing

Stimulus type	Click
Periodic stimulus rate	27.7/sec
Stimulus polarity	Rarefaction and condensation
Duration of click stimulus	0.10 msec
Stimulus intensity	Starting intensity of 60 dB nHL
High pass filter	3000 Hz
Low pass filter	100 Hz
Amplifier gain	150 000
Montage	High forehead (active or non-inverting) Test ear (reference or inverting) Non-test ear (ground)
Minimum sweeps	1200
Output	Monotonic

3.7.2 Material and Apparatus for the Recording of Data

A data collection sheet was completed for each infant during the IHS program (Appendix E). Data collection sheets contain identifying information of each infant and his/her caregiver, risk factors for hearing loss and IHS test results of the amount of visits to a secondary hospital during which the infant's hearing was screened. Information recorded on data collection sheets is discussed below.

Identifying information

Identifying information was recorded pertaining to the mother, such as age, home language, employment, level of education, and health during pregnancy, as well as pertaining to the infant.

Risk factors for hearing loss

Risk indicators were recorded pertaining to the mother, such as delivery information, and hereditary childhood family deafness. Risk indicators for hearing loss pertaining to the infant, based on the JCIH 2000 Position Statement, as well as the risk factor of exposure to HIV/AIDS, as included in this study, were also recorded.

Results of assessment of auditory functioning

Results of immittance screening tests were recorded, including tympanometric screening results with both a 226 Hz and 1000 Hz probe tone, as well as results of acoustic reflexes. Screening otoacoustic emission (OAE) results and automated auditory brainstem response (AABR) results were also recorded on the data collection sheet, in terms of whether the infant received a pass or refer result for the hearing screening test. Lastly, results of a diagnostic assessment, in the case of an infant being referred for a diagnostic assessment were also recorded. Such results indicate whether the infant returned for the diagnostic assessment, as well as whether he/she was diagnosed with a unilateral or bilateral hearing loss or no hearing loss at all.

A Microsoft access database was compiled, into which the researcher entered information obtained from the data collection sheets for each NICU infant and his/her caregiver participating in the IHS program. The Microsoft access database contained the following sections:

- *Demographic Information* pertaining to the infant and the mother, including their name, date of birth, and place of birth.

- *Maternal Information* including general information, antenatal care, information pertaining to their pregnancy, antenatal investigations done, and antenatal treatment provided.
- *Delivery Information* pertaining to the method of delivery, number of fetuses, and any indications for abnormal delivery.
- *Neonatal Information* including APGAR scores, birth weight, special investigations conducted, blood cultures done, and whether the infant was ventilated or not.
- *Medications* administered, including ototoxic drugs.
- *Discharge details* pertaining to the infant's final discharge diagnoses.
- *Hearing Screening* including the test date and infant's age at date of test, immittance results, AABR and OAE screening results, otoscopic examination, and results of a diagnostic assessment if one was conducted.

3.7.3 Material and Apparatus for the Analysis of Data

The Microsoft access data base containing data collected from the IHS program, was converted to a Microsoft excel data sheet. Statistical analyses were carried out by a statistician, using a statistical analysis system (SAS).

3.8 PROCEDURES

Strategic procedures for the collection, recording, and analysis of data were followed in this study. These are discussed below.

3.8.1 Data Collection Procedures

Data was collected at a secondary hospital over a 29 month period. The IHS program was conducted weekly on Wednesdays, which coincided with the high risk follow-up clinic for all NICU infants. Data collection was quantitative and collected over four phases. Phase one consisted of obtaining biographical information of participants and participants' mothers, as well as risk factors for

hearing loss, from participants' hospital files. Phase two consisted of immittance measures that were performed on participants' ears to determine their middle ear functioning. Immittance measures consisted of 226 Hz and 1000 Hz tympanometry. Phase three was a hearing screening protocol using AABR and OAE technologies to screen participants' ears. From August 2005, AABR screening was only conducted on an infant's initial hearing screening visit, and not again on subsequent visits, given that the infant passed the test. Prior to this, AABR screening was conducted on every visit for each participant. Phase four was a diagnostic ABR assessment. Only participants who failed the hearing screening protocol in phase three received a diagnostic ABR assessment. The phases of data collection are displayed graphically in figure 3.5.

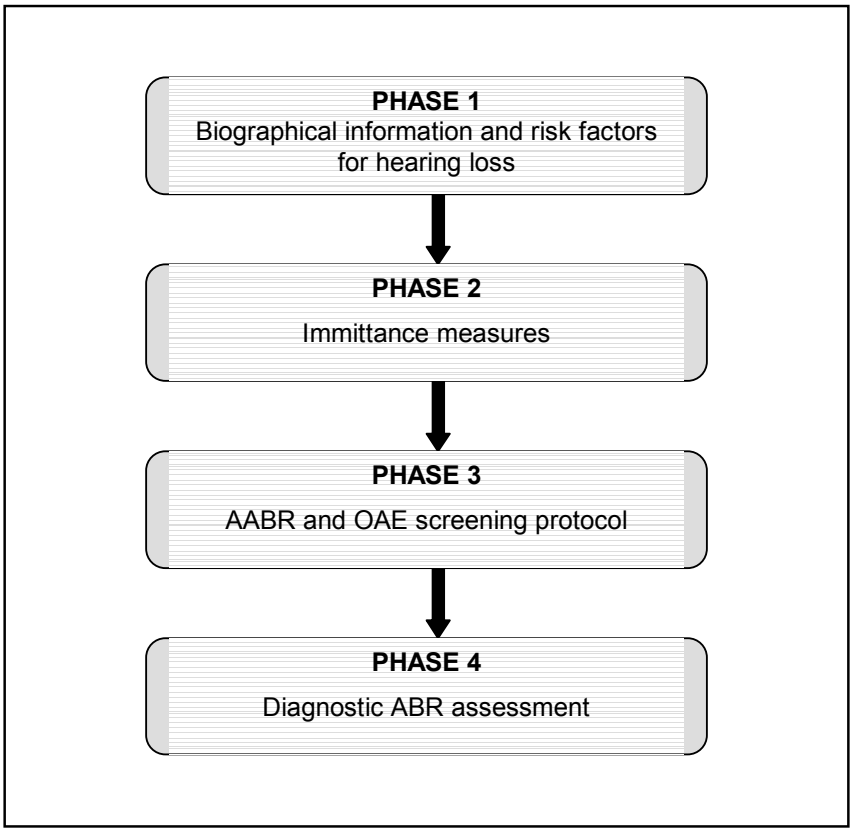

FIGURE 3.5 Data collection procedures

The data collection procedures used to collect the above discussed data are described below.

Phase One: Biographical information and risk factors for hearing loss

Biographical information of participants and caregivers, as well as risk factors for hearing loss, were obtained from participants' hospital files. Hospital personnel obtained this information from caregivers whilst their infant was in the NICU.

Phase Two: Immittance measures

Immittance measures were recorded for both the participants' left and right ears on each visit to the IHS program. The following procedures were followed:

- A probe tip of an appropriate size was selected and inserted into the infant's ear.
- A complete seal was ensured.
- 1000 Hz probe tone tympanograms were recorded.
- Following this, 226 Hz probe tone tympanograms were recorded.
- Lastly, acoustic reflexes were recorded using a 1000 Hz probe tone.
- Immittance results of each participant were printed out, as well as being recorded on a data collection sheet (Appendix E).

Technical difficulties with equipment, and restlessness of infants, resulted in immittance measures not always being recorded on each visit for every infant enrolled in the IHS program. This was however, avoided as far as possible.

Phase Three: AABR and OAE screening protocol

The hearing screening protocol is discussed below, followed by the data collection procedures used for the AABR and OAE screening protocol.

The hearing screening protocol used consisted of both AABR and OAE screening, and was conducted by trained volunteers, under the supervision of an

audiologist. Volunteers were not as experienced in IHS as a trained audiologist, which may have had a negative influence on the pass and refer rates of the IHS results. Each infant was required to undergo both an AABR and OAE on both ears. This was done for the reason that NICU graduates are the population with the highest risk for auditory neuropathy, requiring a combined AABR and OAE protocol to identify this (Mehl & Thomson, 2002:6; Sininger, 2002:197). Risk factors for auditory neuropathy include hyperbilirubenemia, prematurity, low birth weight and anoxia, amongst others. These are all risk factors present in NICU infants, thus placing these infants at an increased risk for auditory neuropathy (Sininger, 2002:195).

The target disorder of this IHS program was both sensorineural hearing loss and middle ear pathology, thereby further justifying the combined AABR and OAE screening protocol. The follow-up structure of the IHS program was as follows. Infants who passed the hearing screening were scheduled to return for a routine follow-up visit in three months time. Infants who failed the hearing screening as a result of suspected middle ear pathology, based on failed OAE and tympanometric results, were referred to the ENT specialist for treatment. A referral follow-up visit to the IHS program was scheduled within two to four weeks time, depending on the nature and duration of their medical treatment. Infants who failed the hearing screening as a result of a possible sensorineural hearing loss, based on failed OAE and AABR results but normal tympanometric results, were scheduled to have a diagnostic ABR performed as soon as possible. Depending on the diagnostic ABR results, either a routine follow-up visit to the IHS program was scheduled if no sensorineural hearing loss was present, or the infant was provided with appropriate rehabilitative services if a sensorineural hearing loss was found to be present.

The AABR and OAE screening protocol is graphically displayed in figure 3.6 below.

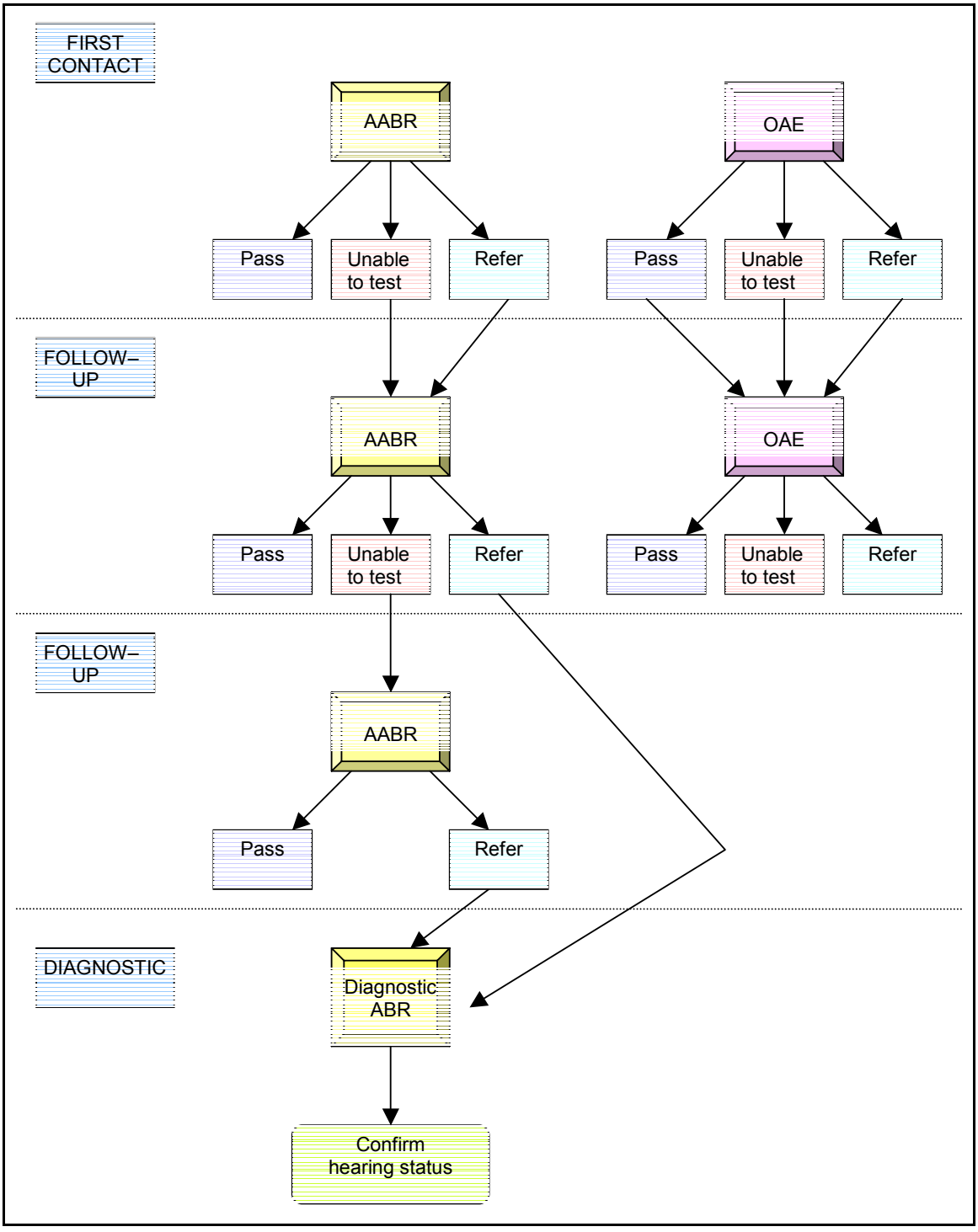

FIGURE 3.6 AABR and OAE hearing screening protocol

Ages of participants enrolled in the IHS program ranged between 0-18 months. Infants of this age are not always cooperative for testing procedures, such as OAEs and AABRs. If infants became restless and uncooperative, the screening procedure was discontinued and repeated at the next follow-up visit. The following procedures were used for the AABR and OAE screening protocol:

- The infant was placed in a comfortable position, and was preferably in a restful state.
- Three electrodes were attached to the participant's head for the AABR. These were attached at Cz (active), A1 and A2. The reference and ground electrodes were switched, depending on the test ear.
- The AABR was recorded.
- If an infant became restless and uncooperative during testing, the AABR was discontinued and repeated on the next follow-up visit.
- From August 2005 onwards, if an infant passed the AABR it was not again repeated on the next visit.
- Results of the AABR were recorded on the infant's hearing screening data collection sheet in terms of a pass or refer result (Appendix E).
- For the OAE an appropriate sized probe tip was selected and inserted into the infant's ear.
- The DPOAE screening protocol was selected on either the Biologic AuDX or the Abaercub, depending on which screening instrument was used. Both the Biologic AuDX and the Abaercub were used interchangeably.
- The above steps for the recording of OAEs were repeated in the opposite ear.
- If a participant failed the OAE screening it was immediately repeated a second time.
- If they repeatedly received a refer result, the OAE screening was repeated on the next follow-up visit.
- Results of the OAE screening were recorded on the infant's hearing screening data collection sheet in terms of a pass or refer result (Appendix E).

At the beginning of 2004 when the IHS program had just begun, AABRs were attempted to be recorded at each visit. This however, was not time effective, and it was thus decided that if an infant passed the AABR it would not again be repeated. From January 2004 until August 2004 infants were furthermore screened before discharge from the NICU with both AABR and OAE testing, as well as at each follow-up visit. Screening before hospital discharge was however, not always found to be possible and effective. From September 2004 infants therefore received their initial hearing screening at their first visit to the IHS program, scheduled at three months post discharge from the NICU.

Phase Four: Diagnostic ABR

A diagnostic ABR was only performed on participants who did not pass the AABR/OAE screening protocol. The data collection procedures for the diagnostic ABR are as follows:

- The infant was placed in a comfortable position, whilst asleep.
- Rarefaction and condensation click stimuli were used.
- The signal to noise ratio was monitored in order to ensure that noise levels were sufficiently low.
- 2000 sweeps were averaged for each intensity.
- An initial starting intensity of 60 dBnHL was used, after which a 10 dB up and 5 dB down threshold-seeking procedure was used.
- This procedure was repeated for the opposite ear.

3.8.2 Data Recording Procedures

Collected data was recorded on a data collection sheet (Appendix E). Data was recorded numerically for immittance measures, and it was also recorded whether a tympanogram had a peak or not. AABR and OAE results were recorded in the form of either a pass or refer result. Biographical information of participants and their risk factors for hearing loss were marked on a tick sheet, which formed part of the participant's data collection sheet. Data from participants' data collection

sheet was entered into a Microsoft access data base by the researcher. This was further converted to a Microsoft excel data sheet, in order for statistical analyses to be carried out by a statistician, using a statistical analysis system (SAS).

3.8.3 Data Analysis Procedures

According to Leedy & Ormrod (2005:245), statistical analyses allow the researcher to find patterns and meaning in numerical data. Once data had been captured onto a Microsoft access data base and then converted to a Microsoft excel data sheet, a statistician conducted statistical analyses on the data set by means of a statistical analysis system (SAS). Both descriptive statistics and inferential statistics were used. Descriptive statistics served to describe the data, whilst inferential statistics allowed for inferences to be drawn on the larger population by analyzing the relatively small sample size used in the current study (Leedy & Ormrod, 2005:252). Statistical procedures used for data analyses were the following: Frequency variables were used to describe various characteristics of the sample being studied. The Chi-square test and the Fisher's exact test were used to establish whether statistically significant relationships existed between variables (Leedy & Ormord, 2004:274). The Logistic regression procedure was conducted in order to determine how effectively one or more variables were able to predict the value of another variable (Leedy & Ormrod, 2005:274).

3.9 VALIDITY AND RELIABILITY

This study used a quantitative research method. Necessary steps were taken in order to ensure that results obtained from the quantitative method used were both valid and reliable. Issues of validity and reliability pertaining to this study are discussed below.

3.9.1 Ensuring Validity

According to Neuman (1997:141) validity can be defined as the degree of fit between a construct and indicators of it. Simply put, validity of a measuring instrument can be defined as the extent to which the measuring instrument measures what it is supposed to measure (Leedy & Ormrod, 2005:28). *External validity* is the extent to which results and conclusions drawn from these results can be generalized to other contexts (Leedy & Ormrod, 2005:99). High external validity is attained when results can be generalized to many situations and many groups of people (Neuman, 1997:145). The researcher aimed to achieve a high degree of external validity in this study, as research that has implications that reach beyond the specific situation being studied, is of far greater value than research that only pertains to the specific situation being studied (Leedy & Ormrod, 2005:99). High external validity was ensured in the following way:

- The IHS program at a secondary hospital took place in a ***real-life setting***, where caregivers and their infants who had previously been in the NICU at a secondary hospital came for regular follow-up visits. Research conducted in a real-life setting allows for broader applicability of its results to other real-life contexts (Leedy & Ormrod, 2005:99).
- Infants and their caregivers participating in the IHS program at a secondary hospital were a ***representative sample*** of the population being studied. The main aim of this study was to describe an IHS program for NICU infants in a *developing context*. The sample participating in this study can be said to be living in a developing South African context, and thus be classified as a representative sample. Conclusions drawn from a study that has a representative sample of the population being studied have higher validity and inferences can be drawn across diverse contexts and situations (Leedy & Ormrod, 2005:99-100).

Based on the above, the conclusion that results of this study can be generalized to many situations and people can be drawn. This study therefore maintained a high degree of external validity.

3.9.2 Ensuring Reliability

According to Leedy & Ormrod (2005:29), reliability is the *consistency* with which a measuring instrument yields certain results when the entity being measured has not changed. A high degree of reliability is necessary in order to ensure trustworthiness of results obtained (Neuman, 1997:145). The following aspects were addressed in this study in order to ensure reliable results:

- Acoustic immittance, OAE, and AABR instrumentation was calibrated yearly during the period between January 2004 and May 2006. According to Wilber (2002:50) the purpose of calibration of audiological equipment is to ensure that results obtained from the equipment are as accurate and reliable as what they can be. Calibrating audiological equipment used for data collection in this study thereby serves to increase reliability of the study. Acoustic immittance equipment was calibrated according to the ANSI S3.39-1987 standard (Wilber, 2002:65-66). According to Wilber (2002:64-65) no ANSI standards exist for calibrating AABR and OAE equipment. AABR equipment was however, calibrated in terms of output level, frequency and time. OAE equipment was calibrated in terms of frequency of the probe signal, air pressure, and the reflex activating system (Wilber, 2002:64-65).
- Acoustic immittance, OAE, and AABR equipment was administered in a consistent way. All persons evaluating auditory functioning of participants' ears were well trained in the use of the equipment. They were thus all able to administer the auditory evaluations in a standardized manner. This served to increase reliability of the measurement instruments being used in the study (Leedy & Ormrod, 2005:93).
- Specific "pass" and "refer" criteria for results of OAE and AABR testing were predetermined. No subjective interpretation of results by test personnel was

therefore required, serving to eliminate issues of interrater reliability, and thus further increase reliability of the measurement instruments being used (Leedy & Ormrod, 2005:93).

- A single person, namely the researcher, was the only person to enter data collected into the Microsoft access data base. This served to ensure consistency of the data selected and used for research purposes of this study (Leedy & Ormrod, 2005:93).

Measuring instruments used in this study were therefore consistent, and results obtained can be viewed as being trustworthy.

3.10 SUMMARY

This chapter was introduced by a motivation for selecting the research methodology to be described in the chapter. The main aim and sub-aims of the study were formulated, followed by the research design used to achieve the aims of the study. Ethical considerations were discussed in depth. Following this, the sample that took part in this study was discussed. Material and apparatus used for the collection, recording, and analysis of data was described, followed by procedures used for data collection, recording, and analysis. Finally, issues of validity and reliability were addressed as they relate to the current study.

CHAPTER 4

RESULTS AND DISCUSSION

AIM: To present, describe and discuss the results of the study, in order to answer the research question posed.

4.1 INTRODUCTION

Reports of studies documenting large-scale infant hearing screening (IHS) programs in the developing world are scarce (Olusanya & Roberts, 2006:1). However, infants in developing countries are exposed to an array of additional environmental risk factors for hearing loss, not evident in developed countries (Swanepoel, Hugo & Louw, 2005c:79-80). The incidence of hearing loss in developing countries is therefore expected to be higher than in developed countries (Swanepoel, Hugo & Louw, 2005a:12). This necessitates an urgent need for widespread implementation of IHS programs in developing countries, if the benefits of EHDI programs are to reach these vulnerable infants. In order for IHS programs in developing countries to gain the necessary legislative support and research funding, research documenting the results of pilot IHS programs is required to address the dearth of contextually relevant data (Swanepoel, Hugo & Louw, 2006:1242; Olusanya, Luxon & Wirz, 2004:289; Swanepoel, Delport & Swart, 2004:634-635). This study therefore aimed to describe an IHS program for NICU infants in a secondary hospital in Gauteng, South Africa.

Data was collected from hearing screening procedures conducted at an IHS program at a secondary hospital. Results were documented on a data collection sheet depicting biographical information and risk factors for hearing loss, as well as results of the IHS process, which included DPOAE screening, AABR screening, and high- and low-frequency tympanometry. The IHS program will be

described in this chapter by discussing the three sub-aims of this study. Figure 4.1 graphically displays how the main aim of the study was addressed by addressing the sub-aims.

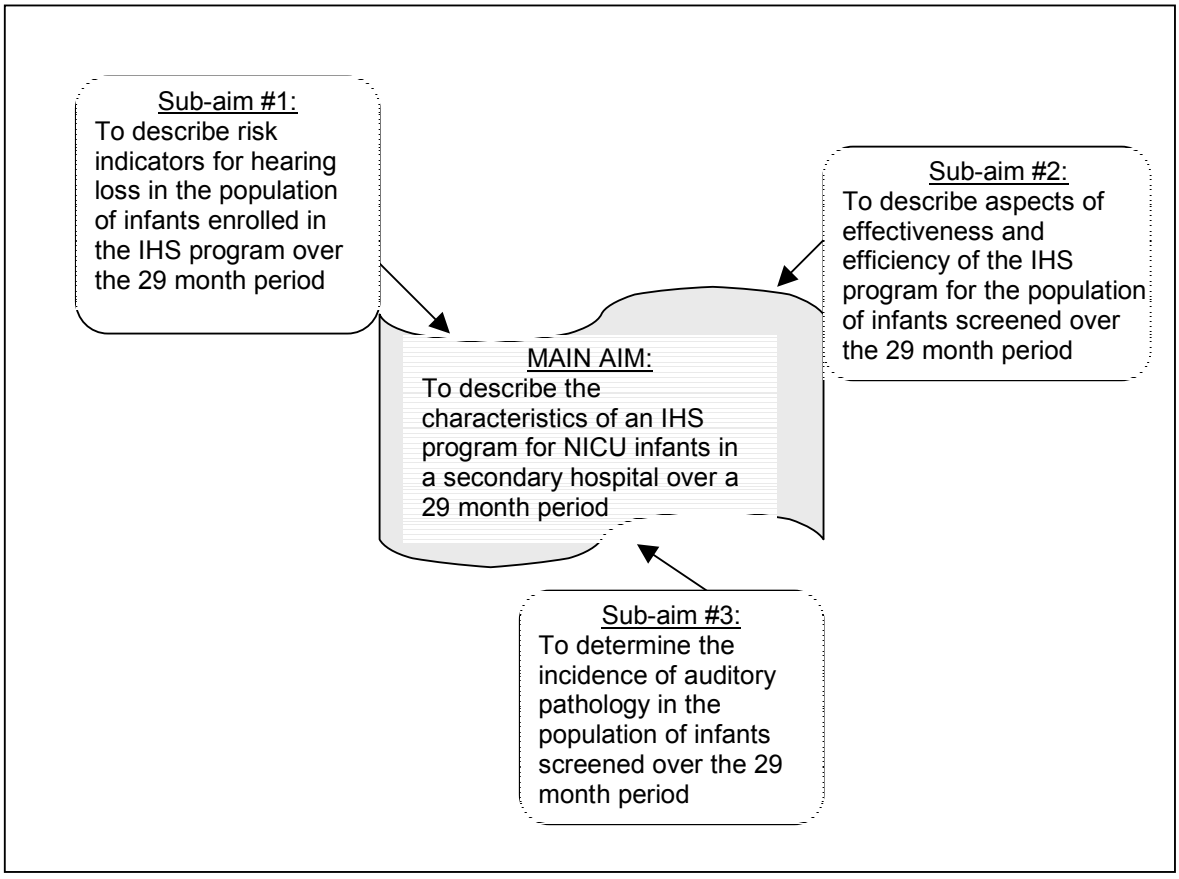

FIGURE 4.1 Graphic representation of the main aim and sub-aims of the study

4.2 RESULTS AND DISCUSSION OF SUB-AIM #1: RISK INDICATORS FOR HEARING LOSS IN INFANTS ADMITTED TO THE NICU

The first sub-aim was to describe the risk indicators for hearing loss present in the participant sample of this study. Risk indicators for hearing loss present in this sample of participants were obtained from the data collection sheets used to

record biographical information and risk indicators for hearing loss. Risk indicators are described for the total sample of participants (n=129), for the sample of infants who passed their initial hearing screening (n=72), as well as for the sample of infants who failed their initial hearing screening (n=57).

4.2.1 Risk indicators for hearing loss

Risk indicators for hearing loss present in the total sample of participants (n=129) according to the risk factors of the Joint Committee on Infant Hearing (JCIH) 1994 and 2000 position statements (1994:155; 2000:19-20) are graphically displayed in table 4.2 below.

TABLE 4.1 Risk indicators for hearing loss present in the total sample of participants (n=129)

RISK INDICATOR	RESULT		DESCRIPTION
Birth weight < 1500g (n=129)	**YES** NO	**55%** 45%	*71 infants had a birth weight less than 1500g.*
Birth asphyxia (APGAR score of <4 at 1 minute (n=129)	**YES** NO	**26%** 74%	*34 infants had an APGAR score of <4 at 1 minute.*
Birth asphyxia (APGAR score of <6 at 5 minutes (n=129)	**YES** NO	**19%** 81%	*25 infants had an APGAR score of <6 at 5 minutes.*
Hyperbilirubenemia (n=129)	**YES** NO	**20%** 80%	*26 infants had hyperbilirubenemia.*
Hyperbilirubenemia requiring an exchange transfusion (n=129)	**YES** NO	**9%** 91%	*11 of the 26 infants with hyperbilirubenemia required an exchange transfusion.*
Ototoxic Medication (n=129)	**YES** NO	**91%** 9%	*118 infants received amikacin and 13 infants received vancomycin.*
Persistent pulmonary hypertension & prolonged mechanical ventilation > 5days (n=129)	**YES** NO	**6%** 94%	*8 infants had persistent pulmonary hypertension with prolonged ventilation for 5 days or longer.*
Syndrome present (n=129)	**YES** NO	**0%** 100%	*No infants were recorded as having a syndrome according to their IHS program records*

The risk indicator for hearing loss with the highest incidence in the total sample of participants was exposure to ototoxic medication (91%). Birth weight less than 1500g (55%) was the second most prevalent risk indicator, followed by birth asphyxia (26%), hyperbilirubenemia (20%), exchange transfusion (9%), and persistent pulmonary hypertension with prolonged mechanical ventilation (6%). No infants were reported to have a syndrome. Infants participating in the current study display all risk factors for hearing loss as stipulated by the JCIH (1994:155; 2000:19-20), except for the fact that no infants had a syndrome. The fact that infants displayed all but one risk factor for hearing loss as stipulated by the JCIH (1994:155; 2000:19-20) was to be expected, as the infants were all high-risk NICU graduates, and therefore all belong to the high-risk register.

In order to draw conclusions about risk indicators for hearing loss, which are closely associated with auditory impairment in this group of infants, risk indicators for the group of infants who referred their hearing screening need to be compared to those of the group of infants who passed their hearing screening. Infants were classified as having referred the hearing screening if they had a refer result for either DPOAEs or AABR in at least one ear. According to these criteria 57 infants referred the hearing screening on their initial visit. If infants had both DPOAE and AABR screening performed, they were required to pass both DPOAE and AABR screening in both ears in order to be classified as having a pass result. Infants, who had only DPOAE or AABR screening performed, but who passed this screening, were also classified as having a pass result. According to these criteria, 42 infants who had DPOAE and AABR screening performed, passed the hearing screening on their initial visit. An additional 30 infants, who only had either DPOAE or AABR screening performed, passed the screening. A total of 72 infants passed the hearing screening on their initial visit. Figure 4.2 graphically compares the incidence of risk indicators for hearing loss in infants who referred their initial hearing screening, to the group of infants who passed their initial hearing screening.

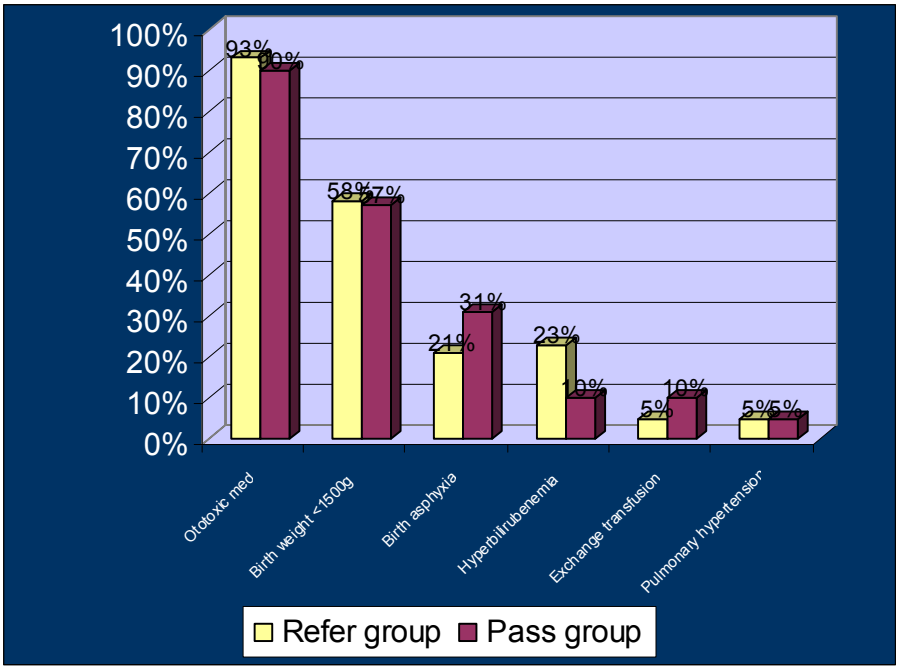

FIGURE 4.2 Comparing risk indicators for the refer and pass groups

Figure 4.2 shows that the incidence of most risk indicators for hearing loss do not vary by more than 5% when comparing the group of infants who referred the initial hearing screening and those who passed. When comparing the incidence of hyperbilirubenemia in the two groups however, the group of infants who referred the initial hearing screening had a 13% higher incidence than those infants who passed the hearing screening. This may be attributed to the fact that hyperbilirubenemia is a high risk indicator for both sensorineural hearing loss and auditory neuropathy (Sininger, 2002:195; Yoon et al., 2003:354). Four infants belonging to the group of infants who referred their initial hearing screening were later diagnosed with either sensorineural hearing loss or auditory neuropathy. Furthermore, birth asphyxia was 10% more prevalent in the group of infants who passed the hearing screening, than in the refer group.

The number of risk indicators present per infant was furthermore compared for the group of infants who referred their initial hearing screening, and those infants who passed their initial hearing screening. Figure 4.3 graphically displays the number of risk indicators present per infant for the total sample, the refer group, and the pass group.

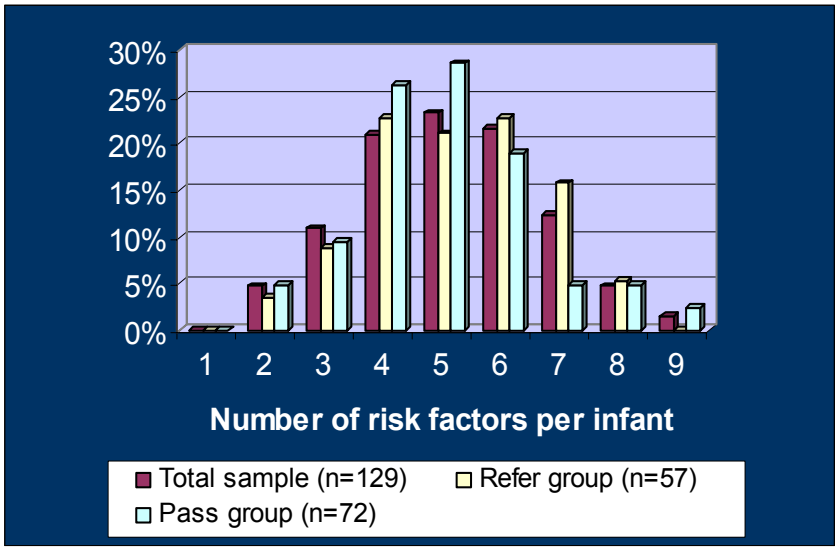

FIGURE 4.3 Number of risk indicators per infant for the total sample (n=129), refer group (n=57), and pass group (n=72)

Figure 4.3 graphically shows that the number of risk indicators per infant varied between two and nine. The greatest percentage of infants in both the refer and pass groups displayed between four and six risk indicators for hearing loss. Infants in the refer group, who failed the initial hearing screening, displayed a greater number of risk indicators per infant. 43.9% of infants in the refer group had six or more risk factors per infant, whilst only 31% of infants in the pass group had six or more risk factors per infant. These results imply that 12.9% more infants belonging to the refer group, displayed six or more risk factors than infants belonging to the pass group. 69% of infants in the pass group had five or less risk factors per infant, whilst 56.1% of infants in the refer group had five or

less risk factors. The mean number or risk indicators present per infant was 5.19 in the refer group (±1.49 SD) and 4.92 in the pass group (±1.52 SD). Statistically, there was no significant difference between the number of risk indicators present per infant in the refer group and the pass group. Infants who failed their initial hearing screening did however, present with a greater number of risk indicators per infant than the group of infants who passed their initial hearing screening.

4.2.2 Environmental risk factors for hearing loss

It is important to determine environmental risk factors for hearing loss present in the current sample, as infants from developing contexts are said to have additional risk factors for hearing loss. Risk factors for hearing loss may vary across communities, and it is therefore important that each community establish their individual risk factors for hearing loss (Olusanya, Luxon & Wirz, 2004:296). South Africa has the following environmental risk factors: high incidence of teenage pregnancies; poor maternal education levels; high incidence of infectious diseases, such as HIV/AIDS (Swanepoel, Hugo & Louw, 2005c:79; Swanepoel, Hugo & Louw, 2006:1242; Goldstein, Pretorius & Stuart, 2003:15). Teenage pregnancies and poor maternal education levels have been associated with poor EHDI program compliance and poor follow-up rates for IHS (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:79). HIV/AIDS exposure has been shown to greatly increase infants' risk for infectious diseases, such as Otitis Media and meningitis (Bankaitis & Keith, 1995:353; Swanepoel, Hugo & Louw, 2005c:80). These environmental risk factors for hearing loss, and for the success of EHDI programs, specific to South Africa, will be discussed below.

Maternal Education

Maternal education levels of caregivers participating in the study are displayed below in figure 4.4.

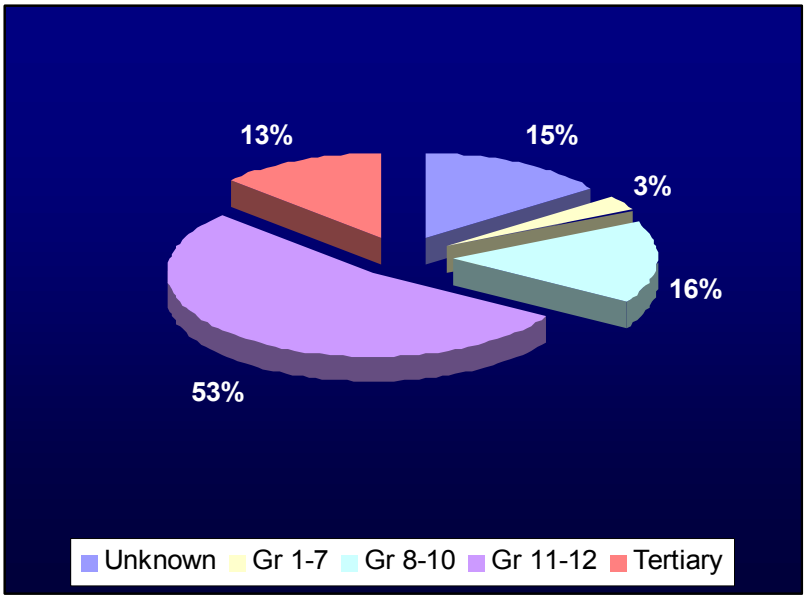

FIGURE 4.4 Maternal education levels (n=129)

Figure 4.4 shows that whilst 53% of mothers participating in the current study either had their Grade 11 or Grade 12, and 13% had a tertiary education, 16% of mothers had Grade eight to ten, and 3% only had Grade one to seven. No mothers had no education at all, whilst the education of 15% of mothers was unknown, as it was not recorded on the data collection sheets. 32% of mothers participating in the current study did not complete high school. This figure may be estimated to be even higher when the mothers, whose education levels were unknown (15%), are taken into consideration. Poor maternal education levels are considered to be an environmental risk factor for hearing loss due to the fact that mothers who did not complete high school are less likely to complete the hearing screening follow-up process than those who are more educated. Not completing the screening follow-up process threatens the success of EHDI programs (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:79). Poor maternal education levels also increase the likelihood of unemployment. This subsequently increases the risk of poor involvement of parents in EHDI programs (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:79). Poor maternal education

levels therefore have dire consequences for the effectiveness of EHDI programs, particularly in a group of NICU infants, who already display a variety or risk factors for hearing loss. The large percentage of mothers, who did not complete high school, is therefore said to be an additional environmental risk factor identified in this sample of participants.

Maternal Age

In order to determine the percentage of infants born to teenage mothers and older mothers, the age of mothers was investigated as an environmental risk factor in the current study. Teenage pregnancies are an environmental risk factor, as the youngest mothers are at greatest risk for adverse reproductive and parenting outcomes. Teenage mothers have an increased risk of giving birth to low birth weight infants, thereby placing these infants at an increased risk for developmental disorders, such as hearing loss (Northern & Downs, 2002:284; Swanepoel, Hugo & Louw, 2005c:79). Furthermore, teenage mothers have a greater risk for poor follow-up rates, resultant of their poor education levels (Prince et al., 2003:1204). Mothers over the age of 36 years have an increased risk for birth complications and Down's syndrome. Infants with Down's syndrome are more susceptible to chronic middle ear pathology than normal infants, thereby increasing these infants' risk for hearing loss (Northern & Downs, 2002:95-96). Figure 4.5 displays the age distribution of mothers participating in this study.

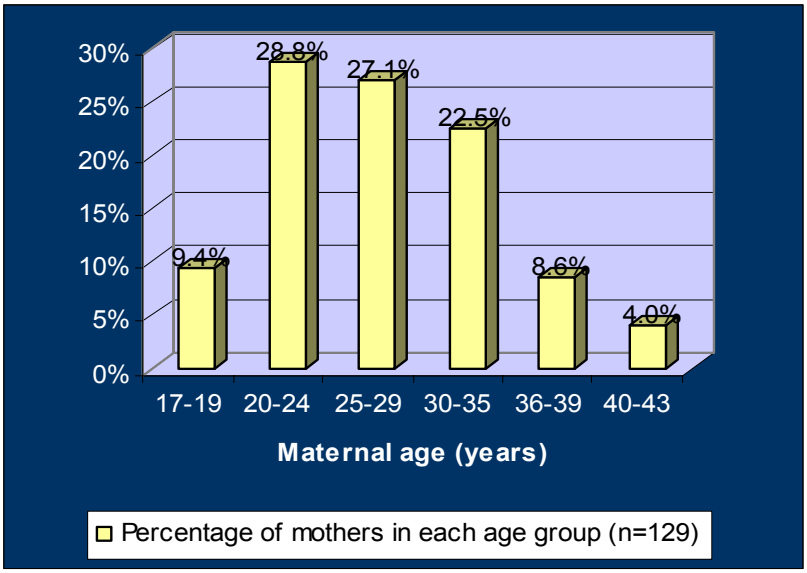

FIGURE 4.5 Age distribution of mothers (n=129)

Figure 4.5 displays shows that only 9.3% of infants (n=12) participating in the current study were born to teenage mothers. 90.7% of infants were therefore not born to teenage mothers. 12.6% of infants (n=16) were born to mothers aged 36 years or older. 87.4% of infants were therefore not born to mothers over the age of 36 years. The average age of mothers was found to be 27 and a half years, and the standard deviation was 6.32. Although a small percentage of infants were born to teenage mothers, as well as mothers over the age of 36 years, teenage pregnancies and increased maternal age do not appear to be a significant environmental risk factor in the sample participating in this study.

Prenatal HIV/AIDS exposure

Lastly, prenatal HIV/AIDS exposure as a risk factor for auditory impairment, as present in the current study, was investigated (Swanepoel, Hugo & Louw, 2005c:80). Prenatal HIV/AIDS exposure has been shown to increase infants' risk for infectious diseases, such as Otitis Media (Bankaitis & Keith, 1995:353; Swanepoel, Hugo & Louw, 2005c:80). Chronic Otitis Media can in some cases lead to eventual permanent damage to the auditory pathways (Boone, Bower &

Martin, 2006:395). It was thus essential to investigate prenatal HIV/AIDS exposure in this sample of infants, in order to determine whether it proved to be a significant environmental risk factor for hearing loss or not. Prenatal HIV/AIDS exposure was recorded on infants' data collection sheets. 21% of infants in the entire sample (n=129) were prenatally exposed to HIV/AIDS. 62% of the entire sample was not prenatally HIV/AIDS exposed, whilst 11% of mothers declined testing, and the HIV/AIDS status of a further 6% of mothers was not recorded.

According to the National HIV and Syphilis Antenatal Sero-Prevalence Survey conducted in 2005, 30.2% of pregnant women were estimated to be HIV positive in South Africa (Department of Health, 2006:10). Furthermore, the estimated prevalence rate of HIV/AIDS in childbearing women in the province of Gauteng is 32.4% (Department of Health, 2006:11). The prevalence of HIV/AIDS in the total sample of mothers participating in the current study is 21%. This is 11% lower than in the reported literature. However, 11% of mothers declined testing, and the HIV/AIDS status of 6% of mothers was unknown. When the group of mothers who declined testing, as well as the group of mothers whose HIV/AIDS status was unknown, is taken into account, prevalence rates of HIV/AIDS in the current sample of mothers may well be comparable to those of childbearing women reported in the literature (Department of Health, 2006:10-11).

In order to establish the relationship between prenatal maternal HIV/AIDS exposure and the referral of the hearing screening protocol, the incidence of prenatal HIV/AIDS exposure in the group of infants who referred their hearing screening needed to be compared to that of the group who passed their hearing screening. Infants were classified as having a refer result if they failed DPOAE or AABR screening in at least one ear. Infants were classified as having a pass result if they passed both DPOAE and AABR screening in both ears. If infants only had either DPOAE or AABR screening performed, but passed the hearing screening, they were also classified as having a pass result. Percentages of infants with prenatal HIV/AIDS exposure in the total sample of infants (n=129),

the refer group (n=57) and the pass group (n=72) are graphically compared below in figure 4.6.

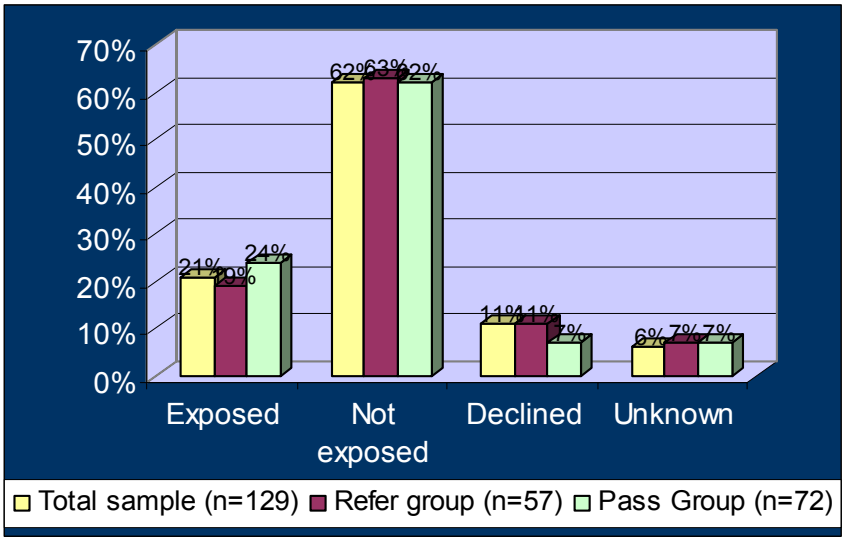

FIGURE 4.6 Comparison of prenatal HIV/AIDS exposure between the total sample (n=129), the refer group (n=57) and the pass group (n=72)

Figure 4.6 displays the fact that prenatal HIV/AIDS exposure does not vary greatly between the total sample of infants (n=129), the sample of infants who failed their initial hearing screening (n=57), and the sample of infants who passed their initial hearing screening (n=72). Infants in the refer group (n=57) had a 2% lower prenatal HIV/AIDS exposure rate than the total sample, whilst infants in the pass group had a 3% higher prenatal HIV/AIDS exposure rate than the total sample. The 3% higher rate of prenatal HIV/AIDS exposure in the pass group may be explained by the fact that the pass group had a 4% lower rate of mothers who declined HIV/AIDS testing, than the total sample and the refer group. The refer group had a 1% higher rate of not being HIV/AIDS exposed than both the total sample and the sample of infants who passed their initial hearing screening. These results indicate that prenatal HIV/AIDS exposure was not directly related to whether an infant failed their initial hearing screening or not. Infants in the current study did however, display a high incidence of middle ear pathology.

HIV/AIDS exposure places an infant at increased risk for middle ear pathology (Bankaitis & Keith, 1995:353; Swanepoel, Hugo & Louw, 2005c:80). The high incidence rate of middle ear pathology documented in the current study may therefore in part be attributed to the high incidence rate of HIV/AIDS exposure in this sample of infants.

4.2.3 Summary of sub-aim #1: Risk indicators for hearing loss in infants admitted to the NICU

Results of sub-aim #1 are summarized below in table 4.2.

TABLE 4.2 Summary of sub-aim #1

Risk indicators for hearing loss according to the JCIH (1994:155; 2000:19-20) • No statistically significant difference between the incidence of risk indicators in infants who failed the hearing screening, when compared to infants who passed the hearing screening, was found. • Infants who failed the hearing screening did however, display a greater number of risk indicators per infant, than infants who passed the hearing screening.
Environmental risk indicators for hearing loss • The large percentage of mothers who did not complete high school was identified as an environmental risk indicator for hearing loss, as poor maternal education has negative consequences for the effectiveness of EHDI programs • At least 21% of the current sample of infants were prenatally exposed to HIV/AIDS, and this too was identified as an environmental risk indicator for hearing loss • HIV/AIDS exposed infants did not show higher referral rates on screening tests, when compared to infants who were not HIV/AIDS exposed.

4.3 RESULTS AND DISCUSSION OF SUB-AIM #2: ASPECTS OF EFFECTIVENESS AND EFFICIENCY OF AN IHS PROGRAM FOR INFANTS ADMITTED TO THE NICU

The second sub-aim aimed to describe aspects of effectiveness and efficiency of the IHS program for high-risk NICU infants. Aspects of the effectiveness and efficiency of the IHS program is described below in terms of coverage rate;

AABR, DPOAE and immittance screening results; follow-up rates, and by compiling normative data for high frequency immittance measures.

4.3.1 IHS program coverage rate

The coverage rate of the IHS program will be described in terms of screening tests used. Screening tests included AABR screening, DPOAE screening, and immittance screening. Of the 129 infants participating in this study, 67% (n=86) had an AABR performed on their initial visit. 33% of infants (n=43) did therefore not have AABR screening performed on their initial IHS visit. Of the 67% of infants who did have an AABR performed, 8% of infants (n=7) had an AABR performed unilaterally, whilst the remaining 92% of infants (n=79) had an AABR performed bilaterally. A total of 64% of ears (n=165) therefore had an initial bilateral AABR screening performed.

Of the 129 infants participating in this study, 88% of infants (n=114) received a DPOAE screening on their initial visit. Of the 88% of infants who had DPOAE screening performed, 3.5% of infants (n=4) infants had a DPOAE performed unilaterally, whilst 96.5% of infants (n=110) had DPOAEs performed bilaterally. A total of 87% of ears (n=224) therefore received DPOAE screening on their initial visit to the IHS program. This 87% coverage rate obtained in the current study, as with the 67% AABR coverage rate, falls short of the quality indicator set by the JCIH (2000:6) advocating that a 95% coverage rate should be achieved before hospital discharge. AABR and DPOAE coverage rates achieved in the current study were therefore shown not be efficient.

Of the 129 infants participating in the current study, 93% of infants (n=120) had low- and high-frequency tympanometry performed on their initial visit to the IHS program. Of the 93% of infants who had tympanometry performed, 94% of infants (n=113) had bilateral tympanograms recorded, whilst the remaining 6% (n=7) had unilateral tympanograms recorded. This amounts to a total of 90% of ears (n=233) that had immittance screening performed on their initial hearing

screening visit. Coverage of infants using immittance measures can be compared to the study conducted at immunization clinics by Swanepoel, Hugo & Louw (2006:1244). Using tympanometry, a coverage rate of 94% of ears of infants of similar ages to the current study was achieved by Swanepoel, Hugo & Louw, (2006:1244) using tympanometry. This is a 4% higher coverage rate than that achieved in the current study. The 90% coverage rate achieved in the current study is however, comparable to that achieved by Kei et al. (2003:23), who report a 87.9% coverage rate for immittance measures.

Figure 4.7 graphically compares the age distribution (weeks) of infants who were not able to have AABR, DPOAE, and immittance screening conducted on their initial IHS visit.

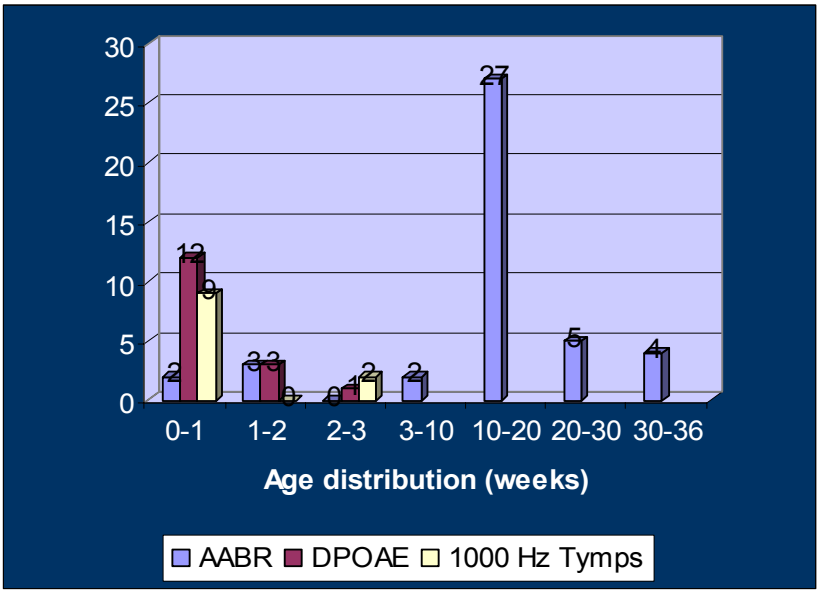

FIGURE 4.7 Age distribution of infants who did not have AABR (n=43), DPOAE (n=16) and immittance (n=11) screening performed

Figure 4.7 displays the fact that the majority of infants (63%) who did not have AABR screening conducted on their initial hearing screening visit were aged ten to 20 weeks. 21% of infants (n=9) who did not have AABR screening conducted

were aged 21 to 36 weeks. Infants at this age are more restless than newborns, providing a reason for the fact that AABR screening could not be conducted. Swanepoel, Hugo & Louw (2006:1243-1244) conducted an IHS program at immunization clinics in South Africa, where the mean age of infants was 14 weeks, comparable to the age distribution of infants in the current study. According to Swanepoel, Hugo & Louw (2006:1243-1244) AABR screening did not prove useful as infants were wakeful and restless.

Resultant of high artifacts and unreliable AABR responses, wakefulness and restlessness of infants were also recorded as reasons for infants not being able to receive an AABR screening. AABR screening is lengthy and complex in nature. Electrodes have to be positioned on the infant's head, making reliable recordings difficult to obtain on wakeful and restless infants. AABR screening is therefore not useful in infants aged ten to 20 weeks or older, as infants of this age are wakeful and restless during the screening procedure, making AABR screening difficult or impossible to conduct. AABR screening should thus be conducted on infants younger than ten weeks, in order to ensure reliable AABR recordings. Only six infants (13.9%) participating in the current study, who were aged zero to ten weeks, were not able to have AABR screening conducted on their initial IHS visit.

Figure 4.7 furthermore shows that 75% of infants (n=12) who could not have DPOAE screening performed on their initial visit were aged zero to one week. 15% of infants (n=3) that did not have DPOAE screening performed were aged one to two weeks and 5% of infants (n=1) that did not have DPOAE screening performed were aged two to three weeks. No infants over the age of three weeks fell into the group of infants who could not have DPOAE screening conducted on their initial IHS visit. Similarly 82% of infants (n=9) that did not have 1000 Hz immittance screening performed on their initial IHS visit were aged zero to one week, whilst 18% of infants (n=2) were aged two to three weeks. As with DPOAE

screening, there were no infants over the age of three weeks who could not have reliable immittance screening conducted.

Interestingly, infants who could not have DPOAE and immittance screening conducted, were not older infants who were restless during the testing procedure, but were the youngest infants participating in this study. Reasons for these infants not being able to have DPOAE and high frequency immittance screening performed on their initial IHS visit may be attributed to the fact that infants aged zero to three weeks were more than likely younger than 38 weeks gestational age. Infants of this gestational age have exceptionally small ear canals. As the probe tips available for the screening were too large for infants' ear canals, this may have prevented DPOAE and immittance screening from being performed. In addition to this, amniotic fluid from the uterus, remaining in infants' ear canals may furthermore prevent accurate DPOAE and immittance recordings.

The above discussed findings highlight important guidelines when conducting DPOAE and high frequency immittance screening on NICU infants. DPOAE and immittance screening is not useful on infants who are younger than 38 weeks gestational age, as the size of infants' ear canals does not permit reliable DPOAE and immittance recordings. When conducting IHS on prematurely born NICU infants, it is important to ensure that infants are older than 38 weeks gestational age, in order to reliably conduct DPOAE and immittance screening. This should serve to increase the coverage rate of hearing screening in NICU infants enrolled in IHS programs, and to subsequently improve the efficiency of the program.

Figure 4.8 below displays an overview of the bilateral coverage rates achieved by AABR, DPOAE, and immittance screening.

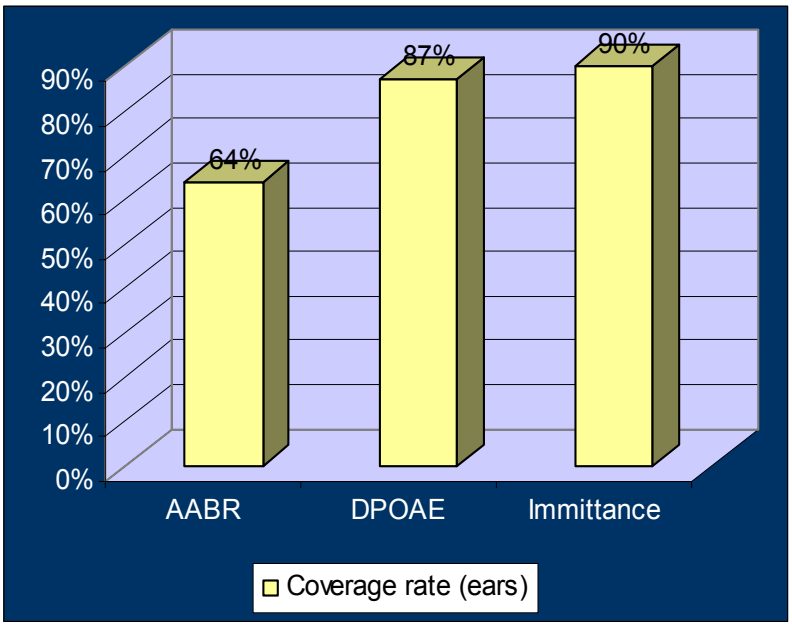

FIGURE 4.8 Coverage rates using AABR, DPOAE, and immittance screening

From figure 4.8 it is evident that immittance screening achieved the highest coverage rate (90%), DPOAE screening the second highest coverage rate (87%), with AABR screening achieving the lowest coverage rate (64%). These differences in coverage rate may be attributed to the complexity of the screening procedure, the time taken to conduct the screening procedure, and how quiet the test requires the infant to be. AABR screening is lengthier than DPOAE and immittance screening, and is more complex in nature, as electrodes have to be positioned on the infant's head. DPOAE and immittance screening merely requires the insertion of a probe into the infant's ear. DPOAE screening however, requires the infant to be quiet during the screening procedure, while immittance screening is not as dependant on a quiet infant. The longer the time taken by the screening procedure, and the more complex the test, the greater the chance that infants may become restless. A resultant lower coverage rate with lengthier and more complex screening procedures may therefore be expected.

4.3.2 AABR and DPOAE screening results

Of the 165 ears that had an AABR performed on the infants' initial visit to the IHS, 73% of ears (n=121) passed the AABR screening, whilst 27% of ears (n=44) had a refer result. Of the 224 ears that had DPOAEs performed, 69% of ears (n=154) passed the DPOAE screening, whilst 31% of ears (n=70) received a refer result. AABR and DPOAE screening results are displayed graphically below in figure 4.9

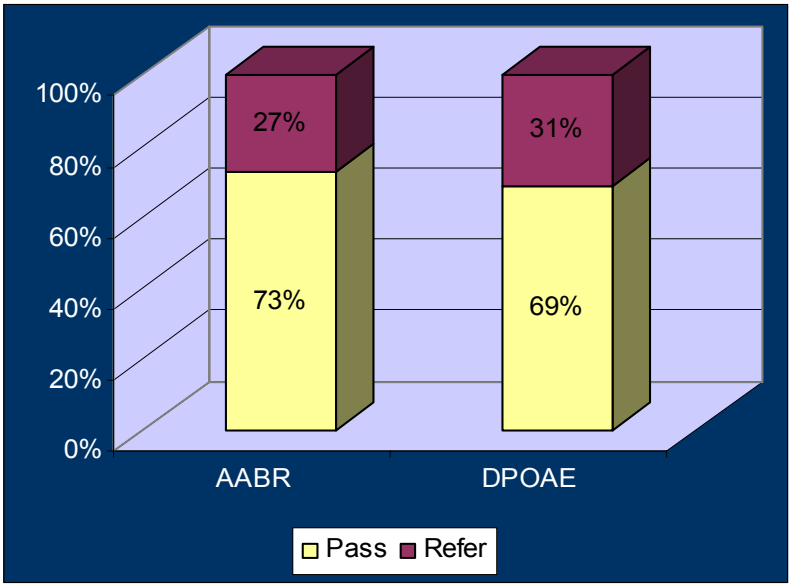

FIGURE 4.9 Graphic representation of AABR and DPOAE screening results for ears

Figure 4.9 shows that AABR screening resulted in a 4% higher pass result than DPOAE screening. DPOAE screening displayed a 4% higher refer result than AABR screening. This is a very small difference, which may be explained in the following manner: Pressure in the middle ear, resultant of middle ear pathology, reduces DPOAE amplitudes (Rhodes, Margolis, Hirsch et al., 1999:800). DPOAEs are therefore more affected by middle ear pathology than what AABR recording are. NICU infants display a high incidence of middle ear pathology (Swanepoel et al., 2007:50; Rhodes et al., 1999:800). This provides an

explanation for the higher referral rate on DPOAE screening when compared to AABR recordings.

When comparing DPOAE and AABR pass results to previous studies done on high-risk NICU infants, the current study shows a lower pass rate for ears on both DPOAE and AABR screening. DPOAE and AABR screening results obtained in the current study, and reported by Rhodes et al. (1999), Meyer et al. (1999), and Chiong et al. (1999) are compared below in table 4.3. In order to reliably compare referral rates obtained in the current study to previous studies conducted, only infants who received bilateral AABR and DPOAE screening were included in this analysis

TABLE 4.3 Comparing referral rates of hearing screening tests of various studies

	Bilateral AABR refer result	**Unilateral AABR refer result**	**Bilateral DPOAE refer result**	**Unilateral DPOAE refer result**
Current study	13.9%	24%	21.8%	17.3%
Rhodes et al. (1999)		17% referral rate in at least one ear		11% referral rate in at least one ear
Meyer et al. (1999)	2%	3.3%	16.4%	13.1%
Chiong et al. (2003)	Not done	Not done	29%	20.2%

A point that emerges from table 4.3 is that hearing screening results vary across countries, as well as across various studies (Rhodes et al., 1999:803; Chiong et al., 2003:216; Meyer et al., 1999:902). Referral rates of screening tests were found to be higher in developing countries, whilst younger infants were found to have lower referral rates than older infants.

Rhodes et al. (1999:803) reports a 17% refer rate for ears on AABR screening, and an 11% refer rate for ears on DPOAE screening in a study done on 87 NICU

infants in the USA. The current study therefore shows a 10% higher AABR refer rate, and a 20% higher DPOAE refer rate when compared to that of Rhodes et al. (1999:803). A study conducted in Germany on high-risk NICU infants, screened before hospital discharge, revealed an overall referral rate of 29.5% on DPOAE screening (Meyer et al. 1999:902). Of the 29.5% of infants who did not pass DPOAE screening, 13.1% showed a unilateral referral rate, whilst 16.4% showed a bilateral referral rate (Meyer et al., 1999:902). The 31% referral rate of participants for DPOAE screening recorded in the current study is not significantly different to results of the study conducted by Meyer et al. (1999:902), as infants in the current study were required to fail DPOAEs in at least one ear, in order to be recorded as having referred the DPOAE screening test. Meyer et al., (1999:901) furthermore report a 5.3% AABR referral rate, which is nearly 22% lower than the AABR referral rate of this study. Two percent of infants referred the AABR screening bilaterally, whilst 3.3% of infants had a unilateral refer result (Meyer et al., 1999:901).

Reasons for higher referral rates obtained in the current study, when compared to the studies conducted by Rhodes et al. (1999:803) and Meyer et al. (1999:902) may be attributed to the following reasons: The current study was a pilot study, and personnel performing hearing screening may have been inexperienced in the use of DPOAE and AABR screening equipment, thereby resulting in increased referral rates on tests. AABR and DPOAE pass rates are however, expected to improve over time. Furthermore, infants participating in the current study were much older than infants participating in the studies conducted by Rhodes et al. (1999:801) and Meyer et al. (1999:901). Infants in the current study were approximately three months of age. Infants participating in the study conducted by Rhodes et al. (1999:801) were on average one month old, whilst infants participating in the study of Meyer et al. (1999:901) were screened before hospital discharge. The mean age of infants on their initial visit to the IHS was 13.81 weeks (±6.69 SD). Infants in the current study were therefore more likely to be more restless during the test procedures, thereby contributing to higher

referral rates on screening procedures. Furthermore, older infants display an increased incidence of Otitis Media, when compared to younger infants (Rhodes et al., 1999:805). The higher referral rate of screening procedures recorded in the current study, when compared to previous reports, can thus also be attributed to an increased incidence of middle ear pathology present in this sample of infants.

Higher referral rates in the current study may furthermore be attributed to the fact that the IHS program was conducted in South Africa, which is a developing country (McPherson & Swart, 1997:2; Swanepoel, Hugo & Louw, 2006:1242). Developing countries have a high incidence of middle ear pathology, thereby leading to high rates of false positive screening test results (Olusanya et al., 2004:296). Furthermore, the incidence of auditory impairment has been proven to be directly related to poor socio-economic conditions, evident in developing countries (Kubba et al., 2004:123). The majority of infants participating in the current study were from poor socio-economic conditions, and this resulted in an increased incidence of abnormal hearing screening results, as evident from the above results.

The view that IHS tests result in higher referral rates in developing countries, than in developed countries, is supported by the results of a study conducted by Chiong, Llanes, Tirona-Remulla et al. (2003:215). Chiong et al. (2003:215) conducted DPOAE screening on NICU infants in the Philippines, which is also a developing country. Results of their study revealed a 49.2% referral rate of subjects for DPOAE screening (Chiong et al., 2003:216). The same criteria were applied to the current study, wherein only 31% of infants were recorded as having a DPOAE refer result.

Infants participating in the study conducted by Chiong et al. (2003:216) were screened before hospital discharge, whereas infants in the current study were screened at approximately three months of age. Screening infants before hospital discharge, whilst they were still in the NICU, may have resulted in high

false positives in the study conducted by Chiong et al. (2003:217). The environment of the NICU nursery setting was reported to be noisy, which contributed to unreliable screening results (Chiong et al., 2003:217). Infants participating in the current study were screened in a quiet environment, thereby eliminating false positives resultant of excessive background noise. It is nevertheless important to note that referral rates in both the current study and the study conducted by Chiong et al. (2003:217) were higher than referral rates reported in developed countries.

4.3.3 Low frequency immittance screening results

Of the 233 ears that had 226 Hz tympanograms recorded on their initial hearing screening visit, 78% showed a discernable peak (n=182 ears), whilst 22% did not (n=51 ears). In adults and young children a discernable peak within reasonable limits is indicative of normal middle ear functioning, whilst an absent peak indicates a form of middle ear pathology (Fowler & Shanks, 2002:177). The percentage of peaked 226 Hz tympanograms in the current study is considerably lower than the percentage of peaked tympanograms reported in previous studies.

Rhodes et al. (1999:803) reported a peaked 226 Hz tympanogram rate of 93% in a study done on 87 infants in the USA. A study evaluating the choice of probe tone in tympanometry undertaken in a group of infants aged two to 19 weeks, reported that peaked 226 Hz tympanograms were recorded in 95% of all ears (Baldwin, 2006:425). The studies conducted by Rhodes et al. (1999:803) and Baldwin (2006:425) were performed on NICU infants who ranged between a few hours and 19 weeks of age. The current study was conducted on infants between the ages of three and 18 months. The incidence of middle ear pathology has been reported to increase with an increasing infant age (Rhodes et al., 1999:805). This may have possibly contributed to the higher rate of unpeaked 226 Hz tympanograms in the current study, when compared to previous studies.

Furthermore, infants enrolled in the IHS were from a developing South African context, thereby placing them at an increased risk for middle ear pathology (Olusanya, Luxon & Wirz, 2004:296). Middle ear pathology has been reported to have a high incidence rate in developing countries (Olusanya, Luxon & Wirz, 2004:296). Increased infant age and poor socio-economic conditions therefore lead to a higher rate of unpeaked low frequency tympanometry, as these factors result in an increased incidence of abnormal middle ear functioning. Lastly, probe tips used during the screening procedure, which are not small enough for the size of infants' ear canals, may result in measurements being recorded as being against the ear canal wall, instead of the tympanic membrane. This too, may result in high false positive results on immittance screening.

The important point worth arguing is however, the fact that low frequency tympanometry is reported to produce peaked tympanograms in the presence of middle ear pathology, in infants younger than seven months (Baldwin, 2006:426). Infants participating in the studies conducted by Baldwin (2006:425) and Rhodes (1999:803) were between a few hours and 19 weeks of age. The high rate of peaked 226 Hz tympanograms reported in these studies can therefore not be assumed to be an accurate representation of the actual middle ear status of infants, but may in fact be as a result of false negatives produced by 226 Hz tympanometry. Infants participating in the current study ranged between three and 18 months of age. A large percentage of infants were over the age of seven months. This may account for lower rates of peaked 226 Hz tympanograms recorded in this study, as the accuracy of detecting middle ear pathology by means of 226 Hz tympanometry increases in older infants (Baldwin, 2006:426).

4.3.4 High frequency immittance screening results

1000 Hz tympanometry was performed in order to validate results of previous studies suggesting 1000 Hz tympanometry to be a more accurate means of recording immittance values in infants younger than seven months (Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:22; Rhodes et al.,

1999:804). In order to prove that 1000 Hz tympanometry is more accurate in assessing middle ear functioning of infants younger than seven months, 1000 Hz tympanograms were compared to 226 Hz tympanograms, controlled by DPOAE results.

Results of 1000 Hz tympanometry revealed the following: Of the 233 ears that had 1000 Hz tympanometry performed on their initial hearing screening visit, 55% (n=129) had a discernable peak, indicating normal middle ear functioning. 45% of ears (n=104) did not show a discernable peak, suggestive of middle ear pathology. This is a high percentage of abnormal 1000 Hz tympanometry, when compared to previous studies (Swanepoel et al., 2007:51; Rhodes et al., 1999:804).

Swanepoel et al. (2007:51) reported an 8% rate of unpeaked 1000 Hz tympanograms in a sample of neonatal ears. The study by Swanepoel et al. (2007:51) was however, conducted on a sample of neonates, of whom the majority did not spend time in the NICU, and were not exposed to the additional risk factors for auditory impairment that NICU infants are exposed to. NICU infants have been shown to be particularly prone to middle ear pathology (Swanepoel et al., 2007:49; Rhodes et al., 1999:800). Baldwin (2006:425) reported unpeaked 1000 Hz tympanograms in 28.6% of neonatal ears between the ages of two and 19 weeks. Although Baldwin (2006:425) reported a higher rate of unpeaked 1000 Hz tympanograms when compared to the study by Swanepoel et al. (2007:51), Baldwin's study (2006:425) also showed a lower rate of unpeaked 1000 Hz tympanograms when compared to the current study.

Reasons for the lower rate of unpeaked 1000 Hz tympanograms recorded may be the fact that infants participating in the current study were between the ages of three and 18 months, and therefore presented with a higher incidence of middle ear pathology (Rhodes et al., 1999:805), than the younger group of infants participating in the study by Baldwin (2006:425). Another contributing

factor to the lower rate of unpeaked 1000 Hz tympanograms recorded in the current study was the fact that the screening procedures were conducted by inexperienced personnel, thereby leading to screening results which were not always reliable.

4.3.5 Comparing low frequency and high frequency immittance screening results

Results of 226 Hz tympanometry and 1000 Hz tympanometry are compared below in terms of whether they displayed a discernable peak, a double peak, or no peak at all. Figure 4.10 displays a graphic comparison of 1000 Hz and 226 Hz tympanograms in terms of whether they displayed a discernable peak or not. This comparison was done for infants younger than seven months, and infants aged seven months and older.

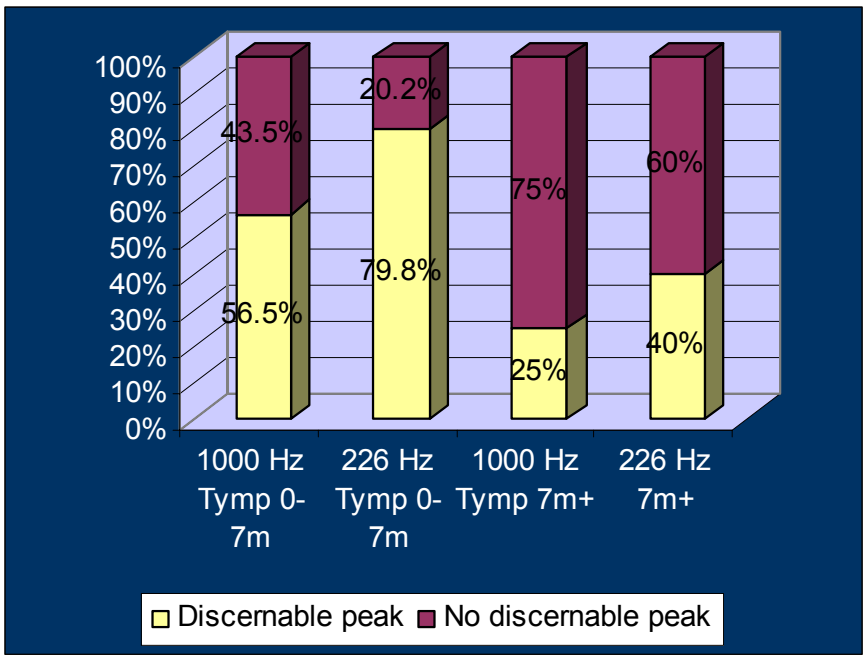

FIGURE 4.10 Comparing 1000 Hz and 226 Hz tympanometry in terms of a discernable peak for age groups 0-7 months and 7 months and above (n=233 ears)

Figure 4.10 displays the fact that 226 Hz tympanograms had a 23.3% higher rate of peaked tympanograms than 1000 Hz tympanograms in infants younger than seven months. 79.8% of 226 Hz tympanograms, conducted in infants younger than seven months, displayed a discernable peak, whilst only 56.5% of 1000 Hz tympanograms did. A 15% difference was observed in infants older than seven months, between 226 Hz tympanograms and 1000 Hz tympanograms in terms of whether they displayed a discernable peak or not. Forty percent of 226 Hz tympanograms conducted in infants older than seven months displayed a discernable peak, whilst only 25% of 1000 Hz tympanograms had a discernable peak. Possible reasons for the higher rate of peaked 226 Hz tympanograms include the following: Low frequency tympanometry has been reported to be unreliable in accurately assessing the middle ear status of young infants (Baldwin, 2006:418; Swanepoel et al., 2007:50; Rhodes et al., 1999:800). Peaked 226 Hz tympanograms have been reported in the presence of middle ear pathology (Baldwin, 2006:426).

The low frequency probe tone results in high false negative rates when evaluating a mass-dominated young infant's middle ear system. Low frequency tympanometry therefore has a poor sensitivity rate for accurately detecting middle ear pathology (Swanepoel et al., 2007:50). In the presence of normal middle ear functioning, low frequency tympanometry often results in peaked tympanograms, when there is in actual fact underlying middle ear pathology (Baldwin, 2006:426). High frequency probe tones have however, been demonstrated to be a more reliable means of accurately assessing a mass-dominated middle ear system in young infants (Swanepoel et al., 2007:50; Baldwin, 2006:425). This may explain the increased rate of peaked 226 Hz tympanograms when compared to 1000 Hz tympanograms in the current sample of subjects.

Figure 4.10 furthermore shows that infants older than seven months display a higher rate of both 226 Hz and 1000 Hz unpeaked tympanograms than infants younger than seven months. This may be attributed to the fact that slightly older infants were more likely to have had current or previous episodes of middle ear pathology, resulting in a greater number of unpeaked tympanograms.

Several tympanograms recorded in the current study displayed a double peak. Figure 4.11 graphically compares 226 Hz double peaked tympanograms and 1000 Hz double peaked tympanograms of infants on their initial hearing screening visit. Infants ranged between one and 37 weeks of age on their initial visit to the IHS program.

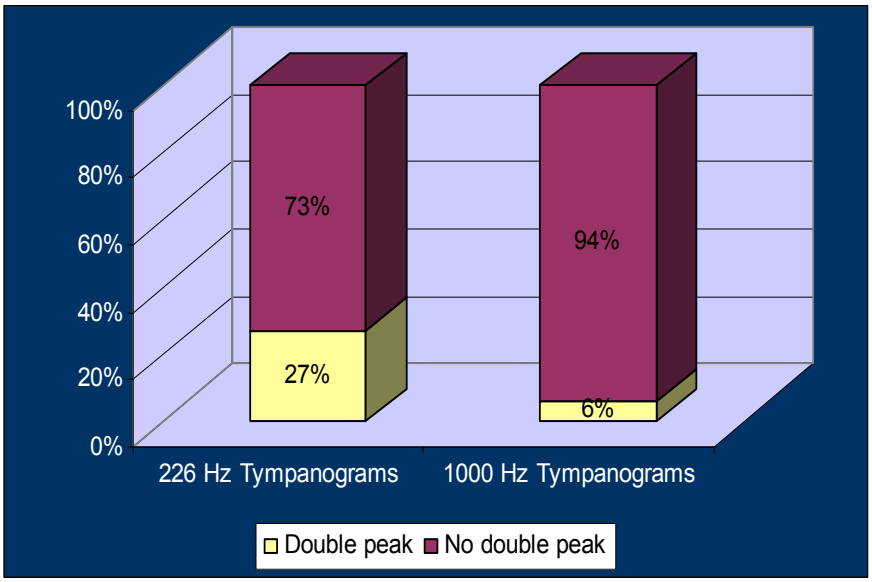

FIGURE 4.11 Comparing 226 Hz and 1000 Hz tympanometry in terms of a double peak (n=233 ears)

Figure 4.11 shows a 226 Hz tympanometry produced a 21% higher rate of double peaked tympanograms than 1000 Hz tympanometry. Double peaked 1000 Hz tympanograms have proven to be indicative of normal middle ear

transmission, as they have been shown to correlate with DPOAE pass results (Swanepoel et al., 2007:51).

The 6% incidence rate of double peaked 1000 Hz tympanograms evident in the current study, correlates with results of the study done by Swanepoel et al. (2007:51), which also reported a 6% incidence rate of double peaked 1000 Hz tympanometry in a sample of infants aged one to 28 days. As double peaked tympanograms are associated with normal middle ear functioning, the 21% higher double peaked 226 Hz tympanograms may be related to the fact that 226 Hz tympanometry has a poor sensitivity rate for detecting middle ear pathology (Baldwin, 2006:425). This is resultant of the fact that young infants have a mass-dominated middle ear system, whereby the ear canal volume is altered by the introduction of pressure into the ear canal. Low frequency tympanometry may therefore indicate normal middle ear functioning in the presence of middle ear pathology, resulting in high false negative rates (Swanepoel et al., 2007:50; Rhodes et al., 1999:804). A study conducted by Kei et al. (2003:26-27) on neonates between the ages of one and six days also proved that the occurrence of double peaked tympanograms decreases as the frequency of the probe tone increases. This provides further explanation for the 27% occurrence rate of double peaked 226 Hz tympanograms in the current study on infants aged one to 37 weeks (Kei et al., 2003:26-27).

4.3.6 Comparing DPOAE and immittance screening results

The relationship between DPOAE results and 1000 Hz tympanometry are compared in the following section. DPOAEs are a reliable indicator of middle ear pathology, although studies have reported DPOAEs to be recorded in the presence of mild conductive pathology (Baldwin, 2006:418; Margolis et al., 2003:384-385; Rhodes et al., 1999:800; Yeo, Park, Park et al., 2002:797). Comparing 1000 Hz tympanometry to DPOAEs enables the validation of high frequency immittance measures in the infant population (Baldwin, 2006:418).

DPOAEs were used as the gold standard for normal middle ear functioning (Baldwin, 2006:418; Margolis et al., 2003:384-385), and the efficiency of tympanometry was thus compared to DPOAE recordings. Positive results, as measured by a DPOAE pass result and a peaked 1000 Hz tympanogram, are indicative of normal middle ear transmission (Swanepoel et al., 2007:50). Negative results, as measured by a DPOAE refer result and a 1000 Hz tympanogram with no peak, are indicative of possible middle ear pathology (Swanepoel et al., 2007:50). Positive and negative correspondences between DPOAE results and 1000 Hz tympanometry were evaluated for three age groups of infants, namely zero to 26 weeks, 27 to 52 weeks, and 53 to 87 weeks. This was done as there is currently a lack of standardized normative data for high frequency immittance measures in young infants (Swanepoel et al., 2007:50). Positive and negative correspondences between DPOAE and high frequency immittance results for ears of infants aged zero to 26 weeks, 27 to 52 weeks, and 53 to 87 weeks are displayed graphically below in figure 4.12.

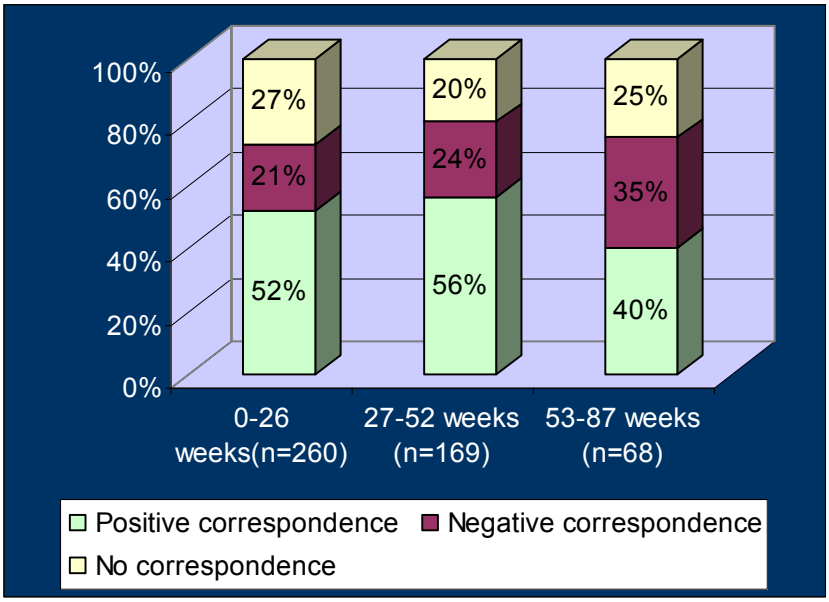

FIGURE 4.12 Comparing positive and negative correspondences between DPOAE and 1000 Hz tympanometry results at various infant ages

The above figure displays a 73% correspondence rate between DPOAE results and 1000 Hz tympanometry results in infants zero to 26 weeks, an 80% correspondence rate in infants 27 to 52 weeks, and a 75% correspondence rate in infants 53 to 87 weeks. According to Fisher's two-sided exact test (Leedy & Ormrod, 2005:274) there is a strong statistically significant relationship between DPOAE results and 1000 Hz tympanometry results for all three age groups ($p<0.0001$). This confirms reports documenting 1000 Hz tympanometry to be effective in determining the middle ear status of the infant population (Margolis et al., 2003:384; Kei et al., 2003:22; Swanepoel et al., 2007:50).

Furthermore, it is important to consider the group of infants that showed no correspondence between DPOAE and 1000 Hz tympanometry results. In infants aged zero to 26 weeks, 10.7% of ears (n=28) had a peaked 1000 Hz tympanogram but absent DPOAEs. 2.4% of ears (n=4) showed a peaked 1000 Hz tympanogram and absent DPOAEs in the age group of infants 27 to 52 weeks. The same pattern of peaked 1000 Hz tympanograms and absent DPOAEs was present in 10.2% of ears in infants aged 53 to 87 weeks. These results indicate a possible sensorineural component, as DPOAEs are dependent on integrity of the outer hair cells of the cochlea, whereas tympanometry is dependent on normal middle ear functioning (Prieve & Fitzgerald, 2002:441; Wiley & Stoppenbach, 2002:169). The absence of DPOAE recordings in the face of normal middle ear functioning may therefore indicate possible sensorineural pathology. Another possible explanation for these results is the fact that ears may have presented with a mild form of middle ear pathology, resulting in DPOAE refer results, as DPOAEs are an indicator of middle ear pathology (Baldwin, 2006:418). Tympanometry was also affected by the middle ear pathology, but a peak on the tympanogram may still have been present (Wiley & Stoppenbach, 2002:169).

Also forming part of the group of infants with no correspondence between DPOAE and 1000 Hz tympanometry results, are those ears with a DPOAE pass result, but an absent 1000 Hz tympanometric peak. This pattern was evident in 16.5% of ears (n=43) in infants aged zero to 26 weeks, in 17.1% of ears (n=29) in infants aged 27 to 52 weeks, and in 14.7% of ears (n=10) in infants aged 53 to 87 weeks. This may be attributed to the fact that high frequency tympanometry has been reported to be more sensitive to middle ear pathology in infants than DPOAE recordings (Rhodes et al., 1999:804). DPOAEs have been reported present, although reduced in amplitude, in some cases of mild middle ear effusion (Baldwin, 2006:418). Infants may therefore have displayed a milder degree of middle ear pathology, strong enough to affect the 1000 Hz tympanograms, but too weak to obliterate DPOAEs completely.

Much doubt has been cast on the accuracy of 226 Hz tympanometry in accurately assessing the middle ear system in young infants (Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:21; Rhodes et al., 1999:800). Low frequency tympanometry has been shown to be inefficient in identifying middle pathology in infants younger than seven months, and results in high false-positive test results (Swanepoel et al., 2007:50; Baldwin, 2006:418; Rhodes et al., 1999:800). High frequency immittance measures have been suggested to be more accurate and reliable in assessing the mass-dominated middle ear system of young infants (Margolis et al., 2003:384; Kei et al., 2003:22; Swanepoel et al., 2007:50). This study therefore investigated the relationship between 1000 Hz tympanometry and DPOAEs, 226 tympanometry and DPOAEs, and compared 226 Hz and 1000 Hz tympanometry, in infants younger than seven months. Results of this investigation are displayed below in figure 4.13.

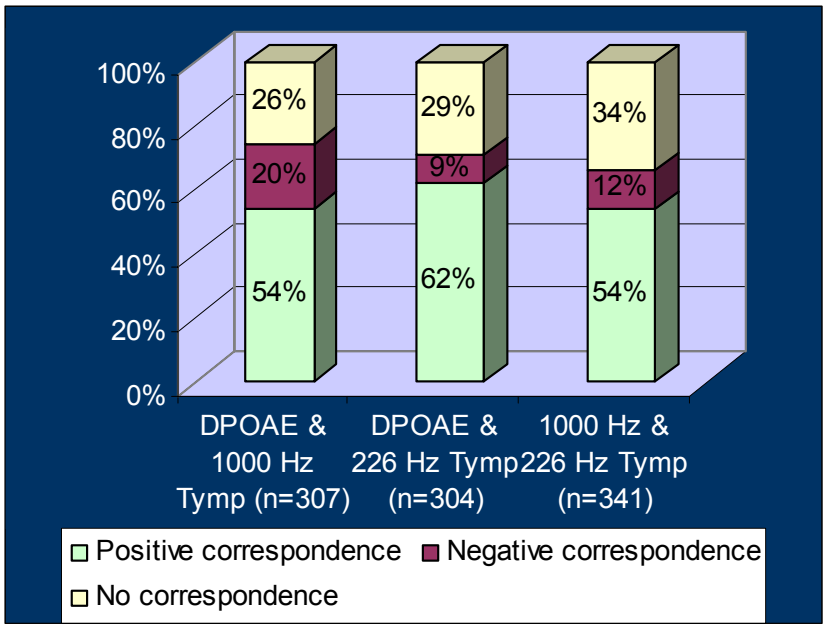

FIGURE 4.13 Comparing correspondences between DPOAE, 1000 Hz tympanometry and 226 Hz tympanometry results in infants younger than 7 months

Figure 4.13 displays that DPOAE and high frequency immittance results have a 74% correspondence rate. DPOAE and low frequency immittance results have a 71% correspondence rate, and high and low frequency immittance results have a 68% correspondence rate. According to the Fisher's two-sided exact test there is a statistically significant relationship between all three of the above DPOAE and tympanometry comparisons ($p<0.0001$). It is important to note that there was an 8% higher positive correspondence rate between DPOAEs and 226 Hz tympanometry than DPOAEs and 1000 Hz tympanometry. An 11% higher negative correspondence between DPOAEs and 1000 Hz tympanometry than DPOAEs and 226 Hz tympanometry was also observed. The higher negative correspondence between DPOAEs and 1000 Hz tympanometry reflects the increased accuracy with which 1000 Hz tympanometry is able to identify middle ear pathology in young infants when compared to 226 Hz tympanometry

(Margolis et al., 2003:384; Kei et al., 2003:22; Baldwin, 2006:418; Rhodes et al., 1999:800).

Furthermore, the Logistic regression procedure (Leedy & Ormrod, 2005:274) was performed in order to determine whether, according to the above results, high frequency and low frequency immittance measures could be used to predict DPOAE results in infants younger than seven months. According to the Logistic regression procedure only 1000 Hz tympanometry is able to statistically significantly predict DPOAE results for infants younger than seven months ($p<0.0001$). These findings are in accordance with current literature, reporting 1000 Hz tympanometry to be more effective than 226 Hz tympanometry in accurately assessing middle ear status of infants younger than seven months (Baldwin, 2006:425; Swanepoel et al., 2007:50).

4.3.7 Normative admittance data (mmho) for 1000 Hz tympanometry

Current literature reports a lack of normative data for high frequency 1000 Hz tympanometry (Swanepoel et al., 2007:50; Margolis et al., 2003:385; Kei et al., 2003:22; Palmu, Puhakka, Huhtala et al., 2001:178). This study collected a significant amount of data on high frequency tympanometry, and therefore aimed to compile normative admittance and pressure data for 1000 Hz tympanometry in three age groups of infants: zero to 26 weeks, 27 to 52 weeks, and 53 to 87 weeks. Normal middle ear functioning was controlled for by a DPOAE pass result, as this was considered the gold standard of middle ear functioning in the current study (Baldwin, 2006:418; Margolis et al., 2003:384-385). Table 4.4 presents normative admittance data (mmho) for all ears of subjects aged zero to 26 weeks, 27 to 52 weeks, and 53 to 87 weeks, who passed DPOAEs and had a peaked 1000 Hz tympanogram.

TABLE 4.4 1000 Hz normative admittance values (mmho) for various infant age groups (n=191)

Variables	Infants 0-26 w (n=110)	Infants 27-52 w (n=55)	Infants 53-87 w (n=26)
Mean	1.09	1.47	1.96
Standard Deviation	0.85	1.04	3.25
Maximum	4.01	4.04	4.01
Minimum	0.02	0.03	0.06
95th Percentile	2.87	3.71	3.80
50th Percentile Median	0.90	1.35	1.09
5th Percentile	0.08	0.07	0.07

Mean peak admittance values were shown to increase with increasing infant age, ranging from 1.09 mmho in infants aged 0 to 26 weeks to 1.96 mmho in infants 53 to 87 weeks. This increase in peak admittance values with increasing infant age may be attributed to the growing size of the middle ear. The range of admittance values for the lower limit (5th percentile) were 0.07 mmho to 0.08 mmho across infant age groups. The range of admittance values for the upper limit (95th percentile) was 2.87 mmho to 3.80 mmho across infant age groups. The median values ranged between 0.90 mmho and 1.35 mmho. These results indicate a general increase in peak admittance values with increasing infant age (Swanepoel et al., 2007:54). Results of admittance values (mmho) for various infant age groups are displayed graphically below in figure 4.14.

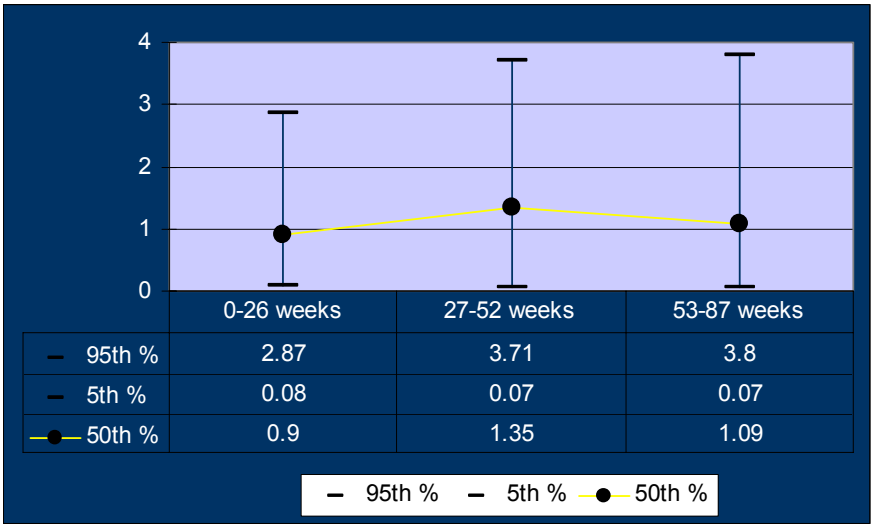

FIGURE 4.14 Age specific peak admittance norms for infants (n=191 ears)

Peak admittance values recorded with a 1000 Hz probe tone in the current study will be compared to various other studies documenting normative admittance values for 1000 Hz tympanometry. Numerous differences exist from study to study, and these are compared below in table 4.5.

TABLE 4.5 Comparison of normative admittance values (mmho) for 1000 Hz tympanometry recorded in various studies

	Current study	**Swanepoel et al., 2007**	**Margolis et al., 2003**	**Kei et al., 2003**
Infant ages	0-87 weeks	0-4 weeks	0-4 weeks	0-1 weeks
Infant population	NICU infants	General newborn population	NICU infants	General newborn population
Type of admittance recording	Compensated	Uncompensated	Compensated	Compensated
5^{th} %	0.07 - 0.08	1.2 - 1.5	1.3	0.39
95^{th} %	2.87 - 3.8	3.4 - 3.8	3.4	1.95 - 2.28
50^{th} %	0.9 - 1.35	2.0 - 2.3	2.1	1.04 - 1.16

Table 4.5 displays the following: Peak admittance values found in the current study are somewhat smaller than those reported in a recent study conducted by Swanepoel et al. (2007:53). Swanepoel et al. (2007:53) report higher median peak admittance values in a study conducted on a cohort of neonatal ears, in infants aged zero to four weeks. Their findings indicate median peak admittance values ranging between 1.8 mmho and 2.39 mmho, which are higher peak admittance values than those found in the current study (Swanepoel et al., 2007:53). Results of the study conducted by Swanepoel et al. (2007:51) however, reflect uncompensated admittance values. Results of the current study reflect compensated values, whereby the distance between the tympanic membrane and the probe tip are taken into account and ear canal effects on the measurement of admittance values are extracted. This may account for differences in peak admittance values between the study conducted by Swanepoel et al. (2007:51) and the current study.

A study conducted by Margolis et al. (2003:385) aimed to compile normative data for NICU infants aged zero to four weeks of age. Margolis et al. (2003:385) report a 5th percentile mean admittance value of 1.3 mmho, a 50th percentile of 2.1 mmho, and a 95th percentile of 3.4 mmho. These values are slightly greater than the ones found in the current study. The study by Margolis et al. (2003:385) was however, conducted on infants with a mean age of 3.9 weeks. Infants were therefore younger than those participating in this study. Furthermore, infants aged zero to four weeks have not had sufficient time to adjust to the external environment. During this adjustment period the external ear canal is cleared of prenatal material and filled with air (Margolis et al., 2003:389). This may in part account for differences between the current study and that of Margolis et al. (2003:389).

Kei et al. (2003:22) conducted a study which aimed to compile normative 1000 Hz tympanometry data for normal neonates aged one to six days. Peak

compensated static admittance values were reported with a 5th percentile of 0.39 mmho, and a 95th percentile ranging between 1.95 and 2.28 mmho (Kei et al., 2003:25). Whilst their 5th percentile peak admittance value is somewhat greater than that obtained in the current study, the 95th percentile documented by Kei et al. (2003:25) is smaller than the value of the current study. Differences between the two studies may be attributed to differences in infant ages, as the study by Kei et al. (2003:22) was conducted on neonates aged one to six days, whilst the current study had a greater age range of participating infants. Furthermore, the current study was conducted on high-risk NICU infants, whilst that of Kei et al. (2003:22) was conducted on full term normal neonates with no high-risk histories. Owing to the increased ages of infants participating in the current study, and the fact that it was conducted on high-risk NICU infants, the participants were more likely to have had previous episodes of Otitis Media (Swanepoel et al., 2007:50). This may also account for the differing peak admittance values of the current study when compared to that of Kei et al. (2003:25).

The conclusion that may be drawn from the differences in peak admittance values of the current study when compared to previous reports documenting 1000 Hz immittance norms is the following: Normative data for 1000 Hz tympanometry varies between full term infants and high risk NICU infants. This is reflected in the fact that greater 95th percentile admittance values were recorded for NICU infants in the current study and in that of Margolis et al. (2003:385), when compared to the study of Kei et al. (2003:25) conducted on full term infants. Differences between various infant age groups also exist, and need to be taken into consideration when compiling 1000 Hz tympanometry norms. The 5th and 50th percentile values recorded for infants participating in the current study, aged zero to 87 weeks, were smaller than those recorded for infants aged zero to four weeks participating in the studies conducted by Margolis et al. (2003:385) and Kei et al. (2003:25).

Results of admittance values (mmho) for ears that had unpeaked 1000 Hz tympanograms and a DPOAE refer result were also compiled, in order to compare admittance values of ears with abnormal middle ear functioning to normative admittance values controlled for by a DPOAE pass result and a peaked 1000 Hz tympanogram. Figure 4.15 below graphically displays admittance values of ears that had a DPOAE refer result for various infant age groups.

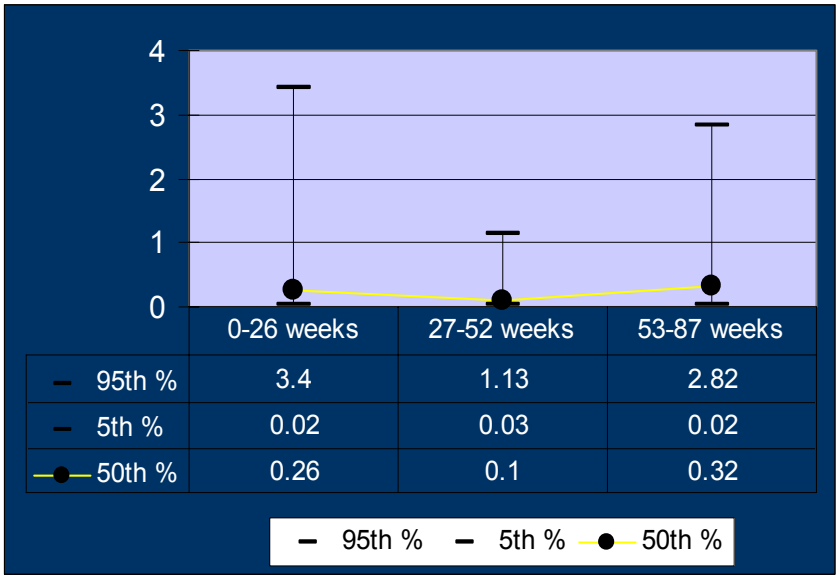

FIGURE 4.15 Age specific distribution of admittance values for infants according to abnormal DPOAE results (n=89 ears)

Median peak admittance values for ears that had abnormal middle ear functioning ranged between 0.1 and 0.32 mmho for various infant age groups. These values are consistently lower than the median peak admittance values for ears with normal middle ear functioning, as described above. The 5th percentile, as well as the 95th percentile peak admittance values of ears with abnormal middle ear functioning, were also smaller than those values of ears with normal middle ear functioning. High frequency peak admittance values for ears with abnormal middle ear functioning are therefore valuable in clarifying false positive

screening results due to middle ear pathology (Swanepoel et al., 2007:55). Although the general trend observed in the current study was that peak admittance values for ears with abnormal middle ear functioning were smaller than those of ears with normal middle ear functioning, admittance values did overlap. This fact needs to be taken into consideration when using peak admittance values to clarify false positive screening results due to middle ear pathology (Swanepoel et al., 2007:55). In order to determine whether middle ear pathology is present or not, peak admittance values should therefore be viewed in combination with pressure values.

4.3.8 Normative pressure data (daPa) for 1000 Hz tympanometry

Current literature also reports a lack of normative data for pressure values (daPa) for 1000 Hz tympanometry (Swanepoel et al., 2007:50; Margolis et al., 2003:385; Palmu et al., 2001:178). Normative pressure values (daPa) were therefore compiled for various age groups, controlled for by a DPOAE pass result and a peaked 1000 Hz tympanogram. Table 4.6 presents normative pressure data (daPa) for all ears of subjects aged zero to 26 weeks, 27 to 52 weeks, and 53 to 87 weeks.

TABLE 4.6 1000 Hz normative pressure values (daPa) for various infant age groups

Variables	Infants 0-26 w (n=124)	Infants 27-52 w (n=65)	Infants 53-87 w (n=29)
Mean	-9.24	7.63	-13.38
Standard Deviation	108.07	93.85	128.11
Maximum	204	200	199
Minimum	-393	-393	-383
95th Percentile	155	156	192
50th Percentile Median	0	9	2.3
5th Percentile	-190	-149	-383

Mean pressure values ranged from -13.38 daPa to 7.63 daPa across the three infant age groups analyzed in this study. The range of pressure values for the lower limit (5th percentile) was -383 daPa to -149 daPa across infant age groups. The range of pressure values for the upper limit (95th percentile) was 155 daPa to 192 daPa across infant age groups. The median pressure values ranged from 0 daPa to 9 daPa across infant age groups. Infants in the 53 to 87 week age group were found to have the greatest pressure ranges when compared to infants aged zero to 26 weeks, and infants aged 27 to 52 weeks. Results of normative pressure values (daPa) obtained in the current study are displayed graphically in figure 4.16 for various infant age groups.

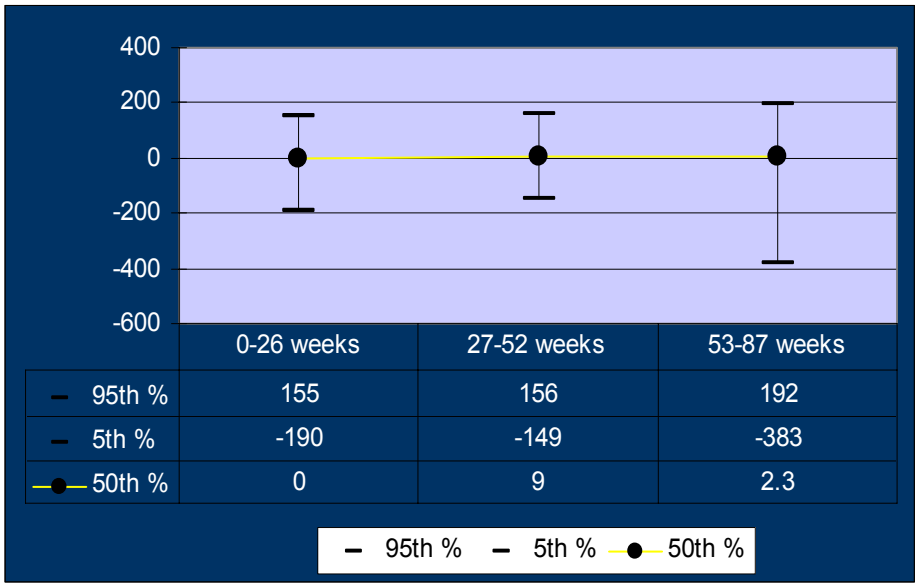

FIGURE 4.16 Age specific pressure norms for infants (n=218 ears)

Figure 4.16 shows that pressure values found in the current study have a greater range, when compared to those of recent literature (Swanepoel et al., 2007:53; Margolis et al., 2003:385; Kei et al., 2003:25). This may be attributed to the fact that the studies conducted by Swanepoel et al. (2007:53) and Kei et al. (2003:22) were conducted on full term neonatal ears of infants aged zero to four weeks, whilst the current study was conducted on NICU infants' ears aged zero to 87

weeks. Although the study by Margolis et al. (2003:385) was also conducted on a sample of NICU infants, the mean age of these infants was 3.9 weeks, which is much younger than participants of the current study.

Results of pressure values (daPa) for ears that had a DPOAE refer result were also compiled, in order to compare pressure values of ears with abnormal middle ear functioning to normative pressure values controlled for by a DPOAE pass result and a peaked 1000 Hz tympanogram. Figure 4.17 below graphically displays pressure values of ears that had a DPOAE refer result for various infant age groups.

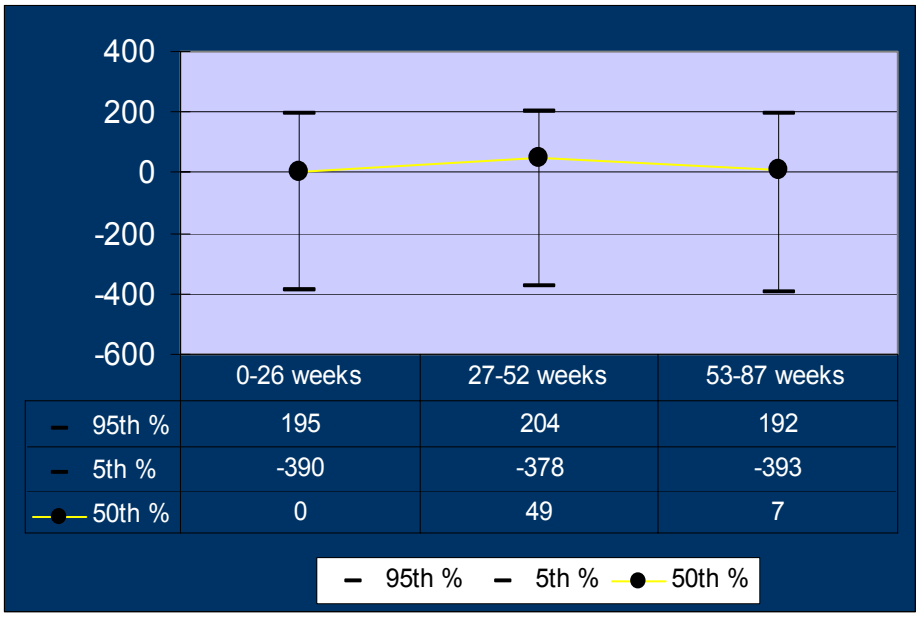

FIGURE 4.17 Age specific pressure distribution for infants with abnormal DPOAE results (n=101 ears)

Median pressure values for ears that had abnormal middle ear functioning ranged between 0 and 49 daPa for various infant age groups. These values were greater than the median pressure values for ears with normal middle ear functioning. The 95th percentile pressure values of ears with abnormal middle ear

functioning were also greater than those values of ears with normal middle ear functioning. The most significant difference observed between pressure values of ears with normal and abnormal middle ear functioning, is the fact that the 5th percentile pressure values of ears with abnormal middle ear functioning were more negative than those of ears with normal middle ear functioning. The tympanic peak pressure point was determined by measuring the highest peak on the tympanograms, regardless of whether the tympanogram was peaked or unpeaked. This resulted in the recording of pressure values which may fall within normal range, despite flat tympanometric configurations.

An important observation made by comparing pressure values for ears with normal and abnormal middle ear functioning, is the fact that there were clear differences in pressure values between normal and abnormal middle ear functioning in infants aged zero to 52 weeks. However, the pressure range for ears aged 53 to 87 weeks was very similar for ears with both normal and abnormal middle ear functioning. The value of normative 1000 Hz pressure values for infants aged 53 to 87 weeks is therefore questionable, and should not be used to draw conclusions about middle ear functioning.

Deviations from atmospheric pressure (0daPa), as evidenced by the 5th percentile values and the 95th percentile values in this sample of ears with abnormal middle ear functioning, are attributed to middle ear effusion and possible Eustachian tube dysfunction (Fowler & Shanks, 2002:184). Negative pressure peaks are associated with a high incidence of recurrent Otitis Media (Fowler & Shanks, 2002:184). NICU infants have a known increased incidence of Otitis Media when compared to infants from the well baby nursery (Yoon et al., 2003:355-356; Swanepoel et al., 2007:49), thereby justifying the pressure values recorded in this sample of ears with abnormal middle ear functioning.

High frequency immittance pressure values for ears with abnormal middle ear functioning are therefore valuable in clarifying false positive screening results due

to middle ear pathology (Swanepoel et al., 2007:55). Pressure values for ears with abnormal middle ear functioning will deviate further from atmospheric pressure than the pressure values obtained from ears with normal middle ear functioning (Fowler & Shanks, 2002:184). This is evidenced by the current study showing the 5th percentile pressure values of ears with abnormal middle ear functioning to be more negative than those of ears with normal middle ear functioning. This makes middle ear pressure values a valuable tool in clarifying middle ear functioning.

4.3.9 Follow-up return rates for infants enrolled in the IHS program

In order to evaluate the effectiveness of an IHS program, it is important that follow-up rates of the program are also described. According to the JCIH (2000:10) IHS programs should achieve at least a 70% follow-up rate in order to be considered effective. Results of follow-up rates of the current study are discussed below.

Of the 57 infants who failed their initial hearing screening, based on a DPOAE or AABR refer result in at least one ear, 56% of infants (n=32) returned for follow-up screening. 44% of infants (n=25) of the initial 57 that failed the initial hearing screening were therefore lost to follow-up. This is a low follow-up return rate when compared to the standard of 70% set by the JCIH (2000:10). Of the 72 infants that passed their initial hearing screening, 69% (n=50) returned for routine follow-up screening. Therefore 31% of infants that passed the initial hearing screening bilaterally were lost to follow-up. This follow-up rate falls marginally short of the recommended 70% follow-up rate by the JCIH (2000:10). Follow-up rates for routine and non-routine IHS visits are compared graphically below in figure 4.18.

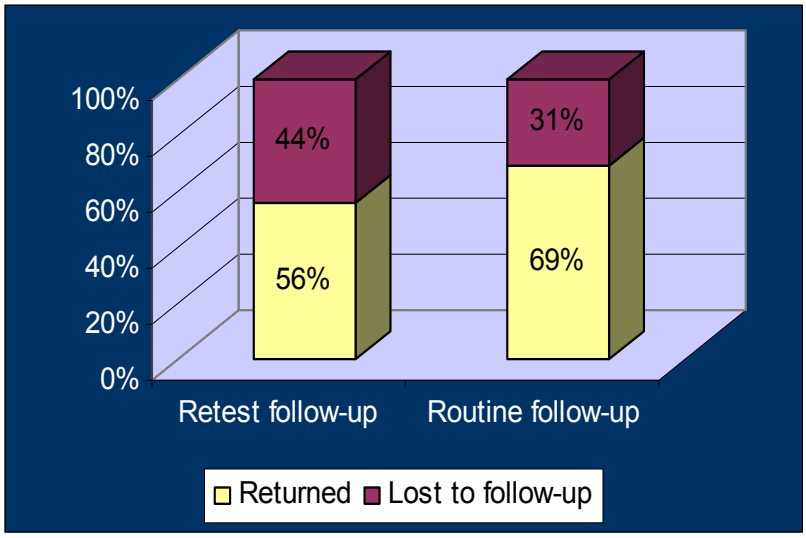

FIGURE 4.18 Comparison of follow-up rates between routine and non-routine follow-up IHS

Figure 4.18 displays the fact that 13% less infants returned for non-routine or retest follow-up hearing screening visits than infants who returned for routine follow-up hearing screening. This is a significantly higher routine follow-up rate. Reasons for this may be attributed to the following: NICU infants often have an array of complex neurological and other health problems, not associated with, but compounded by hearing loss (Roizen, 1999:50). Many of these medical conditions are life-threatening, whilst hearing loss is not. A large percentage of infants may therefore have had medical conditions requiring urgent attention. In such cases hearing loss may not rank highly on these infants' list of priorities in terms of medical care, thereby resulting in poor IHS program retest follow-up rates.

A study conducted by Van Straaten et al. (2003:334-335) evaluated an IHS program implemented in the Netherlands. This study had a 99% follow-up rate of all infants enrolled in the IHS program. These are significantly higher follow-up rates when compared to the follow-up rates achieved in the current study. Poor follow-up rates obtained in the current may be attributed to various factors.

Infants enrolled in the current study were screened as part of an outpatient clinic three months after hospital discharge, whilst infants enrolled in the study conducted by Van Straaten et al. (2003:334-335) were screened as part of an IHS program prior to hospital discharge. Infants and their caregivers in the current study were furthermore required to travel far distances to the IHS program at the secondary hospital, and were dependent on unreliable transport systems (Mukari, Tan & Abdullah, 2006:848). Infants were also subject to stressors resultant of poverty and unemployment, as well as other life threatening conditions (Roizen, 1999:50). The conclusion that can be drawn from the above is that hearing screening conducted prior to hospital discharge results in a much higher yield of infants screened, and proves to be a more effective protocol to follow for IHS in a developing country like South Africa, although it is not always possible.

Another study by Mukari, Tan & Abdullah (2006:847) evaluated follow-up rates of infants enrolled in hospital based IHS in Malaysia. The follow-up rates of infants in that study proved to be 57% (Mukari, Tan & Abdullah, 2006:847). These follow-up rates are more comparable to those obtained in the current study. Poor follow-up rates evidenced in the current study and in the study conducted by Mukari, Tan & Abdullah (2006:847) may be similar, owing to the fact that both South Africa and Malaysia are developing countries, and therefore both display similar difficulties for infants in returning for hearing screening. Barriers to follow-up IHS visits as described by Mukari, Tan & Abduallah (2006:848), and as evidenced in the current study include the following: Geographical distance and transportation proves to be a problem in returning for IHS follow-up visits (Mukari, Tan & Abdullah, 2006:848). Many infants participating in the current study had to travel long distances to the secondary hospital and had to rely on public transport.

In the current study, the IHS program implemented at the secondary hospital was a pilot project, and is the first of its kind to be implemented for high-risk NICU

infants in South Africa. The fact that it was a pilot project, and was not yet well established, may explain the low follow-up rate of infants. Further reasons for poor follow-up may be the fact that caregivers had little knowledge about the importance of infant hearing screening (Olusanya, Luxon & Wirz, 2004:288; Olusanya, 2001:142; Swanepoel, Hugo & Louw,, 2005d:12), given the fact that IHS is not yet widespread in South Africa and is therefore not yet common practice (Swanepoel, Hugo & Louw, 2006:1242). A study conducted by Swanepoel, Hugo & Louw, (2006:1245) at immunization clinics in South Africa reported a 40% follow-up rate of infants who failed their initial hearing screening. This is a lower follow-up rate than the 56% follow-up rate in the current study. The poor follow-up rates evidenced in the study conducted by Swanepoel, Hugo & Louw, (2006:1245) substantiate the above argument, as this study too was a pilot study, and the IHS program was not yet well established.

Lastly, follow-up rates for IHS are heavily dependant on maternal education levels (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:79). Caregivers who did not complete high school are less likely to complete the hearing screening follow-up process than more educated caregivers (Prince et al., 2003:1204). At least 32% of mothers participating in this study did not complete high school. This too may have contributed to the poor follow-up rates evidenced in the current study.

It is important to note however, that timely follow-up of infants enrolled in IHS programs has been reported to increase over time (Lieu, Karzon & Mange, 2006:70; Mehl & Thomson, 2002:3-4). A study conducted by Lieu, Karzon & Mange (2006:70) investigated the follow-up of hearing screening referrals in a group of NICU infants in the USA. Results of this study revealed that timely follow-up did increase over time (Lieu, Karzon & Mange, 2006:70). Mehl & Thomson (2002:3-4) reported follow-up rates of infants enrolled in IHS programs in Colorado to have increased from 48% to 76% over a period of eight years. Follow-up rates of infants enrolled in the IHS program of the current study are

therefore also expected to increase over time, as the IHS program was only initiated in 2004 and is currently still a pilot project. It is therefore recommended that maternal awareness regarding the importance of IHS be raised through educational initiative. This should serve to steadily increase the follow-up rates of the IHS program over time, and to overcome the obstacles preventing infants from returning for follow-up hearing screening.

4.3.10 Time of follow-up for non-routine hearing screening

When evaluating the follow-up rate of an IHS program, it is furthermore necessary to assess when the participants followed-up. The success of EHDI programs depends on timely follow-up (JCIH, 2000:4). Of the 32 infants who returned for follow-up screening after having failed their initial hearing screening, the time when they returned was recorded for 30 infants. Infants who failed the hearing screening due to suspected middle ear pathology were requested to follow-up in 12 weeks time, whilst infants who failed the hearing screening for reasons other than middle ear pathology were requested to follow-up in three weeks time. Figure 4.19 displays when in time (weeks), infants who failed their initial hearing screening, returned for a follow-up hearing screening visit.

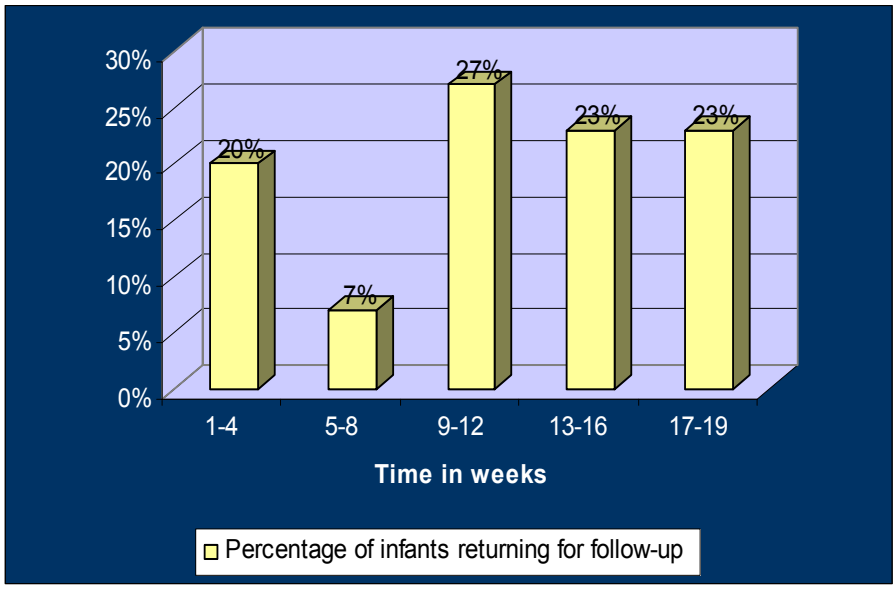

FIGURE 4.19 Time (weeks) when infants returned for retest follow-up visits after the initial hearing screening (n=30)

Figure 4.19 displays the fact that the largest number of infants, who returned for non-routine follow-up hearing screening, did so at nine to 12 weeks after their initial hearing screening (27%). This may be attributed to the large number of infants who failed their initial hearing screening due to suspected middle ear pathology, and who were therefore scheduled to return 12 weeks after their initial hearing screening. 23% of infants who returned for non-routine follow-up hearing screening did so at 13 to 16 weeks and 17 to 19 weeks after their initial hearing screening. This delay in timely follow-up cannot be accounted for in terms of scheduled follow-up appointments provided by the person conducting the hearing screening. However, caregivers from the sample participating in the current study often live far away from the secondary hospital, and often have transport which is unreliable. This may account for caregivers not always being able to bring their infant for follow-up hearing screening when scheduled. In addition to living far from the hospital, NICU infants have other complex medical problems (Roizen, 1999:50), which may have prevented them from following-up when scheduled.

Furthermore, 20% of infants returned for non-routine follow-up hearing screening at one to four weeks after their initial hearing screening. This group of infants is reasoned to be the group who failed their initial hearing screening due to reasons other than middle ear pathology. Possible sensorineural pathology may have been suspected, or the infant may have been too restless to test reliably. This group of infants was scheduled to return after three weeks, and accounts for a large portion of the 20% of infants who returned after one to four weeks. 7% of infants returned after five to eight weeks. These infants had a delay in timely follow-up, and were scheduled to return after three weeks. Reasons for this delay in timely follow-up are again attributed to geographical distance from the IHS and possible difficulty with transport, or poor maternal education levels (Lieu, Karzon & Mange, 2006:70; Prince et al., 2003:1204).

As the IHS program at the secondary hospital is a pilot study and infants are not screened before hospital discharge, the majority of infants only receive their initial hearing screening at three months of age, making it impossible for the current IHS program to be meeting the standards set by the JCIH (2000:4), whereby a permanent hearing loss should be identified by the age of three months. However, this model was used owing to limited time.

4.3.11 Time of follow-up for routine hearing screening

Infants who passed the initial hearing screening were scheduled to return for a routine follow-up hearing screening visit in three months time. The time of routine follow-ups for infants who passed the initial hearing screening was analyzed in order to determine whether the IHS program was meeting the standard of three monthly routine follow-up visits as scheduled. Of the 72 infants that passed their initial hearing screening visit, 69% of infants (n=50) returned for a routine follow-up visit. Figure 4.20 displays how long after their initial IHS visit infants returned for a routine follow-up visit.

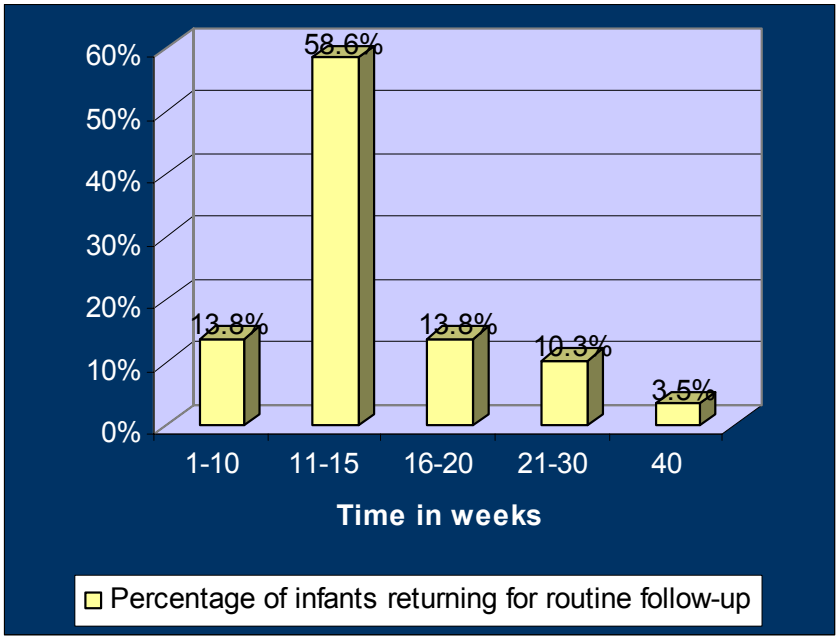

FIGURE 4.20 Time (weeks) when infants returned for routine follow-up visits after the initial hearing screening (n=50)

Figure 4.20 displays the fact that the largest percentage of infants (58.6%) returned for routine follow-up hearing screening 11 to 15 weeks, or approximately three months after their initial visit. This is to be expected, as infants were scheduled to return for follow-up three months after their initial hearing screening visit. 13.8% of infants returned for routine follow-up one to ten weeks after their initial visit, and an additional 13.8% of infants returned 16 to 20 weeks after their initial visit. 10.3% of infants returned after 21 to 30 weeks, whilst 3.5% returned after 40 weeks. Infants who returned for routine follow-up visits which did not fall within their three monthly scheduled visits may be attributed to the fact that infants often live far away from the secondary hospital. Geographical distance and unreliable transport systems may account for the fact that not all infants returned for routine follow-up screening at their scheduled times. When initiating IHS programs in developing contexts, such as South Africa, it is therefore important to ensure that programs are flexible, in order to accommodate infants returning for follow-up hearing screening at any time.

4.3.12 Results of non-routine follow-up IHS

In order to determine program effectiveness, it was not sufficient to look only at follow-up rates. Hearing screening results of those infants who did return for follow-up also needed to be evaluated. This enabled the researcher to determine how many infants presented with actual auditory impairment. Results of infants' follow-up visits will be discussed in terms of DPOAE and AABR screening results. Results of follow-up screening for infants who failed their initial hearing screening are displayed graphically below in figure 4.21.

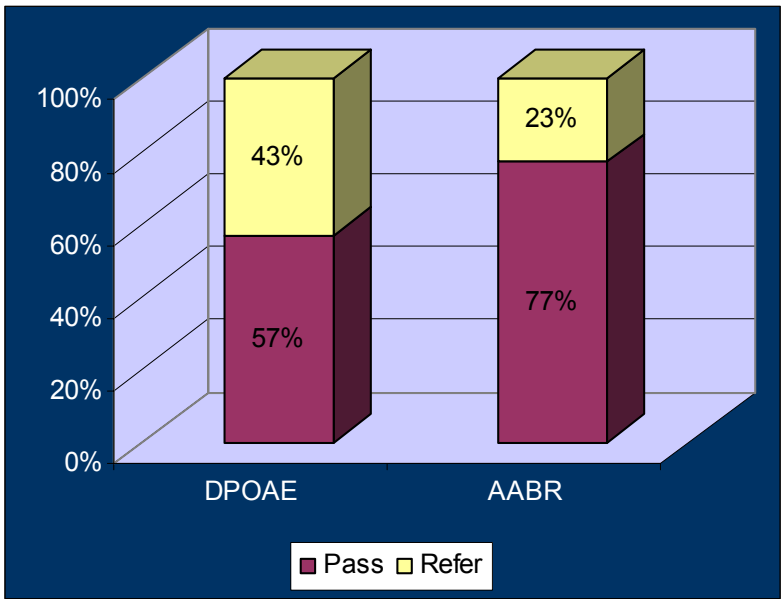

FIGURE 4.21 DPOAE and AABR results for ears on retest follow-up screening

Of the 32 infants who did return for a follow-up visit after having failed their initial hearing screening, based on DPOAE and/or AABR refer results, DPOAEs were recorded for 89% of ears (n=56). 57% of the 56 ears (n=32) received a DPOAE pass result, whilst 43% of ears (n=24) had a refer result. AABR screening was performed on 47% of ears (n=30) on infants' follow-up visit. A reason for AABR

screening not being performed on all infants, was the fact that the screening protocol only necessitated an infant to pass AABR screening once, in order for it not to be repeated again. Of the 30 ears that had AABR screening performed on their follow-up visit, 77% of ears (n=23) had a pass result, whilst 23% of ears (n=7) had a refer result.

Figure 4.21 displays the fact that AABR screening had a 20% higher pass rate than DPOAE screening on infants' follow-up visits. This may be attributed to the fact that DPOAEs are sensitive to middle ear pathology (Rhodes et al., 1999:800). If the reason for infants failing their initial hearing screening was middle ear pathology, this pathology may not yet have cleared up on their return visit. Alternatively, infants may have acquired middle ear pathology in the interim between their initial and their follow-up hearing screening visit. NICU infants have been shown to display a greatly increased incidence of middle ear pathology when compared to infants from the well-baby nursery (Yoon et al., 2003:355-356; Swanepoel et al., 2007:49; Rhodes et al., 1999:800).

Figure 4.21 furthermore shows that 23% (seven out of 30 ears) of infants who had an AABR on their follow-up visit did not pass the AABR. When these results are compared to the results of the number of infants who were referred for diagnostic audiological testing, the results correlate. Four infants (eight ears) were referred for diagnostic testing, whilst seven ears did not pass the AABR screening on either their initial or follow-up hearing screening.

Table 4.7 displays detailed AABR and DPOAE screening results of the follow-up visit of infants who failed their initial hearing screening.

TABLE 4.7 AABR and DPOAE screening results of non-routine follow-up hearing screening (n=57)

	AABR not performed bilaterally	Refer AABR bilaterally	Pass AABR unilaterally	Pass AABR bilaterally
DPOAE not performed bilaterally	29	0	0	0
Refer DPOAE bilaterally	4	3	1	3
Pass DPOAE unilaterally	0	0	0	2
Pass DPOAE bilaterally	9	0	0	6

Table 4.7 displays AABR and DPOAE results of infants that referred their initial hearing screening, regardless of whether they returned for follow-up or not. If infants did not return for follow-up the result of their follow-up visit was merely recorded as not having been performed. Twenty-nine of the 57 infants that failed their initial hearing screening did not have AABR and DPOAE screening performed bilaterally on their next follow-up IHS visit. This is resultant of infants being restless during the screening procedure. Six of the 32 infants (18.75%) that returned for follow-up passed AABR and DPOAE screening bilaterally, indicating definite normal hearing. Three of the 32 infants (9.4%) referred AABR and DPOAE screening bilaterally, indicating a possible sensorineural pathology. Three infants (9.4%) passed AABR screening bilaterally but referred DPOAE screening bilaterally, whilst two infants (6.25%) passed AABR screening bilaterally but referred DPOAE screening unilaterally. These results indicate possible middle ear pathology, thereby leading to poor bilateral pass results on both AABR and DPOAE screening.

The conclusion that can be drawn from the above discussed results is that middle ear pathology is prevalent in the current sample of high-risk NICU infants. Middle ear pathology may therefore potentially lead to high false positive results if not included as a target disorder being screened for. These results give further weighting to literature reports documenting an increased incidence of middle ear pathology in the NICU population (Yoon et al., 2003:355-356; Swanepoel et al., 2007:49; Rhodes et al., 1999:800). Furthermore, the age of infants at screening has a big influence on the viability of the screening procedures, as older infants are more restless and less cooperative during screening. This is particularly true for AABR screening, which requires infants to be still for a longer period of time than DPOAE screening, and needs to be taken into consideration when deciding on an optimal screening protocol for a particular infant population.

4.3.13 Summary of sub-aim #2: Aspects of effectiveness and efficiency of an IHS program for infants admitted to the NICU

Results of sub-aim #2 are summarized below in table 4.8.

TABLE 4.8 Summary of results of sub-aim #2

IHS program coverage rate

- The AABR, DPOAE and immittance screening coverage rate achieved in the current study falls short of the 95% coverage rate benchmark set by the JCIH (2000:6), although DPOAE and immittance screening achieved a better coverage rate than AABR screening.
- AABR screening is not useful in infants age 10 to 20 weeks or older, owing to restlessness on the part of the infant.
- DPOAE and immittance screening is not useful in infants who are younger than 38 weeks gestational age, as the size of their ear canal is too small for the probe tip.

AABR and DPOAE screening results

- Higher referral rates were recorded on both AABR and DPOAE screening when comparing the current study to previous research reports. Reasons for this may be that infants in the current study were older than in previous studies, as well as the fact that this study had a high incidence of middle ear pathology resulting in false positive screening results.

Comparing low frequency and high frequency immittance screening results

- A higher rate of peaked and double peaked 226 Hz tympanograms than 1000 Hz tympanograms were recorded in both infants younger and older than seven months. This may be attributed to the fact that 226 Hz tympanometry has a poor sensitivity for detecting middle ear pathology.

TABLE 4.8 Summary of results of sub-aim #2

Comparing DPOAE and immittance screening results

- According to the Logistic regression procedure 1000 Hz tympanometry is the only screening procedure which is able to statistically significantly predict DPOAE screening results in infants younger than seven months. This is in accordance with reports documenting 1000 Hz tympanometry to be more useful than 226 Hz tympanometry in infants younger than seven months.

Compiling normative admittance (mmho) and pressure (daPa) data for 1000 Hz tympanometry

- Normative admittance and pressure data varies between the general newborn population and the NICU population, as well as between different infant age groups.
- High frequency admittance and pressure norms for ears with abnormal middle ear functioning are useful in clarifying false positive screening results due to middle ear pathology.

Follow-up rates of infants enrolled in the IHS program

- Follow-up rates of both routine and non-routine screening fall short of the 70% benchmark stipulated by the JCIH (2000:10).
- Poor follow-up rates may be attributed to geographical distance; unreliable transport systems; medical conditions requiring more urgent care than hearing loss; the fact that the current study was a pilot program; and poor maternal education levels.
- Follow-up rates are expected to improve over time.

4.4 RESULTS AND DISCUSSION OF SUB-AIM #3: THE INCIDENCE OF AUDITORY IMPAIRMENT IN INFANTS ADMITTED TO THE NICU

The third sub-aim of this study aimed to describe the incidence of auditory pathology in infants enrolled in the IHS program. Auditory impairment discussed in this sub-aim includes permanent congenital hearing loss, as well as middle ear pathology. In order to present results of auditory impairment, data collected during infant hearing screening using DPOAEs, AABR, and immittance screening, as well as diagnostic hearing testing was analyzed.

4.4.1 The incidence of permanent congenital hearing loss according to diagnostic testing

Infants who failed the hearing screening repeatedly were referred for a diagnostic audiologic evaluation using diagnostic ABR testing. Four out of 129 infants (3%),

two of whom were male and two of whom were female, were referred for a diagnostic audiologic evaluation after having failed the hearing screening, and after middle ear pathology had been ruled out. The JCIH (2000:10) recommends that an IHS program should have a 4% or lower referral rate for diagnostic audiologic evaluation. The 3.1% diagnostic referral rate of the current study is therefore in accordance with the benchmarks set by the JCIH (2000:10).

Two of the four infants referred for a diagnostic evaluation were found to have bilateral sensorineural hearing loss, whilst the other two infants were diagnosed with bilateral auditory neuropathy. The two infants with sensorineural impairment displayed a profound degree of hearing loss bilaterally. The two infants with auditory neuropathy were diagnosed according to diagnostic ABR results and DPOAE testing. The incidence of permanent congenital hearing loss as found in this sample of subjects is displayed below in figure 4.22.

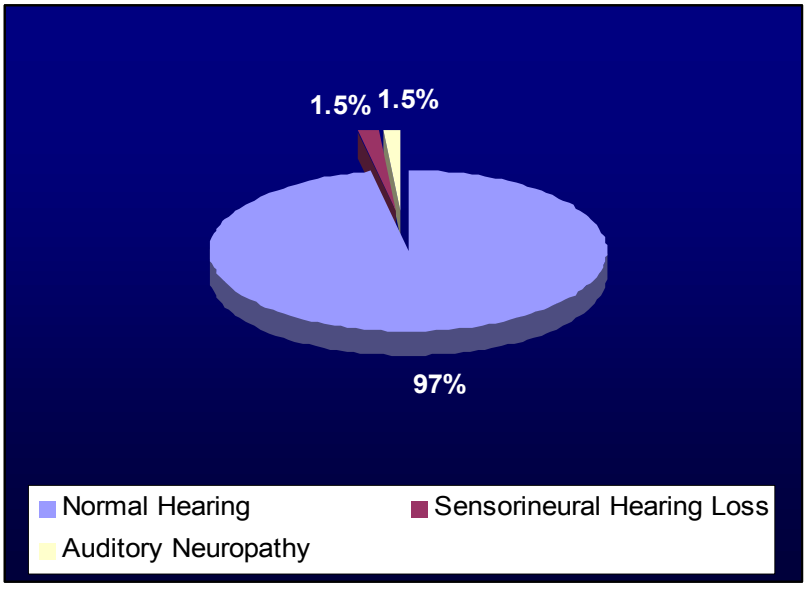

FIGURE 4.22 Hearing status of the total sample of infants (n=129)

Figure 4.22 displays the fact that 3% (n=4) of the total sample were found to have sensory or neural impairment. The literature estimates 0.15%-0.6% of the

general newborn population to be born with congenital hearing loss (Northern & Downs, 2002:267; Olusanya, Luxon & Wirz, 2004:288). This incidence is reported to be 10 to 20 times higher in the high-risk NICU population (Yoon et al., 2003:355; Yoshinaga-Itano, 2004:462). The sample of NICU infants in the current study displayed a 3% incidence rate of permanent congenital hearing loss, which is in keeping with the literature.

However, 44% of infants (n=25) who failed their initial hearing screening, and who were scheduled to return for follow-up hearing screening, were lost to follow-up. The high incidence rate of permanent congenital auditory impairment identified in the current sample of infants is estimated to be even higher, if the percentage of infants who were lost to follow-up is taken into account. When infants who failed the hearing screening but did not return for follow-up (n=25) are included in an estimated incidence rate, the incidence rate of congenital hearing loss is estimated to be 3.75% in the total sample of infants participating in the current study. The estimated 3.75% incidence rate of congenital impairment in the total sample was extrapolated from the 3% incidence rate recorded in the current study, as well as by adding an estimated 3% incidence rate from infants who did not return for follow-up (n=25).

A study conducted by Meyer et al. (1999:903) reports the incidence of permanent hearing loss in the NICU population to be 2.3%. Hess, et al. (1998:81) report the incidence of permanent bilateral hearing loss in an at-risk neonate cohort to be 1.4%. The incidence rate of permanent hearing loss documented in this study is therefore greater than the incidence rate documented in the above two studies conducted in developed countries. The current study's incidence rate of permanent hearing loss is nevertheless still in accordance with reported incidence rates in the NICU population, although it is at the upper limit when taking the estimated actual incidence into account, including those infants who did not return for follow-up (Yoon et al., 2003:355; Yoshinaga-Itano, 2004:462; Northern & Downs, 2002:267).

The current study made use of a very small sample size (n=129), and generalizations about the incidence rate of permanent congenital hearing loss in the wider NICU population can thus not be made. The higher incidence rate of permanent bilateral hearing loss identified in the current study can furthermore be attributed to the following: Infants enrolled in the IHS program were from a developing South African context. Poor socio-economic conditions have been reported to be associated with an increased incidence of auditory impairment (Olusanya, Luxon & Wirz, 2004:296). A further reason for the increased incidence of permanent congenital hearing loss found in the current study is the fact that infants were exposed to additional environmental risk indicators, not prevalent in developed countries. Poor maternal education levels and a high incidence of prenatal HIV/AIDS exposure were identified as important environmental risk indicators in this sample of infants. These are risk indicators for the success of the IHS program, as well as for auditory impairment (Prince et al., 2003:1204; Swanepoel, Hugo & Louw, 2005c:79-80).

Literature currently reports controversy surrounding the incidence of auditory neuropathy, and research regarding the actual incidence of auditory neuropathy is limited (D'Agostino & Austin, 2004:348). According to the JCIH (2000:20), the exact incidence of auditory neuropathy is still largely unknown. Sininger (2002:195-196) estimates the incidence in infants born with risk factors for auditory neuropathy to be 2.3 per 1000 infants. This translates to a 0.23% incidence rate in NICU infants, as these infants are said to display risk factors for auditory neuropathy (Franck, Rainey, Montoya et al., 2002:226). D'Agostino & Austin (2004:348) report the incidence of auditory neuropathy in infants at risk for hearing loss to be one in 433, which also translates to a 0.23% incidence rate. A study conducted by Berg et al. (2005:936) estimated the incidence of auditory neuropathy to be 24.1% in a cohort of NICU infants, based on a profile of failed AABR and passed DPOAE screening. This is a greatly increased incidence rate of auditory neuropathy when compared to previous studies, but was however,

estimated based on screening results only. Infants identified as having a profile of auditory neuropathy based on failed AABR and passed DPAOE screening possibly displayed a degree of auditory immaturity or transient neurologic abnormality. This may have contributed to the AABR refer results, and a subsequent high suspected incidence of possible auditory neuropathy (Berg et al., 2005:937).

The current study identified two out of 129 infants (1.5%) with auditory neuropathy. These results show a significantly greater incidence of auditory neuropathy when compared to the studies conducted by Sininger (2002:195-196) and D'Agostino & Austin (2004:348), and provide further weighting to the fact that the exact incidence of auditory neuropathy has not yet been established. Reasons for the increased incidence of auditory neuropathy recorded in the current study may be attributed to the small sample size (n=129), which limited generalizations of results to the greater NICU population. Possible additional reasons for the high incidence of auditory neuropathy recorded in the current study include the following: The most common risk factors for auditory neuropathy are hyperbilirubenemia at levels requiring an exchange transfusion, and a family history of auditory neuropathy (JCIH, 2000:20; Rapin & Gravel, 2003:716; Sininger, 2002:195; Hood et al., 2002:205). Infants identified as having auditory neuropathy in the current study did not have hyperbilirubenemia, although it was not recorded whether they had a family history of auditory neuropathy or not.

Infants with auditory neuropathy did display additional risk factors for auditory neuropathy, such as prematurity, low birth weight, and exposure to aminoglycosides (D'Agostino & Austin, 2004:347; Berg et al., 2005:933; Sininger, 2002:195). Environmental risk indicators for hearing loss, such as poor socio-economic conditions could furthermore have indirectly contributed to the high incidence rate of auditory neuropathy identified in the current study (Olusanya, Luxon & Wirz, 2004:296) A limitation of the current study in terms of the

incidence rate of auditory neuropathy identified, is the fact that this study had a limited sample size, when compared to previous studies documenting the incidence rate of auditory neuropathy. Generalization of the incidence rate of auditory neuropathy reported in this study is therefore limited (Leedy & Ormrod, 2005:207).

A profile of risk indicators present in the two infants diagnosed with sensorineural impairment and the two infants diagnosed with auditory neuropathy is presented in table 4.7 below.

TABLE 4.7 A profile of infants with auditory neuropathy and sensorineural impairment

PROFILE	INFANT 1 WITH AUDITORY NEUROPATHY	INFANT 2 WITH AUDITORY NEUROPATHY	INFANT 1 WITH SENSORINEURAL IMPAIRMENT	INFANT 2 WITH SENSORINEURAL IMPAIRMENT
Gestational Age	29 weeks	33 weeks	36 weeks	38 weeks
Birth Weight	1176 g	2840 g	1800 g	3580 g
HIV exposure	Not exposed	Not exposed	Exposed	Declined testing
APGAR at 1 minute	5/10	2/10	0/10	5/10
APGAR at 5 minutes	8/10	2/10	9/10	7/10
Days ventilated	0	2	3	2
Hyperbilirubenemia	No	No	No	No
Hyperbilirubenemia & exchange transfusion	No	No	No	No
Ototoxic medication exposure	Penicillin & Amikacin for 1 day	Information unavailable	Penicillin & Amikacin for 1 day	Penicillin & Amikacin for 1 day
Additional diagnoses	Hydrocephalus	Birth asphyxia & respiratory distress syndrome	Birth asphyxia & Intra-uterine growth retardation	Unknown

Table 4.7 displays the fact that neither of the two infants diagnosed with auditory neuropathy had hyperbilirubenemia, which is the most common risk factor for auditory neuropathy (Rapin & Gravel, 2003:716; Sininger, 2002:195; Hood et al., 2002:205). Both infants with auditory neuropathy had a low birth weight, and one of them had birth asphyxia. Exposure to ototoxic medication was evident in one of the two infants with auditory neuropathy, whilst the information regarding

exposure to ototoxic medication was unavailable for the other infant. These too, are risk indicators for auditory neuropathy (D'Agostino & Austin, 2004:347; Berg et al., 2005:933; Sininger, 2002:195). Neither of the two infants presenting with auditory neuropathy had prenatal HIV/AIDS exposure.

Table 4.7 also describes the two infants diagnosed with sensorineural impairment. One of the infants with sensorineural impairment displayed intra-uterine growth retardation, birth asphyxia, and was small for gestational age. This infant was furthermore HIV/AIDS exposed. The other infant with sensorineural impairment had no obvious risk indicators for hearing loss, other than being ventilated for two days. The HIV/AIDS status of this infant's mother was however unknown, as the mother declined testing. Additional discharge diagnoses were not recorded.

4.4.2 Middle ear status of infants on their initial hearing screening visit

The middle ear status of participants' ears was determined from results of high frequency immittance measures and DPOAEs. High frequency immittance measures are sensitive to middle ear functioning in young infants (Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:22). Low frequency tympanometry was not used to analyze the middle ear status of infants on their initial IHS visit, as it has been proven to result in high false negative rates in infants younger than seven months and therefore has a poor sensitivity rate for detecting middle ear pathology (Swanepoel et al., 2007:50; Rhodes et al., 1999:804). Infants participating in the current study were between the ages of zero and 18 months, with a mean age of 13.81 weeks (±6.69 SD) on their initial IHS visit. DPOAEs are sensitive to middle ear pathology, and were necessary to validate results on tympanometry measures (Yeo, et al., 2002:797). The middle ear status of participants' ears on their initial visit to the IHS program will be discussed below in terms of these screening tests. Ears that did not have both DPOAE screening and high frequency immittance measures conducted on participants' initial hearing screening visit were not included in this analysis, as

both DPOAE and high frequency immittance results were considered necessary to determine definite middle ear functioning. According to these criteria 199 ears were analyzed to determine their middle ear status.

In order to be classified as having normal middle ear functioning, ears were required to pass DPOAEs and have peaked 1000 Hz tympanograms (Swanepoel et al., 2007:50). Ears were classified as having definite middle ear pathology if they had a refer DPOAE result and unpeaked 1000 Hz tympanograms (Swanepoel et al., 2007:50). Ears were classified as having a milder form of middle ear pathology if they passed DPOAE screening but had unpeaked 1000 Hz tympanograms. DPOAEs have been reported in the presence of middle ear fluid (Baldwin, 2006:418). If ears failed DPOAEs but had peaked 1000 Hz tympanograms it was attributed to either sensorineural impairment, or a mild form of middle ear pathology. Figure 4.23 below graphically displays the middle ear functioning of participants' ears on their initial visit to the IHS program.

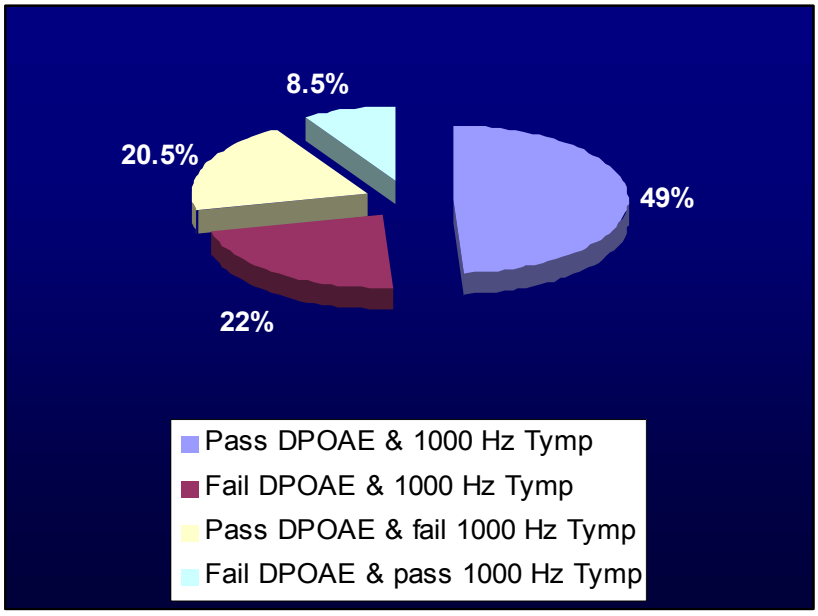

FIGURE 4.23 Middle ear status of participants' ears on their initial visit (n=199)

Figure 4.23 displays the fact that 49% of ears (n=97) had definite normal middle ear functioning, as they passed DPOAEs and had peaked 1000 Hz tympanograms (Swanepoel et al., 2007:50). 22% of ears (n=44) had definite middle ear pathology, as they failed DPOAEs and had unpeaked 1000 Hz tympanograms (Swanepoel et al., 2007:50). An additional 20.5% of ears (n=41) had a milder form of middle ear pathology, as they passed DPOAEs but had unpeaked 1000 Hz tympanograms (Baldwin, 2006:418). A total of 42.5% of ears (n=85) therefore displayed a form of middle ear pathology on their initial IHS visit. The remaining 8.5% of the sample of ears (n=17) displayed peaked 1000 Hz tympanograms but failed the DPOAE screening. DPOAEs are dependent on the integrity of the outer hair cells of the cochlea, whilst tympanometry is dependent on normal middle ear functioning (Prieve & Fitzgerald, 2002:441; Wiley & Stoppenbach, 2002:169). Absent DPOAEs in the presence of peaked 1000 Hz tympanometry may indicate possible sensorineural impairment. Alternatively a mild form of middle ear pathology may have been present, which caused absent DPOAEs but did not cause 1000 Hz tympanograms to have a flat configuration.

In order to calculate an estimated incidence rate of middle ear pathology on infants' initial visit to the IHS, middle ear status needs to be evaluated for all infants, and not only for ears. Infants were classified as having bilateral middle ear pathology if they failed both DPOAEs and 1000 Hz immittance screening in both ears (Swanepoel et al., 2007:50). Infants were classified as having normal middle ear functioning if they passed both DPOAEs and 1000 Hz immittance screening in both ears (Swanepoel et al., 2007:50). In order to be classified as having unilateral middle ear pathology, infants were required to fail both DPOAEs and 1000 Hz immittance screening in at least one ear (Swanepoel et al., 2007:50). Infants who failed DPOAEs but passed 1000 Hz immittance screening were classified as having a milder form of middle ear pathology (Baldwin, 2006:418). Infants who passed DPOAEs but failed 1000 Hz immittance screening were also classified as having a milder form of middle ear pathology

(Baldwin, 2006:418). Figure 4.24 graphically displays the incidence of middle ear pathology in the sample of infants who had both DPOAE and 1000 Hz immittance screening conducted on their initial visit (n=96).

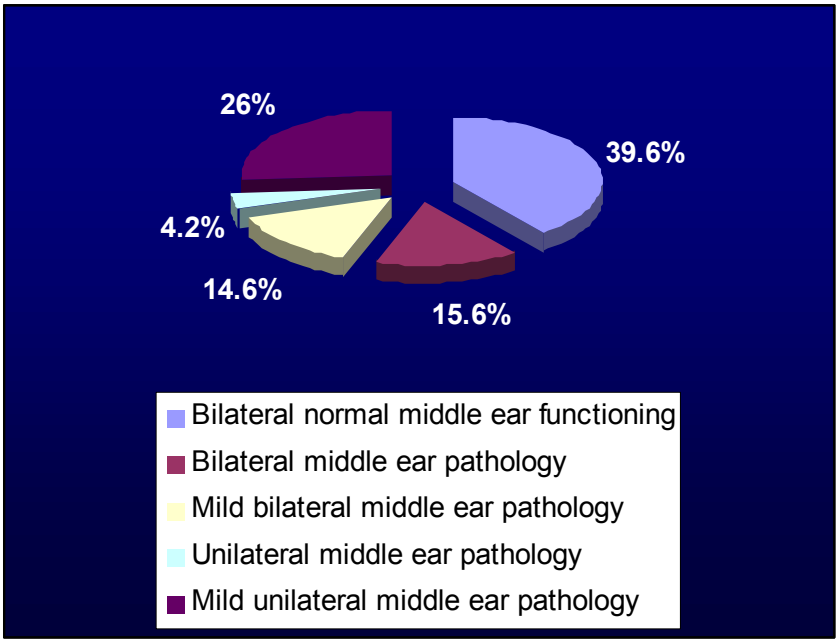

FIGURE 4.24 The incidence of middle ear pathology on infants' initial IHS visit (n=96)

Figure 4.24 shows that 39.6% of infants (n=38) had normal middle ear functioning on their initial IHS visit. 15.6% of infants had definite bilateral middle ear pathology, whilst 4.2% of infants had definite unilateral middle ear pathology. An additional 14.6% of infants had a milder form of bilateral middle ear pathology, whilst 26% of infants had mild unilateral middle ear pathology. A total of 30.2% of infants (n=29) had bilateral middle ear pathology, whilst an additional 30.2% of infants (n=29) had unilateral middle ear pathology. A total incidence rate of definite middle ear pathology was therefore recorded as 19.8%, whilst an incidence rate of 60.4%, which included milder forms of middle ear pathology, was recorded on infants' initial IHS visit.

The high incidence of middle ear pathology recorded in this sample of infants may be accounted for by the fact that NICU infants have an increased incidence of middle ear pathology when compared to infants from the well baby nursery (Yoon et al., 2003:355-356; Swanepoel et al., 2007:49). Middle ear pathology is furthermore more prevalent in developing countries, such as South Africa, than in developed countries, as a result of environmental risk factors that these infants are exposed to (Olusanya, Luxon & Wirz, 2004:296). Infants in the current study are all NICU graduates, and all live in a developing South African context, thereby providing an explanation for the high incidence of abnormal middle ear functioning in this sample of infants.

The conclusion that can be drawn from the above findings is that, in order to adequately address the auditory needs of high-risk NICU infants in developing contexts, such as South Africa, middle ear pathology needs to be included as a target disorder to be screened for. Long-term conductive pathology has been reported to lead to eventual sensorineural impairment, placing these infants with chronic middle ear pathology at risk for developing sensorineural impairment (Boone, Bower & Martin, 2006:395). Inclusion of middle ear pathology as a target disorder to be screened for in IHS programs is therefore a necessary and essential step in practicing preventative Audiology.

4.4.3 The incidence of middle ear pathology over time in infants who had normal middle ear functioning on their initial IHS visit

In order to determine how many ears developed middle ear pathology over time, after having had normal middle ear functioning on their initial IHS visit, DPOAE and 1000 Hz immittance results were analyzed on the infants' second visit to the IHS program. Of the 97 ears that passed both DPOAE screening and 1000 Hz immittance screening on infants' initial visit to the IHS program, 48 ears had both DPOAE and 1000 Hz immittance screening conducted on their second visit to the IHS program. Results of DPOAE and high frequency immittance screening for the above ears are graphically displayed in figure 4.25 below.

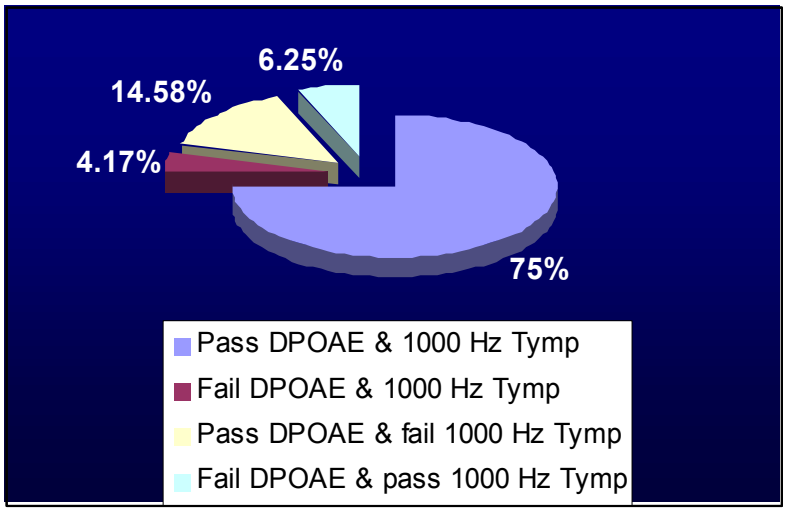

FIGURE 4.25 Middle ear status over time of ears that had normal middle ear functioning on their initial visit (n=48)

Figure 4.25 displays the fact that 75% of ears (n=36) that had both DPOAE and 1000 Hz immittance screening conducted on their second visit, and that had normal middle ear functioning on their initial visit, passed both DPOAE and immittance screening. 25% of ears (n=12) failed either both DPOAE and immittance screening, or one of the two on their second IHS visit. These results indicate that 25% of ears (n=12) that had normal middle ear functioning on their initial IHS visit developed some form of middle ear pathology over time, as measured on their second IHS visit (Baldwin, 2006:418; Swanepoel et al., 2007:50). This 25% of ears is said to have developed some form of middle ear pathology over time, as they either failed both DPOAEs and 1000 Hz immittance screening, or they failed DPOAEs but passed 1000 Hz immittance screening (Baldwin, 2006:418; Swanepoel et al., 2007:50). Alternatively they may also have passed DPOAEs and failed 1000 Hz immittance screening in order to be classified as having a milder form of middle ear pathology (Baldwin, 2006:418). It is however, important to note that the 6.25% of ears that failed DPOAEs but passed 1000 Hz immittance screening may have possibly presented with late-

onset or progressive hearing loss, and did not necessarily have middle ear pathology. The fact that 25% of ears developed middle ear pathology over time, in addition to at least 42.5% of ears being identified with middle ear pathology on their initial hearing screening visit, serves to further contribute to the high incidence of middle ear pathology in the current sample of infants.

In order to calculate an incidence rate of middle ear pathology over time, for infants who had normal middle ear functioning on their initial IHS visit, DPOAE and 1000 Hz immittance results were analyzed for infants. Of the 38 infants who, according to a DPOAE and 1000 Hz immittance pass result, had normal middle ear functioning on their initial IHS visit, 18 infants had both DPOAE and 1000 Hz immittance screening conducted on their second IHS visit. Infants were classified as having normal middle ear functioning if they passed both DPOAEs and 1000 Hz immittance screening (Swanepoel et al., 2007:50). Infants who failed both DPOAEs and 1000 Hz immittance screening were classified as having middle ear pathology (Swanepoel et al., 2007). If infants passed DPOAEs but failed 1000 Hz immittance screening, or if infants failed DPOAEs but passed 1000 Hz immittance screening, they were classified as having a milder form of middle ear pathology (Baldwin, 2006:418). Figure 4.26 displays the incidence of middle ear pathology over time, for those infants who had normal middle ear functioning on their initial IHS visit.

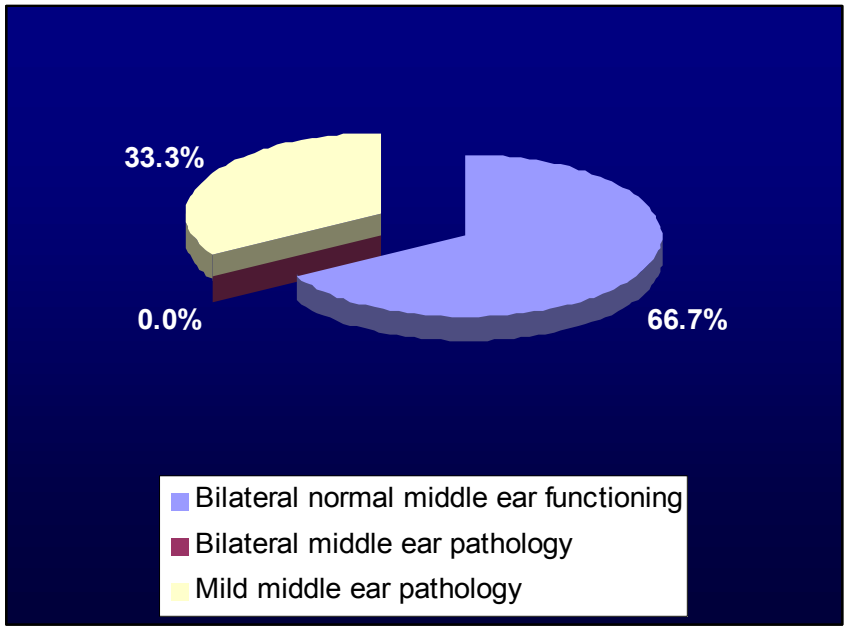

FIGURE 4.26 The incidence rate of middle ear pathology over time (n=18)

Figure 4.26 shows that 66.7% of infants (n=12) that had normal middle ear functioning on their initial IHS visit, again displayed bilateral normal middle ear functioning on their second IHS visit. No infants had bilateral middle ear pathology, whilst 33.3% of infants (n=6) displayed a milder form of middle ear pathology, based on DPAOEs and 1000 Hz immittance screening results.

In addition to the 60.4% of infants who displayed some form of middle ear pathology on their initial IHS visit, an additional 33.3% of the sample of infants who returned for follow-up IHS was identified with middle ear pathology. According to the results at the initial IHS visit and the follow-up of infants without middle ear pathology on their initial IHS visit, a 93.7% incidence rate of middle ear pathology was observed for this group of infants over a 15 week period. This calculated incidence rate of time does however, include both definite cases of middle ear pathology, as well as cases of milder forms of middle ear pathology. An incidence rate of middle ear pathology over time was also calculated only for infants who had definite middle ear pathology. No infants who had definite

normal middle ear functioning on their initial IHS visit had definite middle ear pathology on their second IHS visit. A 19.8% incidence rate of definite middle ear pathology was therefore recorded over a 15 week period.

These are significant findings, and careful consideration is thus necessitated when deciding on the target disorder to screen for in South African infants. Long-term conductive hearing loss can lead to eventual sensorineural hearing loss (Olusanya, 2001:143; 146). It is therefore essential that conductive hearing loss resultant of middle ear pathology be included as a target disorder to screen for in high-risk infants in South Africa. This view is supported by Mencher & De Voe (2001:17), who suggest a shift in target disorder for IHS programs in developing countries from permanent sensorineural hearing loss to long-term conductive hearing loss.

4.4.4 Comparing the incidence of transient middle ear pathology to chronic middle ear pathology

In order to differentiate between infants with transient middle ear pathology and those with chronic middle ear pathology, the DPOAE and 1000 Hz immittance results of infants who were classified as having middle ear pathology on their initial hearing screening visit were analyzed on infants' subsequent IHS visit. Twenty of the 44 ears that had middle ear pathology according to a DPOAE refer results and an unpeaked 1000 Hz tympanogram result on their initial IHS visit (Swanepoel et al., 2007:50) returned for a second IHS visit and had both DPOAEs and 1000 Hz tympanometry performed. This relatively small number of ears included in this analysis may be attributed to the fact that not all infants had both DPOAEs and 1000 Hz immittance measures performed on their second IHS visit, resultant of restlessness on the part of the infant, as well as the fact that not all infants who were classified as having middle ear pathology on their initial hearing screening visit returned for a follow-up visit. Figure 4.27 graphically displays the middle ear status of infants' ears on their second visit, after having had middle ear pathology on their initial hearing screening visit. The time period

over which transient versus chronic middle ear pathology was recorded ranged between one and 19 weeks.

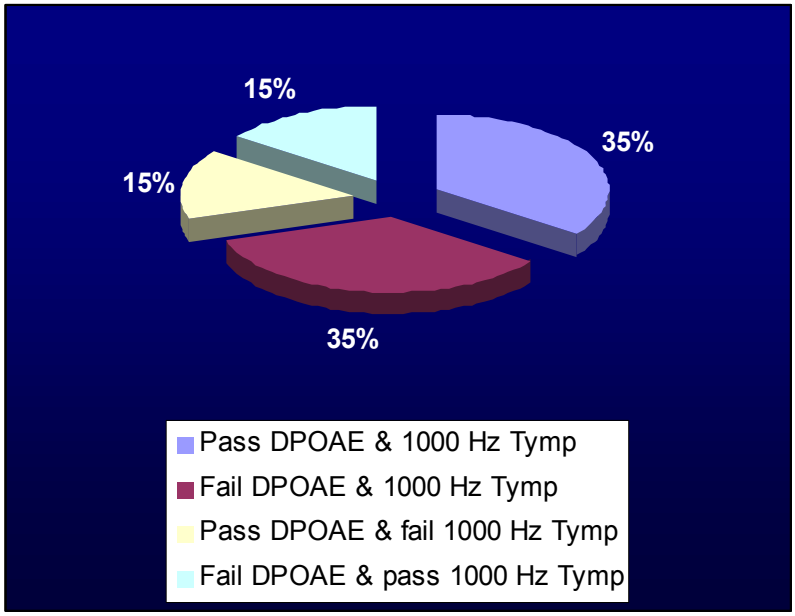

FIGURE 4.27 Differentiating between transient and chronic middle ear pathology for infants ears' that had middle ear pathology on their initial IHS visit (n=20)

Figure 4.27 displays the fact that 35% of ears (n=7) can be classified as having had transient middle ear pathology. According to DPOAE pass results and peaked 1000 Hz tympanograms, these ears had middle ear pathology on their initial hearing screening visit, but had normal middle ear functioning on their second visit. An additional 15% of ears (n=3) are those ears that had peaked 1000 Hz tympanograms but absent DPOAEs. This group of ears may be at risk for possible sensorineural impairment, as DPOAEs are dependent on cochlear integrity (Prieve & Fitzgerald, 2002:441; Wiley & Stoppenbach, 2002:169). They may however, also presented with a mild form of middle ear pathology, which prevented DPOAEs from being recorded, but did not produce unpeaked 1000 Hz tympanograms. If this 15% of ears is classified as having a mild form of middle

ear pathology, a total of 35% of ears displayed transient middle ear pathology. If the 15% of ears with absent DPOAEs and peaked 1000 Hz tympanograms is classified as having possible sensorineural impairment, a total of 50% of ears displayed transient middle ear pathology.

Thirty-five percent of ears (n=7) can be classified as having chronic middle ear pathology, after having again failed DPOAEs and having unpeaked 1000 Hz tympanograms on their second IHS visit. This is a significant number of ears presenting with chronic middle ear pathology. Long-term conductive pathology has been reported to lead to sensorineural impairment in some cases, placing these infants with chronic middle ear pathology at risk for developing sensorineural impairment (Boone, Bower & Martin, 2006:395). 15% of ears (n=3) that had middle ear pathology on their initial IHS visit had a DPOAE pass result but unpeaked 1000 Hz tympanograms on their second IHS visit. This indicates the possibility of middle ear pathology that is in the process of dissipating. This milder form of middle ear pathology may be too mild to obliterate DPOAEs, but significant enough to affect 1000 Hz tympanograms, as DPOAEs are at times recorded in the presence of mild middle ear pathology (Baldwin, 2006:418).

In order to calculate an incidence rate of transient versus chronic middle ear pathology, middle ear status had to be evaluated for infants, and not only for ears. Of the 19 infants that failed both DPOAEs and 1000 Hz immittance screening on their initial IHS visit, nine infants had both DPOAEs and 1000 Hz immittance screening performed on their second visit. This small number of infants that were used for this analysis limits the generalization of these results. Infants were classified as having chronic middle ear pathology if they failed both DPOAEs and 1000 Hz immittance screening in at least one ear (Swanepoel et al., 2007:50). Infants who failed DPOAEs but passed 1000 Hz immittance screening in at least one ear, were not able to be classified as having definite chronic or definite transient middle ear pathology, as middle ear pathology may still be present, but may also be dissipating (Baldwin, 2006:418). Furthermore,

infants who passed DPOAEs but failed 1000 Hz immittance screening were also classified as having either possible chronic or possible transient middle ear pathology. Infants who passed both DPOAEs and 1000 Hz tympanometry in both ears were classified as having transient middle ear pathology, as the middle ear pathology recorded on their initial IHS visit had cleared up by the time of their second IHS visit (Swanepoel et al., 2007:50). The incidence of chronic versus transient middle ear pathology is graphically displayed in figure 4.28.

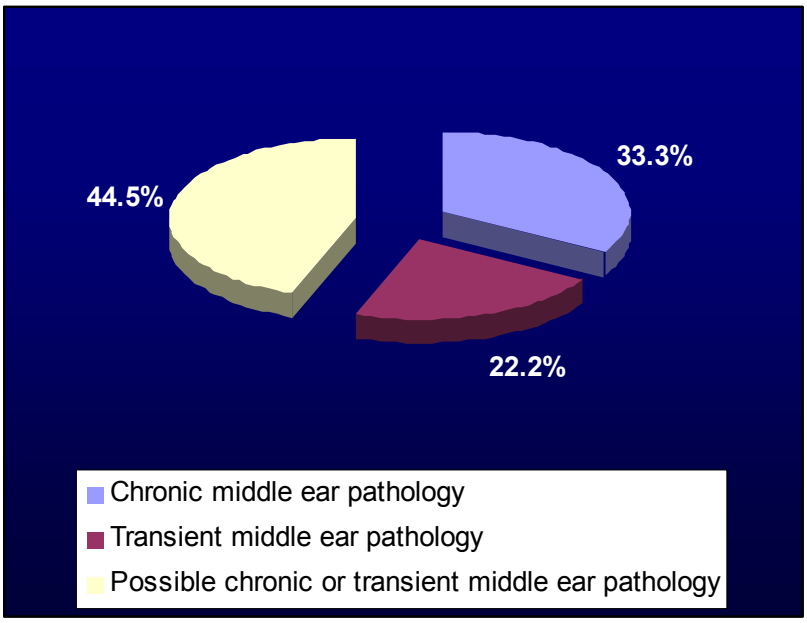

FIGURE 4.28 The incidence of chronic versus transient middle ear pathology (n=9)

Figure 4.28 displays the fact that 33.3% of infants (n=3) had chronic middle ear pathology, after again failing both DPOAEs and 1000 Hz immittance screening on their second IHS visit (Swanepoel et al., 2007:50). This is a high incidence rate of chronic middle ear pathology, and can be estimated to be even higher if those infants, whose middle ear pathology could not definitely be classified as being chronic or transient, are taken into consideration. 22.2% of infants (n=2) displayed normal middle ear functioning, according to a DPOAE and 1000 Hz

immittance pass result, and were thus classified as having had transient middle ear pathology. 44.5% of infants (n=4) had possible middle ear pathology according to DPOAE and 1000 Hz immittance results (Baldwin, 2006:418). These infants were thus classified as having possible chronic or transient middle ear pathology.

The high incidence of chronic middle ear pathology recorded in the current study provides further weighting for middle ear pathology to be included as a target disorder to be screened for in high-risk NICU infants in South Africa. This is necessary in order to prevent chronic middle ear pathology from eventually developing into sensorineural pathology (Boone, Bower & Martin, 2006:395).

4.4.5 Summary of sub-aim #3: The incidence of auditory impairment in infants admitted to the NICU

Results of sub-aim #3 are summarized below in table 4.10.

TABLE 4.10 Summary of sub-aim #3

The incidence of permanent congenital hearing loss according to diagnostic testing

- The 3.1% diagnostic audiological referral rate recorded in the current study is in accordance with the benchmarks set by the JCIH (2000:10).
- Two infants (1.5%) were identified as having sensorineural hearing loss, whilst two infants (1.5%) were identified with auditory neuropathy.
- The total incidence of permanent congenital hearing loss in the current sample is estimated to be 3.75% if those infants, who did not return for follow-up, are taken into account. The incidence of permanent congenital hearing loss in the current sample of infants is at the upper limits of the incidence rate reported in NICU infants in the literature.

Middle ear status of infants on their initial IHS visit

- A 60.4% incidence rate of middle ear pathology was identified on infants' initial IHS visit, including bilateral and unilateral pathology. This is a high incidence of middle ear pathology, which may be attributed to the fact that the current sample consisted of NICU infants, which have a reported higher rate of middle ear pathology than infants from the well baby nursery. Furthermore, infants in the current study are from a developing context, placing them at further risk for middle ear pathology.

The incidence of middle ear pathology over time in infants who had normal middle ear functioning on their initial IHS visit

- 66.7% of infants who had normal middle ear functioning on their initial IHS visit again displayed normal middle ear functioning on their second IHS visit. 33.3% of infants developed a mild form of middle ear pathology.

Summary of sub-aim #3 continued: The incidence of auditory impairment in infants admitted to the NICU

- The high incidence rate of middle ear pathology identified necessitates the inclusion of middle ear pathology as a target disorder to be screened for in high-risk NICU infants in a developing South African context.

Comparing the incidence of transient middle ear pathology to chronic middle ear pathology

- 33.3% of middle ear pathology was identified as being definite chronic middle ear pathology, whilst 22% was identified as being definite transient middle ear pathology. 44.5% of infants had possible middle ear pathology, and were thus classified as having either transient or chronic middle ear pathology.
- The high incidence of chronic middle ear pathology provides further weighting for the inclusion of middle ear pathology as a target disorder to be screened for in South Africa.

4.5 CONCLUSION

The current study described an IHS program for NICU infants at a secondary hospital in Gauteng, South Africa, in order to address the dearth of research on contextually relevant data for IHS in developing countries (Olusanya & Roberts, 2006:1; Swanepoel, Hugo & Louw, 2006:1242). The NICU is one of the platforms recommended for IHS by the HSPS Year 2002 (HPCSA, 2002:5), and no documented studies have described an IHS program for NICU infants in South Africa to date.

Results of this study revealed important factors which need to be taken into consideration when implementing IHS for NICU infants in South Africa. Risk indicators for auditory impairment stipulated by the JCIH (1994:155; 2000:19-20) were prevalent in this sample of infants. Additional environmental risk indicators for hearing loss unique to the South African context, such as prenatal HIV/AIDS exposure and poor maternal education levels were also identified, and therefore need to be included in a list of risk indicators for South African infants. Coverage rates using various hearing screening tests were not yet found to be optimal, but are expected to improve over time (Lieu, Karzon & Mange, 2006:70). Poor follow-

up rates of infants documented in the current study (JCIH, 2000:10) raise the urgent need for increasing maternal awareness on the importance of early identification of and intervention for hearing loss in South Africa (Olusanya et al., 2005:2; Northern & Downs, 2002:259). Furthermore, the most optimum screening protocol for use in young infants, in terms of immittance measures, was determined. The incidence of auditory impairment was also determined in this sample of infants, and revealed a high incidence of sensory, neural, and middle ear pathology. The high incidence of auditory impairment identified in the current study highlights the importance of implementing widespread IHS programs in South Africa, if the benefits of EHDI programs are to reach all South African infants. Results of this study provide a valuable contribution towards addressing the dearth of research on IHS for NICU infants in South Africa, and provide guidelines for the future implementation of IHS programs.

4.6 SUMMARY

This chapter provided a presentation and discussion of results obtained from this study. Results were presented according to the three sub-aims of the study, and were discussed by relating results to current literature. Finally a conclusion of the chapter was provided.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

AIM: To draw conclusions about the research, identify implications of the findings, critically evaluate the study, and make recommendations for further research.

5.1 INTRODUCTION

The developing world faces the challenge of absent or very limited early hearing detection and intervention (EHDI) services for infants and children with hearing loss. Limited EHDI services are resultant of healthcare funds being allocated to conditions which are considered to be more life-threatening than hearing loss (Olusanya, 2001:142; Swanepoel, Hugo & Louw, 2005a:14). It nevertheless remains an important priority for developing countries, such as South Africa, to afford children with hearing loss, equal opportunities in life. This is achievable by enrolling infants in EHDI programs (Swanepoel, Hugo & Louw, 2006:1245). Infants with hearing loss and no additional disabilities, who are identified early and enrolled in EHDI programs, have the potential to develop language and communication skills equivalent to their normal hearing peers (Yoshinaga-Itano, 2004:455). EHDI programs can therefore lead to long term economic returns for a country (Swanepoel, Delport & Swart, 2006:4). The current study aimed to address the scarcity of contextually relevant research on infant hearing screening (IHS) in South Africa, by describing the characteristics of an IHS program for high-risk NICU infants, one of the platforms recommended for IHS by the Hearing Screening Position Statement Year 2002 of the Health Professions Council of South Africa (Swanepoel, Hugo & Louw, 2005c:76; HPCSA, 2002:5).

This chapter aims to draw conclusions and make recommendations based on the findings of the current study, in order to contribute towards the lack of contextually relevant research on IHS for high-risk NICU infants in South Africa. Conclusions and recommendations based on the findings of this pilot study should serve to guide much needed further research on IHS in South Africa. Such research should serve to provide the highest possible level of EHDI service delivery for infants with hearing loss in South Africa.

5.2 CONCLUSIONS AND IMPLICATIONS

This was a pilot study which aimed to describe the characteristics of an IHS program for NICU infants in South Africa. Conclusions and implications deduced from the findings of the current study are presented in accordance with the three sub-aims below.

5.2.1 Conclusions and implications of sub-aim #1: Risk indicators for hearing loss in infants admitted to the NICU

Risk indicators for hearing loss, as identified by the JCIH (1994:155; 2000:19-20) were found to be prevalent in the sample population participating in this study. 43.9% of infants who failed their initial hearing screening had six or more risk factors, whilst 31% of infants who passed their initial hearing screening had six or more risk factors. This highlights the need for, and importance of, the widespread implementation of IHS programs for NICU infants. Additional environmental risk factors for hearing loss and for the success of EHDI programs were identified. Environmental risk factors for hearing loss and for the success of the IHS program included poor maternal education levels and prenatal HIV/AIDS exposure. At least 32% of mothers participating in this study did not complete high school. Prenatal HIV/AIDS exposure was present in at least 21% of the current sample of infants. Resultant of the fact that additional environmental risk

factors for hearing impairment were identified in the current study, South Africa requires an expanded risk indicator list for targeted IHS.

Risk indicators, such as poor maternal education levels and prenatal HIV/AIDS exposure are not exclusive to the NICU population, but are expected to be pervasive throughout the general newborn population in South Africa (Swanepoel, Hugo & Louw, 2005c:79; Swanepoel, Hugo & Louw, 2006:1242; Goldstein, Pretorius & Stuart, 2003:15). Research investigating the incidence of environmental risk indicators for hearing loss and the success of EHDI programs, is necessary in the well baby nursery in order to determine their exact incidence and the effect of environmental risk indicators on the incidence of auditory impairment. The urgent need for the implementation of IHS programs across the entire general newborn population in South Africa is thereby brought to the forefront.

5.2.2 Conclusions and implications of sub-aim #2: Aspects of effectiveness and efficiency of an IHS program for infants admitted to the NICU

Measures of effectiveness of the IHS program included the following: coverage rate using screening tests; AABR and DPOAE screening results; low frequency and high frequency immittance results; and follow-up rates of infants. The current study's coverage rates of infants, using various IHS procedures, fall short of the quality indicator set by the JCIH (2000:6), advocating that a 95% coverage rate should be achieved. A 67% coverage rate was achieved with AABR screening, and an 88% coverage rate was achieved with DPOAE screening. 93% of infants had immittance screening performed on their initial visit to the IHS program. Poor coverage rates are attributed to the following: AABR screening did not prove to be useful in infants aged ten to 20 weeks and older, due to restlessness on the part of the infant. DPOAE and immittance screening was not useful in infants who were younger than 38 weeks gestational age, due to the very small size of their ear canals, and possible amniotic fluid remaining in their ear canal.

The implications of these findings are that the age of infants enrolled in IHS programs need to be taken into account when conducting AABR, DPOAE and immittance screening procedures. According to coverage rates obtained in this study, AABR screening should be conducted on infants younger than ten weeks, in order to ensure reliable recordings. The recommendation is made that AABR screening is conducted on infants prior to hospital discharge, in order to ensure that they are younger than ten weeks of age. DPOAE and immittance screening should not be conducted on infants who are younger than 38 weeks gestational age, in order to ensure reliable recordings of these screening tests. These recommendations should serve to increase the coverage rate achieved by IHS programs.

When using statistical analyses to evaluate the effectiveness of immittance screening test procedures used in the current study, high frequency immittance measures were identified as being more accurate in assessing middle ear status in young infants, than low frequency immittance measures. High frequency tympanometry demonstrated an increased sensitivity for identifying middle ear pathology in infants younger than seven months, when compared to low frequency tympanometry. This was evidenced in an increased correspondence rate between DPOAEs and high frequency immittance measures, when compared to low frequency immittance measures. (Baldwin, 2006:425; Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:22). These results are in accordance with the growing body of literature already advocating the use of high frequency immittance measures in young infants (Baldwin, 2006:425; Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:22).

The use of high frequency immittance measures for infants younger than seven months should therefore be widely implemented in conjunction with DPOAE screening, in order to decrease false positive results by low frequency tympanometry (Baldwin, 2006:425; Rhodes et al., 1999:800; Swanepoel et al.,

2007:50). This should ensure the accurate and timely identification of middle ear pathology in young infants. In developing countries, such as South Africa, where the prevalence rate of middle ear pathology is high (Olusanya, Luxon & Wirz, 2004:296), IHS programs cannot financially afford to falsely diagnose the middle ear condition of young infants. By using a combined high frequency immittance and DPOAE protocol, early identification of middle ear pathology can be achieved. These infants can therefore be afforded the opportunity of early intervention for middle ear pathology, instead of it developing into possible chronic middle ear pathology, with the possibility of eventual permanent sensorineural hearing loss (Boone, Bower & Martin, 2006:395-396). Early identification of middle ear pathology can therefore serve as a measure of preventative audiological healthcare.

Norms for high frequency immittance measures in NICU graduates were determined. Normative 1000 Hz tympanometry data obtained, revealed the fact that, resultant of changes to the middle ear structure, peak admittance values were shown to increase with increasing infant age. In order to obtain an accurate evaluation of middle ear functioning at various infant ages, the need for age specific norms for 1000 Hz tympanometry during the implementation of IHS programs is highlighted. Differences in peak admittance values and pressure values identified in this study, when compared to previous research reports (Swanepoel et al., 2007:52-53), indicate a possible need for specific 1000 Hz tympanometry norms for various infant populations, such as the NICU population and the general newborn population. However, 1000 Hz tympanometry was not exclusively carried out on infants under the age of seven months, which is the recommended age for 1000 Hz tympanometry (Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:22), but was carried out on all infants participating in the study, aged zero to 18 months. This may have accounted in part for differences in peak admittance and pressure values obtained between the current study and previous research reports.

Poor follow-up rates of infants enrolled in the IHS program were identified as not yet meeting the 70% benchmark for follow-up rates set by the JCIH (2000:10). 56% of infants who failed their initial hearing screening returned for follow-up, whilst 69% of infants who passed their initial hearing screening returned for follow-up. Follow-up IHS visits were furthermore not always timely, as infants did not all return at their scheduled dates. These poor follow-up rates may be attributed to a number of factors including a lack of awareness of the importance of IHS, poor maternal education levels, geographical distance between the hospital and the home of the infant, and the fact that this was a pilot study.

Follow-up rates of IHS have been found to be heavily dependant on maternal education levels (Prince et al. 2003:1204; Swanepoel et al., 2005c:79). Adequate follow-up rates for IHS programs are documented as being a constant challenge for IHS programs, even in developed countries (White, 2003:85). In South Africa, where IHS programs are not common practice, and where maternal education levels are poor, a pressing need for raising caregiver awareness of the importance of EHDI programs arises (Olusanya, Luxon & Wirz, 2006:619). Raising caregiver awareness, through educational means, of the importance of early identification of hearing loss should serve to not only improve follow-up rates, but also timely follow-up of IHS programs. Poor follow-up rates may also in part be attributed to the fact that this was a pilot project. Consistent service delivery of IHS for NICU infants over time, should furthermore serve to increase follow-up rates of IHS programs.

In order to further improve coverage rate of infants and follow-up rates of infants enrolled in IHS programs, the following recommendations can be made: Infants should receive AABR screening before hospital discharge, and should then receive follow-up hearing screening as part of an outpatient clinic. Follow-up IHS visits are essential to identify middle ear pathology, which was found to be prevalent in this sample of infants. NICU infants also have an increased incidence of progressive or late-onset hearing loss when compared to the

general newborn population, necessitating follow-up IHS visits in order to identify this type of hearing loss (Yoon et al., 2003:356). Infants should receive follow-up IHS as part of the procedures at a general developmental follow-up clinic or at the time of immunization visits, whereby the sole purpose for the visit to the hospital is not only hearing screening. Follow-up rates of infants enrolled in IHS programs are expected to improve as a result of this.

5.2.3 Conclusions and implications of sub-aim #3: The incidence of auditory impairment in infants admitted to the NICU

The 3% (n=4) incidence rate of permanent congenital hearing impairment, identified in this study, was found to be higher than the figures documented in the literature, ranging between 1.4% and 2.3% (Hess, et al., 1998:81; Meyer et al., 1999:903). If the percentage of infants who were lost to follow-up is taken into account, the incidence of permanent congenital hearing impairment is estimated to be 3.75%. The estimated 3.75% incidence rate of permanent congenital hearing loss of this study is higher than incidence rates reported in developed countries, but remains at the upper limits of documented incidence rate for the NICU population (Yoon et al., 2003:355; Yoshinaga-Itano, 2004:462; Northern & Downs, 2002:267). The 1.5% incidence rate of auditory neuropathy identified in the current study was found to be higher than the 0.23% incidence rate reported in the literature (Sininger, 2002:195-196; D'Agostino & Austin, 2004:348). It is however, important to note that this study had a very small sample size, which limited generalization of the recorded incidence rates.

The high incidence of auditory neuropathy identified in the current study (1.5%) is attributed to environmental risk indicators, such as poor socio-economic conditions (Olusanya, Luxon & Wirz, 2004:296). According to the JCIH (2000:19-20) auditory neuropathy is not included as a target disorder to be screened for in infants. The JCIH (2000:23) does however, recommend that once the prevalence and natural history of auditory neuropathy in the newborn population is determined, hearing screening protocols be revised to possibly include auditory

neuropathy as a target disorder to be screened for. The high incidence rate of auditory neuropathy identified in the current study, when compared to previous research reports, necessitates the inclusion of auditory neuropathy as a target disorder to be screened for in high-risk NICU infants.

The current study revealed a 60.4% incidence rate of bilateral and unilateral middle ear pathology combined. This figure included both definite middle ear pathology, as well as milder forms of middle ear pathology. This is a high incidence rate of middle ear pathology in the NICU population, when compared to that of developed countries (Olusanya, Luxon & Wirz, 2004:296; Rhodes et al., 1999:803). This supports literature documenting high incidence rates of middle ear pathology in NICU infants (Swanepoel et al., 2007:49). The incidence of middle ear pathology was also found to increase with increasing infant age over time (Rhodes et al., 1999:805). At least 33.3% of middle ear pathology identified in the current study did not resolve in time, but was found to be long-term conductive impairment. These results indicate that IHS programs for NICU infants in developing contexts may necessitate the inclusion of middle ear pathology as a target disorder to be screened for (Boone, Bower & Martin, 2006:395-396).

Recurrent Otitis Media has been suggested to lead to eventual permanent sensorineural hearing loss in certain cases (Boone, Bower & Martin, 2006:395-396). This places the NICU population in developing countries at an increased risk for developing late onset sensorineural hearing loss, resultant of recurrent conductive impairment. The inclusion of long-term conductive hearing impairment as a target disorder to be screened for in future IHS programs may therefore be able to ensure that these infants receive timely intervention for middle ear pathology, thereby preventing permanent hearing impairment. This has important clinical implications not only for South African infants, but for all NICU infants in developing countries, as prevention of hearing impairment in developing

countries is able to have huge financial benefits for countries with an already limited healthcare budget (Olusanya, Luxon & Wirz, 2004:288).

5.3 CRITICAL EVALUATION OF THE STUDY

A critical evaluation of the research project is necessary, in order to interpret the findings of the research within the context of its strengths and limitations. Strengths and limitations of this descriptive quantitative study are provided below.

5.3.1 Strengths of the study

Strengths of the current study include the following in terms of data collection methods, data collection material and research participants:

- Data was collected over a 29 month period and analyzed retrospectively. This provided the researcher with longitudinal data. It was thus possible to describe various aspects of the IHS program, such as follow-up rates, middle ear status of infants over time, as well as to compare screening protocols in infants of various age groups. These results serve as a valuable contribution towards addressing the lack of contextually relevant research on IHS in developing countries, in terms of risk indicators for hearing loss, follow-up rates, suitable hearing screening protocols, and the incidence of various auditory pathologies (Olusanya, Luxon & Wirz, 2004:289; Swanepoel, Hugo & Louw, 2005c:76; Swanepoel, Hugo & Louw, 2005d:15).
- Data was collected weekly at the high-risk clinic for NICU infants. This allowed for utilization of an already existing platform within the secondary hospital (Swanepoel, Hugo & Louw, 2005b:17). All NICU infants whose caregivers provided consent for participation in this research were therefore able to be included in this study. This enabled the researcher to gain an

accurate representation of the population being studied (Leedy & Ormrod, 2005:198).

- The HSPS Year 2002 (HPCSA, 2002:5) recommends that IHS be conducted by nurses and/ or lay volunteers, and that the IHS program be supervised and managed by a qualified audiologist. The current study met these recommendations, as data collection was conducted by assistant nursing staff, under the supervision of a qualified audiologist. This allowed the researcher to collect data which provided an accurate representation of the screening practice recommended by the HSPS Year 2002 (HPCSA, 2002:5).
- The screening protocol implemented at the secondary hospital included a wide variety of screening methods, namely AABR screening, DPOAE screening, as well as high and low frequency immittance measures. This allowed for accurate differentiation between sensorineural and conductive impairment. The inclusion of high frequency and low frequency immittance measures enabled the researcher to compare these methods, and determine that 1000 Hz immittance measures are most useful in accurately assessing the middle ear status of young infants (Swanepoel et al., 2007:50; Margolis et al., 2003:384; Kei et al., 2003:22).
- The descriptive quantitative research design used, enabled the researcher to observe auditory characteristics of infants admitted to the NICU and enrolled in the IHS program under investigation (Leedy & Ormrod, 2005:179). This type of research design did not involve changing or modifying the IHS program being studied, thereby giving the researcher an objective, realistic view of the IHS program (Leedy & Ormrod, 2005:179).

5.3.2 Limitations of the study

Limitations of the current study include the following:

- Despite the fact that this study was conducted over a 29 month period, only 129 infants had complete hearing screening information for their initial visit to the IHS program. This is a relatively small number of participants, thereby

limiting the generalization of results obtained in this study (Leedy & Ormrod, 2005:207).

- Infants were not screened before hospital discharge, but as part of an outpatient clinic where high-risk NICU infants' general development was monitored. Infants were therefore approximately three months of age when they received their initial hearing screening, making hearing screening more difficult, due to restlessness on the part of many participants. This resulted in the fact that DPOAE, AABR and immittance screening was not able to be conducted in all cases. A true representation of the auditory status of all infants at each IHS visit could therefore not be gained, limiting the generalization of results obtained.
- Risk indicators for auditory impairment were not complete on all participant records. This also holds true for the HIV/AIDS status of mothers, which was in many cases unknown. Some mothers declined testing and in other cases the mother's HIV/AIDS status was simply not recorded. Such missing data resulted in underreporting of the incidence of risk indicators for hearing loss, including the incidence of infants' prenatal HIV/AIDS exposure. This is a limitation of the current study, in that a truly accurate representation of the population being studied, in terms of risk indicators for hearing loss, could not be gained.
- The current study described an IHS pilot program. Owing to the fact that this was a pilot program, an accurate representation of an established IHS program could not be obtained. The fact that the IHS program was a pilot program may have contributed to poor follow-up rates obtained in the current study. Follow-up rates are reported to increase over time (Lieu, Karzon & Mange, 2006:70; Mehl & Thomson, 2002:3-4). In order to gain an accurate description of follow-up rates over time, and to ascertain whether follow-up showed a steady increase over time, would require further data collection. Such information is necessary to determine whether the IHS program is meeting the standards set by the HSPS Year 2002 (HPCSA, 2002:10).

- The actual hearing screening process was conducted by assistant nursing staff. Inexperience in the use of IHS techniques may have possibly contributed to the high referral rates obtained in the current study. These results may have possibly influenced the described incidence rate of middle ear pathology in this group of infants.
- Normative data compiled for 1000 Hz tympanometry was done from a relatively small sample of ears. Lack of generalization to the wider NICU population is therefore limited. Furthermore, when compiling normative data for 1000 Hz tympanometry, gender was not taken into consideration in the current study. According to Swanepoel et al. (2007:52) there is a statistically significant difference for peak admittance values between male and female ears, although this does not hold true for tympanic peak pressure values. Resultant of the fact that there was no gender differentiation when compiling normative data for 1000 Hz tympanometry in this study, the use of the normative peak admittance data obtained may be limited.

5.4 RECOMMENDATIONS FOR FURTHER RESEARCH

Recommendations for further research on areas of IHS requiring further investigation in South Africa were identified in the current study. Recommendations for further research are discussed below.

- Pilot studies on IHS in the well-baby nursery should be conducted. The well-baby nursery is one of the three platforms recommended by the HSPS Year 2002 (HPCSA, 2002:5) for IHS in South Africa. Such research should determine whether environmental risk indicators for hearing loss and for the success of EHDI programs, such as poor maternal education levels and high rates of prenatal HIV/AIDS exposure, as identified in the current study, are prevalent in the general newborn population. The incidence rates of middle ear pathology in the well-baby nursery should also be determined, in order to

establish whether middle ear pathology should be included as a target disorder to be screened for in infants from the well-baby nursery in developing countries, such as South Africa. Such information should guide choices on the best protocol to be used for IHS in the general newborn population in South Africa.

- The current study found a high incidence rate of auditory neuropathy in a sample of high-risk NICU infants. However, the sample size of the current study was limited, thereby limiting generalization of results for the greater population. The exact incidence of auditory neuropathy in high-risk NICU infants in South Africa should therefore be investigated on a larger sample of infants, in order for inferences to be made about the larger NICU population. Such research will provide valuable information on the need for inclusion of auditory neuropathy as a target disorder to be screened for in the South African NICU population.
- Research investigating maternal awareness of the importance of IHS in South Africa should be conducted. Awareness of risk indicators for hearing loss, as well as maternal attitudes and cultural perceptions towards IHS should be investigated. Maternal perceptions of hearing screening should also be researched. Such research will provide possible additional explanations for poor follow-up rates identified in the current sample of participants. It will furthermore identify the extent to which there is a need for raising maternal awareness on the topic of IHS in South Africa.
- This study pointed towards possible differences in norms for 1000 Hz tympanometry between the NICU population and the general newborn population (Kei et al., 2003:22). It also showed differences in normative values with increasing infant ages. However, the current study was conducted on a limited sample of infant ears. Furthermore, this study did not differentiate between male and female ears when determining normative data. Previous research has indicated statistically significant differences between male and female ears for peak admittance values (Swanepoel et al., 2007:52). Further

research investigating age specific and gender specific norms for 1000 Hz tympanometry in the NICU population should therefore be conducted.

5.5 CONCLUDING REMARK

This study revealed that risk indicators for hearing loss, as well as both sensorineural and middle ear pathology, are prevalent in South African NICU infants. In order to ensure that all infants with hearing loss receive equal opportunities in terms of language, social and cognitive development, as well as job opportunities, widespread implementation of IHS programs in South Africa is an essential first step (Swanepoel, Delport & Swart, 2006:5). It is the responsibility of South African healthcare professionals to conduct contextually relevant research, and to implement appropriate IHS programs for infants in South Africa, if the benefits of EHDI programs are to reach all South African children.

"The fact is that treatment is not the same in one country as it is in every other, due to the grim realities of economic inequities. Acceptance of this tragedy as a reality that cannot be changed is not acceptable morally, not realistic practically and not defensible intellectually." (Helene Gayle, 1998).

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APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E