PREVELANCE OF NEURODEVELOPMENTAL SEQUELAE IN INFANTS WHO SUFFERED MODERATE TO SEVERE NEONATAL ASPHYXIA

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SUMMARY

The proportion of neurodevelopmental sequelae in infants who suffered moderate to severe neonatal asphyxia.

Globally four to nine million cases of newborn asphyxia occur each year. Despite major advances in monitoring technology, obstetric care and knowledge of fetal and neonatal pathologies, asphyxia remains a serious condition causing significant mortality and long-term morbidity. More than a million newborns that survive asphyxia at birth develop long-lasting problems such as cerebral palsy, speaking, hearing and visual disabilities. The role of the physiotherapist in the follow up, assessment and early intervention of at risk infants is poorly researched and subject to much debate.

The aims of the study were two-fold. The primary aim was to determine the proportion of neurodevelopmental sequelae in infants who suffered moderate to severe neonatal asphyxia. The secondary aim was to describe the population regarding maternal, neonatal and referral risk factors associated with asphyxia.

This retrospective descriptive study included a study population of all infants diagnosed with grade II or III neonatal asphyxia admitted to the Pelonomi Hospital neonatal unit. All subjects had to have had a physiotherapy neurodevelopmental assessment between the ages of six weeks and twelve months of age. A total of 40 subjects were included in the study. Five subjects were lost to follow up and five did not meet the inclusion criteria. Information contained in the subjects' medical record and physiotherapy file were used to complete a data form. The Data form contained the neurodevelopmental assessment score (NDS), which served as the objective measure for neurodevelopmental outcome.

The NDS for the grade II and grade III subjects showed no statistical difference, whilst there was a tendency towards the grade III's having a higher score indicating poorer developmental performance. The results indicated that 32% of the subjects presented with neurodevelopmental sequelae following moderate to severe birth asphyxia.

In terms of risk factors this study found that hypertensive disease of pregnancy and intrauterine growth restriction were the most prevalent maternal risk factors. Neonatal

risks indicated the majority of subjects had low (< 7) Apgar scores at both five and ten minutes of life. Five infants required mechanical ventilation following initial resuscitation. In 41% of the subjects, mothers resided outside of Bloemfontein at the time of the birth, and 37% of the deliveries occurred at a primary health care facility. Of the subjects 62% were delivered vaginally and 38% via caesarian section.

In conclusion the study indicates that developmental sequelae are common in this study population. In some cases developmental delays were observed as early as six weeks of age. Neurological impairments however were only observed from nine months of age. It would therefore be suggested that all moderate to severely asphyxiated infants be followed up routinely and assessed by a physiotherapist for developmental problems from six weeks of age and on. A routine assessment by an occupational and speech therapist is also advised.

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LIST OF ABBREVIATIONS

%	Percentage
AIDS	Acquired Immune Deficiency Syndrome
AMPA	Amino-3-hydroxy-5-methyl-4-isoxazole- proprionate
ATNR	Assymetric tonic neck reflex
ATP	Adenosine triphosphate
° C	Degrees celsius
CI	Confidence interval
CP	Cerebral palsy
CNS	Central nervous system
CO_2	Carbon dioxide
CT	Computerized tomography
EEG	Electroencephalograph
ELBW	Extremely low birth weight
H^+	Hydrogen ion
HIE	Hypoxic-ischaemic encephalopathy
HIV	Human immunodeficiency virus
IUGR	Intrauterine growth restriction
K^+	Potassium ion
LBW	Low birth weight
MRI	Magnetic resonance imaging

Na^+	Sodium ion
NBW	Normal birth weight
NCPP	National Collaborative Perinatal Project, Britain
NDS	Neurodevelopmental assessment score
NDT	Neurodevelopmental therapy
NEC	Necrotising enterocolitis
NH&MRC	National Health and Medical Research Council, Australia
NCU	Neonatal Care Unit
NMDA	N-methyl-D-aspartate
NO	Nitric Oxide
O_2	Oxygen
PET	Pre-eclampsia
PHC	Primary health care
PPIP	Perinatal Problem Identification Project, South Africa
PT	Physiotherapy or physiotherapist
PVL	Periventricular leukomalacia
USA	United States of America
VLBW	Very low birth weight
WHO	World Health Organization

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CHAPTER 1

Introduction

1.1 INTRODUCTION AND MOTIVATION

Seven million perinatal deaths occur annually, mostly in developing countries (Costello & Manandhar, 1994:F1). According to the World Health Organization (WHO), four to nine million cases of newborn asphyxia occur each year (WHO, 2005). In spite of major advances in monitoring technology, obstetric care and knowledge of foetal and neonatal pathologies, asphyxia remains a serious condition causing significant mortality and long-term morbidity (Raju, 2003:1). More than a million newborns that survive asphyxia at birth develop long-term problems such as cerebral palsy, mental retardation, speaking, hearing, visual and learning disabilities (WHO, 2005).

Asphyxia can be explained simply as an insult to the foetus or newborn due to lack of oxygen and/or lack of perfusion to various organs. It is associated with tissue hypoxia and acidosis (Khreisat & Habahbeh, 2005:30).

The problem in defining the incidence of birth asphyxia is that incidence figures vary depending on the definition used to diagnose the condition, as well as the gestational age of the infant (Khreisat & Habahbeh, 2005:31-32). Raju (2003:2) stated that severe asphyxia is a rare occurrence in the United States (USA). An incidence of between two and four cases per 1000 births has been reported. Internationally the incidence in most technologically advanced nations of the world is consistent with that in the USA. However in the developing world the incidence of asphyxia is believed to be considerably higher due to the increased prevalence of risk factors.

Risk factors associated with the developing world, such as women in poor health when they become pregnant, poor nutritional state of mothers, hard manual labour during pregnancy and poor socio-economic conditions, are believed to contribute to the increased incidence. Risk is further compounded by the often-inadequate physical facilities and medical care in these areas (WHO, 1997; Department of Health, 2005).

Accurate statistics are not available for the developing world, but based on studies done in such settings, the incidence is suggested to vary between five and ten per 1000 live births (McGuire, 2004).

The Perinatal Problem Identification Program (PPIP) run in South Africa has identified the incidence of birth asphyxia as being seven per 1000 live births in rural communities and six per 1000 live births in urban areas (Thurley *et al.,* 2004:1). The incidence is relatively high in world terms.

Asphyxiated infants account for a significant number of admissions to neonatal care units (NCU) in South Africa. At neonatal follow-up clinics, a large proportion of infants with developmental delays or cerebral palsy retrospectively have a history of birth asphyxia (Mokhachane *et al*., 2002:1). Birth asphyxia thus remains a major contributing factor to the high perinatal mortality rate in South Africa, and long-term problems such as cerebral palsy, mental retardation, speaking, hearing, visual and learning disabilities (WHO, 2005).

The WHO has recognized that newborn care has been a neglected area worldwide but especially in developing countries. As a result, improvement in newborn care has become a priority. Developments in neonatology, including improved neurodevelopmental care, and support services such as physiotherapy will have an impact on the quality of neonatal services provided in South Africa (Department of Health, 2005).

Some of the shortcomings and limitations identified in the quality of neonatal care currently provided in the public sector in South Africa include insufficient staffing,

including support staff such as physiotherapists, and the lack of neonatal follow up programs especially for high risk infants are to name but a few of the problems (Department of Health, 2005). These shortcomings often negatively impact on the quality of care and outcome of at risk infants.

The role of the physiotherapist in the care and early intervention of the high-risk neonate is subject to much debate. Neonatal physiotherapy is an advanced practice sub-specialty area within paediatric physiotherapy. Therapists who provide services to neonates need advanced clinical skills and training in neonatal intensive care and intermediate care settings. Physiotherapists working in this field also need to be able to support anxious families and collaborate with other professional team members in the development of care plans for at risk infants (Chartered Society of Physiotherapy, 2003; Weindling *et al.*, 1996:1110).

Dunn (2000:1) suggests that vast medical advances in both diagnosis and treatment of children are currently driving trends in paediatric physiotherapy. Changing trends are also being fuelled by the increased survival of at risk infants. Many of these infants display developmental disabilities that require therapeutic intervention. As these numbers grow, the ability to identify children with early developmental problems has become a priority.

As the referral age continues to decrease and physiotherapists become more involved as front line practitioners they will need to become more skilled in screening to identify the need for intervention. In order to efficiently provide this service, therapists must possess an intimate knowledge of normal development as well as a solid grasp of how a diagnosis affects development (Dunn, 2000:1).

Following extensive Medline, OVED, CINAHL, KOVSIEDEX, NISC (South African Studies) and GOOGLE searches, it can be concluded that to date very limited physiotherapy research has been done in the field of neonatal pathologies and the follow up of at risk infants. Cole (1988) concurred that high-risk follow up programs specifically for physiotherapists have not been widely

reported or studied (as cited by Lekskulchai & Cole 2001:170). The available research primarily centres on the role of chest physiotherapy in the neonate, and the follow up of premature and low birth weight infants. No physiotherapy generated studies on the neurodevelopmental outcome and/or follow up of asphyxiated infants could be found.

The role of developmental and neonatal intervention programs for at risk infants as reported by Downs *et al*. (1991), Korner (1990) and Updike *et al*. (1986), suggest that appropriate activities during the early period of life may play an important role in muscle fibre differentiation and subsequent hypertrophy, as well as being effective in promoting the infants' further development (as cited by Lekskulchai & Cole: 2001:169).

In January 2004 physiotherapy program was initiated in the Pelonomi Hospital neonatal care unit. The program aimed at involving the physiotherapist as a front line practitioner in the monitoring, assessment and intervention of high-risk infants nursed in the unit. Infants identified as at risk, including all moderate to severely asphyxiated infants, were placed on a routine developmental monitoring program whilst in the unit as well as post discharge. In cases where problems were identified intervention was immediately initiated.

In the light of the large numbers of infants with moderate to severe asphyxia seen by the researcher, it was deemed essential for studies such as this to be performed.

1.2 AIMS

The aims of the study were two-fold.

The primary aim was to determine the prevalence of neurodevelopmental sequelae in infants who had suffered moderate to severe neonatal asphyxia.

The secondary aim was to describe the population regarding maternal, neonatal and referral risk factors associated with asphyxia.

1.3 VALUE OF THE STUDY

The value of this study will be in determining whether routine physiotherapy monitoring, assessment and post discharge follow up programs are indicated for moderate to severely asphyxiated infants. It will also assist in identifying the age at which developmental problems become evident, and whether follow up and assessment from as early as six weeks is indicated.

If such programs are appropriate, this study will assist in ensuring that they are continued and expanded. The role of the physiotherapists in the care of the neonate and at risk infant will also then be reaffirmed.

This study also hopes to serve as the pilot for further physiotherapy research of asphyxiated infants.

1.4. DEFINITION OF KEY CONCEPTS

Below the key concepts are defined as used in this study.

Apgar score refers to a scoring system developed by Dr. Virginia Apgar in 1960. This score is used to evaluate the infant's physical condition and is performed at one minute, five minutes and ten minutes after birth. The score is based on a rating of five factors that evaluate the infant's ability to adapt to extra uterine life (Henning, 1993:4; Anderson, 1994:111). Refer to Appendix A for the complete Apgar scoring system.

Astasia describes a motor nerve condition where a person is unable to walk or sit without assistance (Anderson, 1994:135).

Asymmetric tonic neck reflex is elicited when the infant's head is turned to one side and held in the position for approximately fifteen seconds. The "fencing

position” is momentarily assumed (arm and the leg on the side to which the baby is facing extends, whilst the other arm and leg remain flexed). The reflex is abnormal in the case where the infant does not revert to a normal symmetrical position within a few seconds. The reflex is less obvious during the first month, but becomes more obvious from months two to four, and disappears completely by six months (Henning, 1993:132).

Automatic walking reflex is elicited when the baby is supported in a standing position with the soles of the feet flat on a firm surface, and the head and shoulders held slightly forward. The baby alternatively places one foot in front of the other. This reflex is present shortly after birth in the case of a term baby, and disappears in four to six weeks (Henning, 1993:132).

Birth weight refers to the weight of the infant in grams at birth (Lee & Cloherty, 2004:44 – 45)

- Extremely low birth weight (ELBW) refers to a birth weight of less than 1 000 grams
- Very low birth weight (VLBW) refers to birth weight of less than 1 500 grams
- Low birth weight (LBW) refers to a birth weight of less than 2 500 grams
- Normal birth weight (NBW) refers to a birth weight of between 2 500 – 3 999 grams

Cerebral palsy (CP) or static encephalopathy is defined as a primary abnormality of movement and posture secondary to a non-progressive lesion of a developing brain (Brown, 2001).

Neurodevelopmental delay refers to a lag in development rather than to a specific condition causing that lag. It represents a slower rate of development, in which a child exhibits a functional level below the norm for his or her age. A child may have an across-the-board developmental delay or a delay in specific areas. When a child's development appears to lag, many service providers prefer to apply the less specific term "developmental delay," rather than a more specific

disability diagnosis, since symptoms of specific disabilities may be unclear in young children. Developmental delay indicates that the child is functioning at least 25% below his or her chronological age in two or more of the following developmental areas - cognitive development, physical development, including fine motor, gross motor, and sensory development (vision and hearing); communication development; social/emotional development and adaptive skills or functioning at least 40% below his or her chronological age in one of the areas listed above (Valdivia, 1999; Tennessee Department of Education, 2005).

Encephalopathy - This is a clinical and not an etiological term used to describe the altered level of consciousness. This includes reversible conditions for example hypoglycemia and exposure to maternal medications. It describes any abnormal condition of the structure or function of the tissues of the brain (Aurora & Snyder, 2004:537; Anderson, 1994:546).

Gestational age refers to the age of the foetus or newborn, usually expressed in weeks dating from the first day of the mother's last menstrual period (Lee & Cloherty, 2004:44; Henning, 1993:7).

Gestational age can be used to describe the infant as follows:

- Term infant refers to an infant born after 38 completed weeks of pregnancy
- Preterm infant refers to an infant born before 38 completed weeks of pregnancy
- Post term infant refers to an infant born after 42 completed weeks of pregnancy

Hypoxic ischaemic encephalopathy (HIE) - This term is used to describe the encephalopathy as defined above, with objective data to support the hypoxic/ischaemic incident (Aurora & Snyder, 2004:537).

Hypoxic ischaemic brain injury refers to a brain injury due to the exposure to hypoxia or ischaemia as substantiated by biochemical and pathologic or electrophysiological (EEG) means (Aurora & Snyder, 2004:537).

Infant describes a child in his earliest stage of extra uterine life, a time extending from the first month until twelve months of age. In some cases it is even described as up to 24 months of age (Anderson, 1994:806).

Metabolic acidosis is defined as a condition where excess acid is added to the body fluids, or bicarbonate is removed. Significant acidosis is indicated by pH of less than seven (Lin & Simmons, 2004:108-109; Anderson, 1994:983).

Moro Reflex - this vestibular reflex is the best known of the spinal reflexes. The reflex is observed when the baby is held at a 45-degree angle to the examination surface. The head is lifted by approximately two centimetres, then allowed to suddenly fall a couple of centimetres. Sudden abduction and extension of the arms with associated spreading of the fingers follows. This is then followed by an embracing reaction as the arms adduct and flex back into the resting position (Henning, 1993:134).

Muscle tone is the resting tautness or laxity of a muscle, ideally somewhere in the middle of the range between total contraction and total relaxation. Tone is a characteristic of a muscle brought about by the constant flow of nerve stimuli to the muscle. Abnormal muscle tone can be defined as hypertonus (increased muscle tone, as in spasticity), hypotonus (reduced muscle tone or flaccid paralysis) or atony (loss of muscle tone). Muscle tone is evaluated as part of the standard neurological exam (M.S. London health services centre, 2005).

Neonatal period is the term used to describe the period of time covering the first 28 days of life (Anderson, 1994:1055).

Parachute reflex is elicited when the baby is held on its stomach in ventral suspension with its head down. The baby is suddenly dropped downwards and

extension and forward flexion of the arms is noted in order to protect the head. This reflex appears after six months and never disappears (Henning, 1993:135).

Perinatal or neonatal asphyxia is defined as an insult to the foetus or newborn due to a lack of oxygen (hypoxia) and/or a lack of perfusion (ischaemia) to various organs, of sufficient magnitude and duration to produce more than fleeting functional and/or biochemical changes. It is associated with tissue lactic acidosis (Aurora & Snyder, 2004:536).

Perinatal hypoxia, ischaemia, and asphyxia - these terms respectively refer to a lack of oxygen, blood flow and gaseous exchange to the foetus or newborn (Aurora & Snyder, 2004:536).

1.5 SCOPE

This dissertation is divided into six chapters. Chapter one includes the introduction and motivation for the study, whilst the aims for the study are also stated.

In chapter two a comprehensive review of the current literature will be provided. This will include the conceptual definition of asphyxia, classification, discussion of the prevalence and incidence of asphyxia, etiology and risk factors associated with asphyxia, pathophysiology, consequences, management and outcome. The discussion will focus on the characteristic neuropathological lesions, and subsequent neurodevelopmental delays and impairments.

Methods used to conduct the study are described in chapter three. The study design, study population and study procedures are outlined. Furthermore the selection of the measuring tool, validity and reliability are also found in this chapter. Statistical analysis of the results is described. Practical problems experienced whilst conducting the study will also be discussed.

In chapter four the results of the study will be depicted using amongst others, tables and graphs.

A discussion of the results is contained in chapter five. The data is interpreted and compared to other studies in the scope of the topic. Possible explanations for results are also given.

The conclusions are set out in chapter six. Recommendations are given and a short summary capturing the study will be included.

CHAPTER 2

Literature review

2.1 INTRODUCTION

In this chapter the definition, prevalence and incidence of asphyxia, classification of hypoxic ischaemic encephalopathy (HIE), etiology and risk factors, pathophysiology of asphyxia and hypoxic ischaemic encephalopathy as well as the clinical signs, symptoms, diagnosis, management and complications of asphyxia are discussed. Early physiotherapy intervention in high-risk infants is also discussed in this chapter.

2.2 CONCEPT DEFINITION OF ASPHYXIA

Asphyxia is a complex condition comprising of various elements. Defining the components of asphyxia is often a controversial issue in itself (Osborn, 1998:1). Numerous definitions can be found throughout the available literature, but a universal definition is lacking (Goldstein, 1980:1).

Woods and Malan (1996:1) and Adhikari (1999:114) concur that asphyxia can be defined as the failure to initiate spontaneous, sustained and regular respiration after birth.

This definition is however not complete. The American association of Paediatricians has emphasized that the diagnosis of asphyxia should also include evidence of a multi-organ dysfunction (Lau & Lao, 1999:251). The National Health and Medical Research Council (NH&MRC) report of the Health Care Committee Expert Panel on Perinatal Morbidity in Australia have

provided a more comprehensive definition, defining asphyxia as a condition prevailing in a neonate where there is a combination of the following:

- An event or condition during the perinatal period that is likely to severely reduce the oxygen delivery and result in acidosis.
- A failure to function of at least two organs (which may include the heart, liver, brain, lungs, kidneys and haematological system) consistent with the effects of acute asphyxia (Osborn, 1998:1).

Asphyxia is thus an insult to the foetus or newborn due to a lack of oxygen (hypoxia or anoxia) and/or a lack of perfusion (ischaemia) to various organs. The effects of hypoxia and ischaemia, although not identical, are often difficult to separate clinically. Anoxia would describe a complete lack of oxygen as a result of various primary causes. Hypoxia would refer to an arterial concentration of oxygen that is less than normal. Ischaemia refers to a situation where the blood flow to the cells or organs is insufficient to maintain normal function. (Aurora & Snyder, 2004:536; Khreisat & Habahbeh, 2005:30 and Behrman & Kliegman, 2002:195).

2.3 PREVALENCE

Prevalence refers to the number of cases of a disease that are present in a particular population at a given time (Anderson 1994:1272).

In developing countries 25% of all neonatal deaths have been found to be due to birth asphyxia. A review of twenty studies published in the 1990's from South Asia and Sub-Saharan Africa estimated that 24-61% of deaths during the perinatal period were caused by birth asphyxia. These estimates are useful as indicators of the prevalence of birth asphyxia in developing countries. Moreover, it is very likely that they are underestimates since a large proportion of deliveries in developing countries occur outside institutional settings and are conducted by untrained persons. Consequently still births and neonatal deaths are not always

recorded by the authorities in developing world countries (ICICI social initiatives, 2005).

2.4 INCIDENCE

Incidence refers to the number of newly diagnosed cases during a specific time period. The incidence is distinct from the prevalence, which refers to the number of cases alive on a certain date (Anderson 1994:800).

It is believed that there has been a significant reduction in the incidence of asphyxia in recent years, but only in mature neonates (Khreisat & Habahbeh, 2005:30). The WHO in its Mother-Baby Package states that 3.6million (3%) of all newborn babies in the developing world develop moderate or severe birth asphyxia. Of these approximately 840 000 die and the same number develop severe sequelae, with devastating human, social and economic consequences (WHO, 1996).

Worldwide incidence figures range from 3.7/1000 live births to 9/1000 live births, the lower range of figures are found to be in resource rich countries such as the United States, Sweden and the United Kingdom (Khreisat & Hababeh, 2005: 30).

The Perinatal Problem Identification Programme (PPIP) database concluded that the two most important causes of neonatal deaths in South Africa were intrapartum asphyxia and birth trauma (Pattinson *et al.*, 2005:6). The PPIP also suggests the incidence of birth asphyxia as being 6.92/1000 live births in rural communities and 6.21/1000 live births in urban areas in South Africa. The incidence of birth asphyxia in South Africa remains relatively high in world terms (Thurley *et al.,* 2004:1).

According to local studies performed by Mokhachane *et al.* (2002:1), Pattinson *et al.* (2005:7), Buchmann *et al.* (2002:899-900) and Pattinson (2003:451-452) contributing factors such as poor antenatal care, lack of suitable

maternity and labour facilities in rural areas, lengthy waiting periods before caesarian sections were performed and lack of neonatal monitoring facilities, are all factors which are largely avoidable.

2.5 CLASSIFICATION OF ASPHYXIA

HIE is viewed as the hallmark, and most important consequence of asphyxia and was first described by Amiel–Tisson in 1969 (Sabrine *et al.*, 1999:369; Thompson *et al.*, 1997:757). HIE is a well-recognized clinical syndrome, and the most common cause of acute neurological impairment and seizures during the neonatal period (Hahn, 2002:1; Thompson *et al.*, 1997:757).

The syndrome of HIE has a large spectrum of clinical manifestations ranging from mild to severe. The clinical staging of Sarnat and Sarnat has been widely used since the 1970's as a staging examination to estimate the severity of the hypoxic ischaemic insult in infants of 36 or more weeks of gestation (Aurora & Snyder, 2004:542; Hahn, 2002:2). The sequential appearance and resolution of the various transient clinical signs and their duration over the first two weeks of life not only suggest the extent and permanence of neurologic impairment, but also helps define the clinical categories that have proven fairly accurate in the early assessment of infants with HIE (Aurora & Snyder, 2004:552).

The Sarnat and Sarnat staging of HIE ranges from mild (grade I) to severe (grade III). The grading system is briefly described below:

- Grade I: mild encephalopathy with the infant being hyper alert, irritable and oversensitive to stimulation. There is evidence of sympathetic over stimulation with tachycardia, dilated pupils and jitteriness. Electroencephalograph (EEG) is normal.
- Grade II: moderate encephalopathy with the infant displaying lethargy, hypotonia and proximal weakness. There is evidence of parasympathetic over stimulation with a low resting heart rate, small pupils and copious secretions. EEG is abnormal, and 70% of the infants will have seizures.

- Grade III: severe encephalopathy with the infant stuporous, flaccid and having absent reflexes. EEG is abnormal with decreased background activity and/or voltage suppression (Aurora & Snyder, 2004:542,552; Osborn, 1998:4; Hahn, 2002:2).

The complete grading system of HIE by Sarnat and Sarnat is provided in Appendix B.

2.6 ETIOLOGY, RISK FACTORS AND ASSOCIATED MEASURES OF RISK

Asphyxia is cited as being primarily an antenatal event, occurring postnatally in approximately 10% of the cases. Behrman *et al.* (2004:566) described the etiology in terms of both antenatal and postnatal factors.

Foetal hypoxia may be caused by factors such as inadequate oxygenation of the maternal blood, low maternal blood pressure, inadequate relaxation of the uterus to permit placental filling, premature separation of the placenta, impedance of blood flow or circulation of blood through the umbilical cord and placental insufficiency due to toxaemia and post maturity.

Furthermore intrauterine growth restriction (IUGR) may develop in a chronically hypoxic foetus. Uterine contractions further reduce the umbilical oxygenation resulting in further depression of the foetal cardiovascular system and central nervous systems, resulting in low Apgar scores and postnatal hypoxia (Behrman *et al.,* 2004:566).

Postnatal hypoxia may be caused by several factors including anaemia or shock severe enough to interfere with the supply of oxygen to the vital organs. Deficit in arterial oxygen saturation from failure to breathe adequately postnatally may be due to a cerebral deficit, narcosis or injury. Failure to oxygenate adequate amounts of blood may also result from severe forms of cyanotic congenital heart disease or pulmonary disease (Behrman *et al.,* 2004:566).

Numerous maternal and neonatal risk factors have been identified. For the purpose of this discussion only the risk factors deemed likely to be prevalent in the study population, namely hypertensive disease of pregnancy, IUGR. Although the Apgar score in itself is a measure of risk, persistent low Apgar scores are considered to be a risk factor (Oswyn, 2000; Aurora & Snyder, 2004)

The risk factors most frequently associated with asphyxia in the literature are depicted in Table 2.1.

Table 2.1: Risk factors associated with asphyxia

Risk category	Risk factors	Studies					
		Oswyn *et al.* (2000)	Pattinson *et al*. (2005)	Badwani *et al.* (1998)	Osborn, (1998)	Aurora & Snyder (2004)	Woods & Malan (1996)
Maternal	Hypertensive disease of pregnancy (pre-eclampsia)	√	√	√	√	√	√
	Maternal diabetes		√			√	√
	Maternal drug use		√	√		√	√
	Intrauterine growth restriction	√	√	√	√	√	√
	Placentae abruptio	√	√		√		
	Induced labour				√		
	Malpresentation of the infant				√	√	√
	Maternal hypoxia		√				
	Maternal infection	√		√		√	
							√
Neonatal	Persistent low Apgar scores	√				√	
	Gestation Postmaturity and prematurity)	√	√	√	√	√	√
	Low birth weight	√				√	
	Mechanical ventilation	√					
Referral	Residency of mother	√	√				√
	Location of delivery	√	√				√
	Method of delivery	√	√				√

2.6.1 Hypertensive disease of pregnancy

Hypertension is one of the most common complications of pregnancy, and has been identified as a major worldwide health problem. Hypertensive disorders occur in 7–10% of pregnancies. It is believed that maternal age (below twenty or above 30 years) and toxaemia during pregnancy have an important influence on the incidence (Nadkarni *et al*, 2001:174). Hypertensive disorders of pregnancy also contribute significantly to maternal and perinatal morbidity and mortality.

Hypertensive disorders of pregnancy predispose woman to acute or chronic uteroplacental insufficiency resulting in antepartum or intrapartum asphyxia that may lead to foetal death, intrauterine growth restriction and/or preterm delivery (Nadkarni *et al*, 2001:177).

2.6.2 Intrauterine growth restriction

IUGR is the failure of appropriate foetal growth (Andrews, 2003:1), and is defined as less than 10% of the predicted foetal growth for gestational age (Vandenbosche & Kirchner: 1998:1-3; Peleg *et al.*, 1998:3). IUGR is the second leading cause of perinatal morbidity and mortality after prematurity (Peleg *et.al.,* 1998:2).

Certain pregnancies are at high risk for growth restriction, although a substantial number of cases occur in the general obstetric population (Peleg *et.al.,* 1998:1). Foetal growth is dependant on genetic, placental and maternal factors (Peleg *et.al*., 1998:2). IUGR is most commonly caused by inadequate maternal–foetal circulation, with resultant decrease in foetal growth. Less common causal factors include chronic hypertension during pregnancy, smoking and alcohol use during pregnancy, intrauterine infections such as rubella and cytomegalovirus and congenital anomalies (Vandenbosche & Kirchner, 1998:1-3; Peleg *et al.*, 1998:3).

Growth restricted foetuses are at a higher risk for complications during labour and delivery (Andrews, 2003:1-2). Approximately one half of infants with IUGR have intrapertum asphyxia and low Apgar scores. A higher incidence of merconium aspiration has also been noted in infants with IUGR. Other morbidities associated with growth restriction include sepsis, hypoglycaemia, polycythemia, hypothermia and metabolic imbalances (Vandenbosche & Kirchner, 1998:9).

2.6.3 Apgar scores

Dr. Virginia Apgar developed the Apgar score in the 1960's. The standardised scoring system was developed for the assessment of the neonate's clinical condition immediately after birth. Dr. Apgar had hoped the score would promote the early identification of severely asphyxiated infants, thereby instituting appropriate resuscitation efforts (Fox, 1994:1).

The Apgar score is based on five clinical parameters namely appearance, pulse, grimace, activity and respiration. Upon assessment the clinician assigns a score of zero, one or two to each parameter. A score out of ten is then calculated. Dr. Apgar concluded that the prognosis for an infant was excellent if the child received a score of between eight and ten, poor if the score was two or less and a score in the intermediate range was not predictive of outcome (Fox, 1994:2).

The use of low Apgar scores as predictors of later morbidity remains controversial. Fox (1994:3) viewed the belief that the Apgar score would predict neurological outcome to be naïve. He felt that the limitations of the Apgar score needed to be recognized, in that Apgar score is not meant to be used to predict survival, long-term outcome, or equate to a diagnosis of birth asphyxia.

Contradicting Fox's opinion Machado and Hill (2003:3) stated that the Apgar score (in particular the ten-minute Apgar score) was a powerful predictor of long-term adverse events in severely asphyxiated infants. Mira *et al.* (1994) deemed

mortality and poor neurological outcome to be inversely correlated to both the five and ten minute Apgar scores (as cited by Machado & Hill, 2003:3).

2.7 PATHOPHYSIOLOGY

2.7.1 Pathophysiology of asphyxia

Most authors are in agreement as to the pathophysiological process involved in asphyxia.

According to Aurora and Snyder (2004:537) and Adhikari (1999:129) 90% of asphyxial insults in term infants occur in the antepartum or intrapartum period as a result of placental insufficiency. Placental insufficiency results in an inability to provide oxygen (O_2) and to remove carbon dioxide (CO_2) and hydrogen ions (H^+) from the foetus. The other 10 % of asphyxial insults occur during the postpartum period and are secondary to pulmonary, cardiovascular, or neurological abnormalities.

During normal labour uterine contractions and some degree of cord compression result in reduced blood flow to the placenta, hence the decreased oxygen delivery to the foetus. At the same time there is increased oxygen consumption by both mother and foetus, also resulting in a decrease in the oxygen saturation of the foetus. Maternal dehydration and maternal alkalosis due to hyperventilation may further reduce placental blood flow. Maternal hypoventilation may further decrease the maternal and foetal oxygen saturation (Aurora & Snyder, 2004:537).

These normal events cause most babies to be born with little oxygen reserve. Newborns, including their central nervous systems (CNS), are fairly resistant to asphyxial damage. Aurora and Snyder (2004:537) furthermore suggest that partial asphyxia of under an hour was unlikely to result in an encephalopathy.

In addition to the normal factors discussed above, any factors that impair maternal oxygenation, decrease blood flow from the mother to the placenta / placenta to foetus, impair gaseous exchange across the placenta or foetal tissue or increase the foetal oxygen requirement will exacerbate perinatal asphyxia (Aurora & Snyder, 2004:538; Behrman & Kliegman; 2002:195; Behrman *et al.*, 2004:566).

In the presence of a hypoxic ischaemic challenge to the foetus, reflexes are initiated causing shunting of the blood to the heart, brain and adrenals and away from the from the lungs, gut, liver, kidneys, spleen, bone, skeletal muscles and skin. This is known as the 'diving reflex' (Aurora & Snyder, 2004:538).

In cases of mild foetal hypoxia there is a decrease in heart rate, and slight increase in blood pressure. Cerebral autoregulation and cerebral blood flow maintain the cerebral perfusion for a period of time. In the case of prolonged asphyxia the early compensatory adjustments begin to fail. Blood pressure falls, resulting in a fall in the cerebral blood flow below critical levels resulting in brain hypoxia (Raju, 2003:2; Adhikari, 1999:129).

As the oxidative phoshorylation fails, the energy reserves become depleted. During asphyxia anaerobic metabolism produces lactic acid, which due to the poor perfusion remains in the local tissue. Systemic acidosis may remain mild until the perfusion is restored and these lactic acid stores are mobilized (Aurora & Snyder, 2004:538).

2.7.2 Pathophysiology of an hypoxic ischaemic brain injury

Brief hypoxia impairs cerebral oxidative metabolism leading to an increase in lactate and a fall in pH. Given the inefficiency of anaerobic glycolysis to generate adenosine triphosphate (ATP), there is a decrease in glycogen, high-energy phosphate compounds, firstly phoshocreatine and then ATP (Aurora & Snyder, 2004:539).

The hypoxic brain increases its glucose utilization. Vascular dilatation caused by the hypoxia increases the availability of glucose for anaerobic glycolysis, leading to an increase in lactic acid production. The worsening acidosis is ultimately associated with decreased glycolysis, loss of cerebrovascular autoregulation and diminished cardiac function. The above results in local ischaemia, decreasing the glucose delivery to the very tissue that had increased its substrate utilization (Aurora & Snyder, 2004:539).

Local glucose stores then become depleted and energy reserves fall even further, the accumulated lactic acid also remains unremoved (Aurora & Snyder, 2004:539).

During prolonged hypoxia the cardiac output falls and the cerebral perfusion is compromised. The combined hypoxic, ischaemic insult produces a secondary failure in oxidative phoshorylation and ATP production, this usually occurs within the 48 hours following the initial insult (Aurora & Snyder, 2004:540).

The energy failure impairs the ion pumps, resulting in the intracellular accumulation of sodium, chlorine and water, and the extracellular accumulation of excitatory amino acid neurotransmitters such as glutamate and aspartate (Aurora & Snyder, 2004:540).

At cellular level, neuronal injury resulting from HIE is an evolving process. The magnitude of the final neurological damage is largely dependant on the nature, severity and duration of the primary injury (Raju, 2003:2).

Following the initial phase of energy failure resulting from the asphyxial injury the cerebral metabolism may recover, only to deteriorate in the second phase. Reperfusion injury is the second determinant of the extent of brain damage. By six to 24 hours after the initial injury, a new phase of neuronal destruction sets in, characterized by apoptosis (programmed cell death) and necrotic cell death. The type of cell death is dependant on whether the asphyxial injury is acute or chronic, and the location and developmental stage of the affected parenchyma.

Reperfusion may also promote the formation of excess oxygen free radicals, which may damage cellular lipids, proteins, nucleic acids and the blood brain barrier. Reperfusion also brings with it neutrophils which, along with activated microglia releases injurious cytokines and tumour necrosis factor (Raju, 2003:2, Aurora & Snyder, 2004:540).

This process is also known as "delayed injury". This phase may continue for days to weeks. The severity of the brain injury in this phase correlates well with the severity of long-term adverse neurodevelopmental outcome in infants (Raju, 2003:3; Aurora & Snyder, 2004:540).

Large cascades of biochemical events follow a hypoxic ischaemic injury. Both hypoxia and ischaemia increase the release of excitatory amino acids, glutamate and aspartate, into the cerebral cortex and basal ganglia. These excitatory amino acids begin to cause neuronal death immediately through the activation of receptor subtypes such as kainate, N-methyl-D-aspartate (NMDA), and amino-3-hydroxy-5-methyl-4 isoxazole propionate (AMPA). The activation of receptors with associated ion channels (e.g. NMDA) leads to cell death due to increased intracellular concentration of calcium. A second important mechanism for the destruction of ion pumps is the lipid peroxidation of cell membranes, in which enzyme systems such as the Na^+/K^+-ATPase reside. This leads to water influx causing cell swelling and death. Excitatory amino acids also increase the local release of nitric oxide (NO), which may exacerbate neuronal damage, although its mechanisms are unclear. It is also quite possible that excitatory amino acids disrupt factors that normally control apoptosis, increasing the pace and extent of programmed cell death (Aurora & Snyder, 2004:548; Raju, 2003:2).

2.8 MEDICAL MANAGEMENT OF ASPHYXIA

An asphyxial injury is to be considered when there is foetal acidosis ($pH < 7.0$), prolonged low Apgar scores (three or less for longer than five minutes) and

presence of HIE including altered tone, level of consciousness and the presence of seizures (Behrman *et al*., 2004:566).

Adhikari (1999:114) considers the most important aspect of management remains prevention. She suggests that by identifying the foetus at risk of asphyxia, and taking the necessary steps to prepare for prompt resuscitation, a large number of asphyxial injuries could be prevented.

Clinicians agree that no specific therapy for HIE exists. The cornerstones of treatment remain seizure control and supportive management directed at the organ system manifestations. Careful attention is to be paid to ventilatory status and adequate oxygentation, blood volume, haemodynamic status, acid-base balance and signs of possible infection (Adhikari, 1999:130; Behrman *et al.*, 2004:567; Shankaran, 2002:679-687; Aurora & Snyder, 2004:538, 544-551; Raju, 2003:6).

To date no established and effective treatment is available for brain tissue injury, although many drugs and procedures are under study. Newer therapies are aimed at neuroprotection, but are still largely experimental and have not been tested in clinical trials. Below the newer therapies and their effects are discussed in brief:

- In a study by van Bel *et al.* (1998) in clinical trial a small group of infants were treated with the free-radical scavenger Allopurinol, a slight improvements in survival and cerebral blood flow was noted (as cited by Raju, 2003:8).
- In another study by Hall *et al.* (1998) high doses of Phenobarbital were given over one hour to infants with severe HIE. Treated infants had fewer seizures and fewer neurological deficits at the age of three years. This is the only study showing any benefits in the use of high-dose Phenobarbital for severe cases of HIE. Currently this treatment is not considered as part of standard care protocols (as cited by Raju, 2003:8).

- The use of excitatory amino acid antagonists such as MK-801 has shown promising results in experimental animals studies and in a limited number of adult trials (Vannucci & Perlman, 1997). It has not as yet been tested on newborn infants. This drug however has serious cardiovascular side effects (as cited by Raju, 2003:8).

The use of hypothermia as a neuroprotective therapy is currently being intensely investigated in clinical trials. Hypothermia's mechanism of protection is not yet completely understood. Explanations include reduced metabolic rate and energy depletion, decreased excitatory neurotransmitter release, reduced alterations in ion flux and reduced vascular permeability, oedema, and disruptions of blood-brain barrier functions (Raju, 2003:8).

The current state-of-the-art hypothermia treatment is “brain cooling”. Cooling of the brain to about 3-4°C below the baseline temperature (to 33-34°C) is believed to be neuroprotective. The optimal level of hypothermia for maximal neuroprotection is not yet known, but extreme hypothermia may cause significant systemic side effects including coagulation defects, leukocyte malfunctions, pulmonary hypertension, and worsening of metabolic acidosis (Raju, 2003:8; Behrman *et al.,* 2004:567; Hahn, 2002:5).

Up to 48-72 hours of cooling may be needed to prevent secondary neuronal loss, the greater the severity of the initial injury, the longer the duration of hypothermia needed for optimal neuroprotection. Cooling must be commenced within one hour of injury where possible. Favourable outcome may be possible if cooling is begun up to six hours after injury. A special device that selectively cools the head is now being tested in clinical studies, but is not available in the market. Some investigators believe that total body cooling may be superior to selective head cooling. The relative merits and limitations of different methods of brain cooling have not yet been studied, and until more is learned hypothermia remains an experimental modality (Raju, 2003:8; Behrman *et al.*, 2004:567; Hahn, 2002:5).

Advanced neuroimaging techniques such as magnetic resonance imaging (MRI), computerized tomography (CT) and cranial ultrasonography are also now being used. MRI studies have become the method of choice to assess the newborn brain, and are believed to be valuable in noting the location and extent of the neurological damage in moderately to severely asphyxiated infants. MRI studies are also considered valuable in the follow up programs of these infants (Raju, 2003:4; Hahn, 2002:4). It is important to note that MRI facilities are more often than not unavailable in local neonatal units in South Africa, and in the developed world in general. Clinicians in these circumstances have to rely on accurate clinical examination methods to assist in predicting outcome (Thompson *et al.*, 1997:757). Electrophysiological measures such as the amplitude integrated EEG are also used as an assessment measure to predict long term outcome (Simon, 1999:774-775).

2.9 CONSEQUENCES OF ASPHYXIAL INSULTS

Asphyxia has a wide range of clinical manifestations, and may result in neonatal depression at birth, low Apgar scores and metabolic acidosis (Osborn, 1998:2). The subsequent development of HIE, is widely believed to be the most important consequence of asphyxia (Aurora & Snyder, 2004:539).

Despite the above neurological manifestations, the infant may also present with a multi- organ dysfunction. A third of infants with HIE will have two or more system involvement resulting in renal compromise, hypoxic cardiomyopathy, pulmonary complications (e.g. respiratory distress, persistent pulmonary hypertension), liver failure, necrotising enterocolitis (NEC) and disseminated intravascular coagulation. In addition to this the infant may manifest with electrolyte and metabolic abnormalities (Aurora & Snyder, 2004:539; Osborn, 1998:2).

For the purpose of this study the discussion will focus on the neurological consequences resulting from asphyxia.

2.10 NEUROLOGICAL INJURIES ASSOCIATED WITH ASPHYXIA

HIE is the characteristic neuropathologic lesion associated with the neurologic sequelae in asphyxiated infants. The presence of early neurologic dysfunction is considered the single most useful indicator that a significant hypoxic ischaemic insult has occurred and is the best indicator of significant neurodevelopmental sequelae in asphyxiated infants (Simon, 1999:767; Hahn, 2002:6).

Hypoxic ischaemic brain injury in the foetus or neonate results from haemodynamic alternations that adversely affect selectively vulnerable areas of the immature brain. There are distinct gestational age dependent differences in the vulnerability of specific cerebral structures (Simon, 1999:767; Hahn, 2002:6).

2.10.1 Characteristic neuropathologic lesions

The areas most vulnerable are those with the highest degree of cerebrovascular and biochemical immaturity at the time of the hypoxic ischaemic insult. The specific site or sites of the brain damage and the severity, duration and timing of the hypoxic ischaemic insult determine the nature of the neurodevelopmental sequelae (Simon, 1999:767).

In term infants the “watershed” areas of the major cerebral arteries are the most vulnerable to hypoxic ischaemic brain injury. The depths of the sulci and the posterior cerebrum are the most vulnerable, the latter representing the vascular border zone of all three the major cerebral arteries. Injury to the parasaggital cortex is the most common hypoxic ischaemic lesion observed in term infants. The cerebral neocortex, where myelinization is occurring, and the sub-cortical white matter are characteristically also involved. Severe injury results in focal or multifocal cortical necrosis, later cortical atrophy and cortical cystic degeneration (Simon, 1999:768; Aurora & Snyder, 2004:540; Raju, 2003:5).

Profound damage to the thalamus, basal ganglia and brainstem may also occur. The thalamus and other diencephalic structures have the highest rate of

vascularization and oxygen consumption during the last trimester of gestation, making them particularly vulnerable to asphyxia during this period. This type of extensive pattern of brain injury in asphyxiated term infants occurs with the relative preservation of the cerebral neocortex and subcortical white matter. In term infants this type of injury has a very high mortality rate, approaching 35% (Simon, 1999:767-768).

Asphyxiated term infants have also been reported to develop cystic periventricular leukomalacia (PVL), especially in association with lesions to the basal ganglia and thalamus. PVL is seen in 30 – 60% of asphyxiated term infants with spastic diplegic cerebral palsy (Simon, 1999:767-768; Behrman *et al.*, 2004:567; Aurora & Snyder, 2004: 540; Raju, 2003:5).

2.10.2 Neurodevelopmental sequelae

The effects of asphyxia on long-term developmental outcome are greater in term infants (Simon, 1999:769). According to Simon (1999:769–772) the most frequently observed major and minor neurodevelopmental impairments outcome are:

- **Motor impairments**

The **periventricular regions** are crossed by the corticospinal tracts (pyramidal pathways), which contain the descending myelinated pathways, serving as the main output pathways for the motor cortex. Fibres within the corticospinal tract interconnect with the basal ganglia, brain stem and cerebellum, all contributing to the control of normal motor movement (Simon, 1999:769).

Motor fibres to the lower body are situated medially within the corticospinal tract, placing them intimately within the periventricular region, and subsequently at risk for injury due to PVL. Even mild degrees of hypoxic ischaemic injury to the periventricular regions will affect the medial motor fibres within the corresponding corticospinal tract, resulting in functional gross and fine motor problems involving

the lower extremities. The most common major impairment due to this type of injury is spastic diplegic cerebral palsy (Simon, 1999:769).

More extensive insults to the periventricular regions affect motor fibers placed more laterally within the corticospinal tract, controlling the upper body and upper extremities. This type of insult results in spastic quadruplegic cerebral palsy. When there is further lateral extension of the injury, motor fibers affecting the eye, facial movements and swallowing also become involved (Simon, 1999:769).

Hypoxic ischaemic damage to the **basal ganglia** results in spasticity or hypotonia often seen in cerebral palsy. One of the main functions of the basal ganglia is to inhibit muscle tone throughout the body, by sending inhibitory signals to both the motor cortex and the brain stem. True hypotonia is seen less frequently and results from more extensive damage to the cerebral cortex, cerebellum and anterior horn cells. The infant with a more global hypoxic ischaemic injury often presents with baseline tone that alters between low and high (Simon, 1999:769).

The basal ganglia are also responsible for modifying intentional gross motor functions, which in turn are refined by the cerebral cortex. If the hypoxic ischaemic injury affects the basal ganglia and spares the cerebral cortex, chorreiform, athetoid and ballistic movements will be the resulting motor abnormality. The onsets of these unintentional movements are usually not apparent before one year of age (Simon, 1999:770).

Hypoxic ischaemic damage to the **cerebellum** results in a diminished capacity for smooth and sequential action between muscle groups. Clinical manifestation of cerebellar damage may not be apparent until the infant is older and required to perform more complex motor activities. Typical motor abnormalities resulting from cerebellar damage are loss of control of range of movements resulting in undershoot or overshoot, motor movements appear irregular and disjointed, a staggering ataxic gait with a tendency to fall and an intension tremor which

intensifies as a movement nears completion. Following more extensive damage to the cerebral to the cerebellum the infant may manifest in hypotonia (Simon, 1999:769 -770)

Term asphyxiated infants generally have more extensive damage to the motor cortex, basal ganglia, thalamus, brain stem and the periventricular regions resulting in major tone and motor impairments. The most common type of motor disabilities seen in severely asphyxiated term infants is spastic quadruplegia and choreoathetoid cerebral palsy, indicating severe cerebral injury with PVL. Survivors of post asphyxial infarcts also usually present with spastic quadruplegia. Generalized hypotonia is also seen more often in the case of term-asphyxiated infants (Simon, 1999:770).

Injury to the **brain stem** and **cranial nuclei** manifest in impaired sucking, swallowing and impaired tongue movements (Simon: 1999:769; Hahn, 2002:7-10).

Cerebral palsy (CP) or static encephalopathy is the most serious motor consequence of asphyxia. CP is defined primarily as an abnormality of movement and posture, secondary to a non-progressive lesion to the developing brain. Abnormal motor function and tone in the absence of an underlying progressive disease is the hallmark of CP (Murphy & Such-Neibar, 2003:146-147).

CP comes in a variety of different forms, and with a continuum of severity. CP can be classified into five main groups namely, hypertonic or spastic, hypotonic, dyskinetic and dystonic, ataxic and mixed. For the purpose of this study a brief description of spastic quadruplegia, spastic diplegia, hypotonia and dyskinetic types will be given (Venter, 2001).

Spastic quadruplegia involves all four limbs. The upper limbs are usually more affected. A high percentage of cortical blindness is also found in this group.

Spastic diplegia refers to involvement of all four limbs, with the lower limbs having a larger involvement.

Hypotonia refers to the group also known as the “floppy child”. Of this group 45% will eventually become hypertonic within two years of age. The other 45% will become dystonic, dyskinetic or develop athetosis.

The dyskinetic group is characterized by the presence of dystonia, chorea and athetosis. Uncontrolled, slow, writhing movements characterize this group. These abnormal movements usually affect the arms, hands, feet or legs. In some cases the muscles of the face and tongue are also affected.

A full classification of the types of cerebral palsies can be found in Appendix C.

- **Visual impairments**

Term infants suffer visual impairments due to hypoxic ischaemic damage to the visual cortex in the parieto-occipital region, which is located in the watershed region of the posterior and middle cerebral arteries. Damage to the visual cortex results in impaired visual association. Cerebral infarctions also contribute to visual impairments. It is postulated that approximately 60% of asphyxiated term infants suffer atrophy of the visual cortex (Simon, 1999:770; Hahn, 2002:7-10).

- **Hearing impairments**

The incidence of sensorineural hearing loss is also increased in term-asphyxiated infants. The precise mechanism of hearing loss is unknown, but is believed to be multifactorial. In addition to the cortical effects, asphyxia causes haemorrhages in the inner ear and damage to the auditory pathway within the brain stem. In addition the cochlear nuclei are damaged in such cases (Simon, 1999:771; Hahn, 2002:7).

- **Cognitive and learning impairments**

The precise cause of cognitive deficits in asphyxiated infants is yet to be determined. Mental retardation is common in severely asphyxiated term infants due to injury to the parasagittal cortex and thalamus (Simon, 1999:771-772).

A number of specific learning disabilities relating to language development and visual spatial abilities have been noted. These disabilities are presumed to be as a result of damage to the posterior parieto-occipital region, where associative functions for auditory, visual and visual–motor functions are located. Term infants who suffered moderate asphyxia, with no major developmental handicaps, have been shown at school age to be at least one year behind in terms of reading, spelling and mathematical skills (Simon, 1999:772; Hahn, 2002:7).

2.11 PROGNOSIS AND OUTCOME

The outcome of HIE ranges from complete recovery to death. Prognosis is dependant on the severity of the asphyxial damage, and whether the metabolic and cardio-pulmonary complications could be treated, the child's gestational age and the severity of the encephalopathy (Behrman *et al.*, 2004:567).

According to studies performed in experimental animals, the degree of asphyxia required to cause permanent brain damage is quite close to that which causes death (25 minutes of acute total asphyxia). Survival with extensive brain damage is largely uncommon in the case of asphyxiated infants, death or intact survival is the most common outcome in this model. As is the case in human subjects, asphyxia severe enough to cause permanent brain damage will more than likely result in death before or shortly after birth. According to available statistics approximately 25% of asphyxiated infants die. Those surviving the asphyxia, even those who had seizures, will overwhelmingly have a normal outcome (Aurora & Snyder, 2004:552).

To the contrary, Adhikari (1999:114) states that asphyxia in term infants asphyxia is still the most common cause of neonatal brain damage, and is the leading cause of cerebral palsy in the developing world.

The main groups of neonates with significant neurological impairment are those who were moderately or severely asphyxiated and yet narrowly escaped death. Thus it can be concluded that the prognosis for infants surviving asphyxia is generally fairly favourable (Aurora & Snyder, 2004:551-554).

When one looks at the indicators of poor outcome within the first two weeks of life it is relatively difficult to offer a prognosis. Some signs for an unfavourable outcome are severe prolonged asphyxia, prolonged low Apgar scores at 20 minutes and the absence of spontaneous respiration at 20 minutes, grade III encephalopathy, early onset of seizures (less than twelve hours after the insult), increased intracranial pressure and the persistence of abnormal neurological signs beyond the first seven days of life (Aurora & Snyder, 2004:522; Behrman *et al.,* 2004:567).

Currently various objective methods to predict long-term neurodevelopmental outcome in asphyxia survivors are under investigation. These methods include the use of biochemical markers (interleukin-1, lactate and creatinine levels), electrophysiologic measures (EEG) and neuroimaging modalities (MRI, CT and ultrasonography). Currently long term outcome predictors are becoming increasingly based on newer imaging modalities, especially MRI studies (Simon, 1999:774-775).

Available statistical data on the outcome of asphyxiated infants suggest that there is a mortality rate of between 10 and 20% in term-asphyxiated infants. The incidence of neurological sequelae in survivors is between 20 and 40% (40% of these are minimal and 60% severe). The outcome in the majority of the cases of infants surviving asphyxia is normal (Aurora & Snyder, 2004:552).

When the above statistics are analysed using the Sarnat and Sarnat staging the following outcomes were found (Aurora & Snyder, 2004:552):

- 100% of infants with a mild encephalopathy (grade I) had a normal neurological outcome
- 80% of those with a moderate encephalopathy (grade II) were normal. The 20% that had an abnormal neurological outcome had stage II signs over the initial seven days.
- 50% of children with a severe encephalopathy (grade III) died, the surviving 50% nearly all suffered major neurological damage with resulting CP, epilepsy, microcephaly and mental retardation.

The risk of developmental delays and CP is elevated to 5-10%, versus 2% per 1000 live births in the case of birth asphyxia. In reality the relative risk is small. Data from the national collaborative perinatal project (NCPP) and the National British Child Developmental Study have suggested that perinatal factors of labour and delivery contribute little to the incidence of mental retardation and seizures. Only 3 -13% of infants with CP had evidence of actual intrapartum asphyxia (Aurora & Snyder, 2004:522).

Very few studies have been done on the outcome of asphyxiated infants. Neurodevelopmental outcome of neonatal asphyxia documented in studies by Thornberg *et al.* (1995); Hull and Dodd (1992); Robertson and Finer (1985); Ellis *et al.* (1999); Thompson *et al.* (1997) and Badwani *et al.* (2005) are depicted in table 2.2.

It can be concluded following the review of these studies that no uniformity exists regarding inclusion criteria, methods, assessors or the period of follow period. This resultantly makes it extremely difficult to compare the outcomes of these studies with each other, and this study.

Only the study by Robertson and Finer (1985) in any way involved a physiotherapist in their follow up regime.

Table 2.2: Studies on the neurodevelopmental outcome of asphyxia

Aspect	Study					
	Robertson & Finer (1985)	**Hull & Dodd (1992)**	**Thornberg *et al.* (1995)**	**Ellis *et al.* (1999)**	**Thompson *et al.* *(1997)***	**Badwani *et al.* (2005)**
Location study	Alberta, Canada	Derby, England	Gotenborg, Sweden	Katmandu, Nepal	Cape Twon, South Africa	Western Australia
Developed/ developing world setting	Developed	Developed	Developed	Developing	Developing	Developed
Inclusion criteria regarding grade of asphyxia/ HIE	All grades of asphyxia/ HIE	All grades of asphyxia/ HIE	All grades of asphyxia/ HIE	All grades of asphyxia/ HIE	All grades	All grades
Total number of subjects	167	301 over 10 years	227	102	40	276
Number of subjects moderate or severe asphyxia	101	107	39	72	Breakdown not given	32
Grading system used for asphyxia	Sarnat & Sarnat	Sarnat & Sarnat	Sarnat & Sarnat	Sarnat & Sarnat	Sarnat & Sarnat	Sarnat & Sarnat
Type of study design	Prospective	Retrospective	Retrospective	Retrospective	Retrospective	Retrospective
Duration of follow up	3.5 yrs at the time of study, but 8 years in the long term	Followed up to 18 months and discharged if there was not severe disability	Followed up to 18 months. Infants having disabilities were followed up beyond 18 months	Twelve months of age	Twelve months of age	5 years

Aspect	Study					
	Robertson & Finer (1985)	**Hull & Dodd (1992)**	**Thornberg *et al.* (1995)**	**Ellis *et al.* (1999)**	**Thompson *et al.* *(1997)***	**Badwani *et al.* (2005)**
Method of neuro-developmental assessment	Neurological and physical examination	Method was not given	Not specified	Assessment included hearing and visual testing, neurological evaluation. Denver developmental screening test, Bayley II scales	Neurological assessment, Griffith scale of mental development	Questionnaire, Griffith scales of mental development. Medical, neurological and psychological examination
Primary assessor	Paediatrician	Paediatrician	Paediatrician	Paediatrician	Paediatrician	Paediatrician & psychologist
PT involved Follow-up	Yes.	No	No	No	No	No
Outcome/ presence sequlae	38 children	17 children	9 children	17children	18 children	32 children
Prevalence sequelae	22.8%	16%	23%	25%	?	13%
Most common type of severe impairment	Did not specify	Spastic quadruplegia, diplegia and hemiplegia	Spastic quadruplegia. Dyskinetic CP	Spastic quadruplegia	Not specified	Spastic quadruplegia and dyskinetic CP
Description of the muscle tone	No	No	No	No	No	No
Association between risk and outcome assessed	Yes. No correlation with maternal risk factors.	No	No	No	No	No

2.11.1 Developmental delay

Much confusion arises with the use of the term developmental delay. Development during the first year of life is extremely rapid, and the picture may change from day to day as the child acquires skills and knowledge. Theoretically developmental delays should be easy to detect, but due to the range of factors playing a role in development, the detection of developmental delays are not always straightforward (Jenkins & Newton, 1981:118).

Developmental delay is regarded as one of the most common child hood problems, with an estimated prevalence of 10%. It is used more frequently as a descriptive rather than a diagnostic term. Delays exist when a child fails to reach specific milestones at an expected age in any area of development. As a result of the wide variation at which children reach particular milestones detection of delays are often challenging (Jenkins & Newton, 1981:118).

There are many possible etiologies for developmental delays, however in many young children no specific diagnosis can be made. Delays are often identified through the concern of a parent or caregiver or through professional screening and/or surveillance (Jenkins & Newton, 1981:118).

There are several factors that need to be taken into account when deciding on whether an infant has a developmental delay, and in the process of making a developmental diagnosis. The quality of maternal care, and therefore stimulation provided to the infant, can have a major impact on the pace at which development occurs in the fields of socialization and motor function. A naturally occurring wide variation in the pace of normal development dependant on the individual and his/her genetic make-up also needs to be taken into account when viewing developmental delays (Jenkins & Newton: 118-119).

Developmental delay indicates a child from birth through two years of age who is functioning at least 25% below his/her chronological age in two or more of the following developmental areas: cognitive, motor communication, social/emotional

development and adaptive skills. It can also be defined as a child functioning 40% or below for his chronological age in one of the above areas of development (Tennessee Department of Education, 2005).

The possible impact of HIV on neurodevelopmental status also needs to be considered. Potterton and Eales (2001:14) found that developmental delays were commonly found in infants who were HIV positive.

2.11.2 Developmental impairment

Developmental impairment refers to defects at organ or system levels, which include abnormalities of muscle tone, strength, control, involuntary movements as well as other findings on the neuromotor examination, such as motor asymmetries, abnormal primitive reflexes and the late development of postural responses. The detection of functional limitations manifested by developmental delays are poorly predictive before at least six months of life. If abnormal neuromotor signs persist a diagnosis of cerebral palsy may then be considered (Palmer: 2004:S8).

2.12 PHYSIOTHERAPY MONITORING AND EARLY INTERVENTION PROGRAMS

2.12.1 Role of the physiotherapist in the neonatal care setting

Neonatal physiotherapy is an advanced field of paediatric physiotherapy. Therapists who provide services to neonates need advanced clinical skills and training in the neonatal care setting. The role of the physiotherapist in the care of the neonate remains debatable considering the rapidly changing physiological status of the neonate (Chartered Society of Physiotherapy, 2003).

Current trends in paediatric physiotherapy are being driven by vast medical advances in diagnosis and treatment. The increasing survival rates of at risk infants is also changing the face of physiotherapy paediatric practice, as many of

these infants display developmental disabilities that require therapeutic assessment and intervention. As these numbers grow, the ability to identify children with early delays in development is a priority (Dunn, 2000:1).

Most neonatal physiotherapy literature is focused on the management of respiratory complications. A single study by Weindling *et al.* (1996:1107-1108) suggests that physiotherapists should be involved in the assessment of at risk infants whilst still in hospital. Therapy at this point in time would consist of advice on handling and positioning, and passive mobilization of limbs is to be shown in cases of spasticity.

Involvement of the physiotherapist in the immediate and long-term assessment, and follow up of the asphyxiated infant remains largely unexplored. The study by Robertson and Finer (1985:475) was the only study on the outcome of asphyxiated infants that in any way consulted the services of a physiotherapist.

2.12.2 Developmental surveillance and follow up of at risk infants

According to Dworkin (1989:1000) in USA and Western Europe there is general consensus regarding the importance of developmental monitoring in the at risk infant.

Any infant who suffered a significant asphyxial episode should be monitored closely for developmental difficulties after hospital discharge (Simon, 1999:767).

The aim of regular monitoring is to identify, as early as possible, the presence of developmental delays and the signs of future disability, ensuring the provision of appropriate services and support to the infant and their families. Despite the uniform opinion being in favour of the regular monitoring of high-risk infants, there is no consensus on how this should take place. The lack of consensus is viewed to be the result of inadequate scientific evidence to guide the design and implementation of such programs. Currently these programs are based on limited

research evidence, clinical experience and the good intentions of health care practitioners (Dworkin, 1989:1000; Simon 1999:772).

Developmental screening can be described as the presumptive identification of disease or defect by the application of tests, examinations and other procedures. Screening procedures can be rapidly applied and are relatively simple and reliable, with a few false-positive or false-negative results. Screening procedures, in most cases, are initiated by health service providers and not the client (Drillien *et al.*, 1988:294; Dworkin, 1989:1001).

Follow up of all moderately to severely asphyxiated infants is suggested, however neurodevelopmental screening on its own is viewed as insufficiently sensitive in identifying children in need of intervention. Evaluations and follow-ups should be multiple and over a period of time. Assessments should include neurological, developmental and psychological evaluation. Routine hearing and visual assessments are also advised (Simon, 1999:774-775; Palmer, 2004:S8).

2.12.3 Early intervention programs

It is widely agreed that delaying intervention makes it more difficult to influence the condition (Copeland & Kimmel, 1989:75). Simon (1999:773) states that all asphyxiated infants with tonal abnormalities and motor difficulties should receive early physiotherapy assessment and intervention from the earliest possible point.

Worldwide and in South Africa more and more physiotherapists are becoming involved in early intervention programs for infants presenting with neurodevelopmental deviations during the first year of life. Therapists are becoming more aware that a holistic approach to the child's development is needed, including addressing sensori-motor, speech, hearing and perceptual aspects of the child's development (Van der Velde, 1983:17-18).

Early intervention programs by physiotherapists are viewed as beneficial for the following reasons (Bobath: 1967:373-374; Van der Velde, 1983:17-18):

- Early treatment is important due to the great adaptability and plasticity of the infantile brain. The first eighteen months of the normal child's life is a period of great, rapid development. At no other stage does the child learn and develop so quickly. It is not only the stage for the highest potential for learning but, also for adjustment to cerebral damage.
- The importance of sensory motor experience lies in the fact that the learning of movement is entirely dependent on sensory experience and sensory input, which not only initiates but guides motor output. Early intervention will assist the infant in achieving more normal milestones.
- Sensori-motor experience also plays an important role in the mental and perceptual development of the child.
- Early treatment often prevents the development of contractures and deformities.
- Due to the time factor very early intervention will in most cases give more rapid and better results, than in cases where intervention is only commenced at a later stage.
- Parents are also taught how to deal with their anxiety more constructively by being taught the correct facilitation and handling techniques. Early intervention often assists parents in adapting to their child's handicap, promoting a better parent–child relationship.

Despite the benefits, a fair amount of criticism has been levelled at the implementation of early intervention programs. It has been suggested that early intervention results in therapists treating children with transient signs, in so doing cause unnecessary anxiety for parents (Van der Velde, 1983:17 -18).

The aims of early intervention and treatment are (Bobath, 1967:374):

- Assisting the child to develop normal postural reactions, and postural tone against gravity for the support and control of movement.
- To counteract the development of abnormal postural reactions and abnormal postural tone.

- Through handling and play the child is taught functional patterns that will later be used in self help activities.
- Prevent the development of contractures and deformities

Treatment can best help the child in reaching his full potential of abilities if started before abnormal patterns are established, it will then help the child to manifest his potential in the most normal way (Bobath, 1967:374).

A concern noted by Cole (1998) and Berrera *et al.* (1986) was that there have been very few studies to evaluate the effects of early intervention programs (as cited by Lekschulschai & Cole, 2001:170). To date the data on the outcome of early intervention programs for at risk infants remains contradictory. Lekschulschai and Cole (2001:175) in their study on early intervention programs in premature infants found early physiotherapy intervention to be beneficial. On the other hand Goodman *et al.* (1985:1329) and Weindling *et al.* (1996:1110) in their studies on early intervention found no benefit to at risk infants who were not to later develop CP.

2.12.4 Neurodevelopmental therapy

Neurodevelopmental therapy (NDT) is only one of the many treatment approaches used by physiotherapists. This approach is based on the work of Dr. Karel Bobath and Bertha Bobath done in the 1940's. Their worked was based on the idea that children with nervous system impairment and cerebral palsy should be assessed and treated within a framework that addressed the neurological and developmental issues of their movement disorders. Therapy is goal orientated, with the primary aim of increasing functional abilities through the facilitation of normal movement patterns (Brown, 2001; Dunn, 2000:2).

NDT has evolved over a period of 50 years, and continues to evolve based on advances in modern neuroscience and movement science, that continue to support the rationale of this approach. In order to be trained as a paediatric NDT

therapist, a therapist needs to successfully complete an eight-week post basic course (Brown, 2001; Dunn, 2000:2).

The NDT approach also emphasizes the importance of teamwork between therapists, clinicians, caregivers and parents. Although the focus of physiotherapy remains on motor function, the ability to identify problems in other areas of development and correctly refer remains imperative (Dunn, 2000:2).

2. 13. SUMMARY

Asphyxia is the failure to initiate spontaneous, sustained and regular respiration after birth. It is also associated with a multi-organ dysfunction. The incidence of asphyxia varies from 3.7/1000 to 9/1000 live births, and is considerably higher in developing countries such as South Africa where the incidence is given as being between 6.21/1000 and 6.92 /1000 live births.

HIE is viewed as the hallmark of asphyxia. HIE is the most common cause of seizures and neurological impairment in the neonate. Hypoxic ischaemic brain injury in the neonate results from the haemodynamic alterations that adversely affect vulnerable areas of the foetal or neonatal brain. The resulting neurological sequelae are largely dependant on the location, severity, duration and timing of the insult. Minor and major neurodevelopmental impairments relating to vision, hearing, motor function, cognition and learning abilities are seen in 20–40% of moderately to severely asphyxiated infants.

There is no specific treatment for HIE. Treatment is aimed at seizure control and supportive therapy aimed at the various organ dysfunctions. To date there is no established treatment for brain injuries. Newer therapies aimed at neuroprotection such as the use of hypothermia, Allopurinol, high doses of Phenobarbitone and excitatory amino acid antagonists are currently under investigation.

It is suggested that moderate and severely asphyxiated infants require long term neurodevelopmental monitoring, as well as routine visual and hearing tests. In cases where abnormal tone and abnormal movement patterns are observed early physiotherapy treatment should be initiated.

Early intervention ensures that the child can be best helped in reaching his full potential of abilities. If treatment is started before abnormal patterns are established, it can help the child to manifest his potential in the most normal way.

Based upon the literature review in Chapter 2, the methodology will be discussed extensively in Chapter 3

CHAPTER 3

Methodology

3.1 INTRODUCTION

This chapter describes the methodology and methods used in the execution of the study. Study procedures, as well as the statistical analysis of the study are included. Furthermore the chapter delimits the context of the study and presents the ethical approval for the performance of this study.

3.2 STUDY DESIGN

A retrospective descriptive study design was used, as it is the first step in the exploration in a given research field.

According to Joubert and Katzenellenbogen (2002:66a) a descriptive study describes the characteristics of a specific group. A descriptive study, also referred to as a survey, sets out to quantify the extent of a problem. A descriptive study, which sets out to comprehensively describe the current state of affairs of a certain aspect of health, is also known as a situational analysis. The main aim of such studies are to give service providers information that will help them design services and allocate resources effectively. Such studies often generate questions for further research.

The presence of a certain characteristic is often expressed in terms of prevalence. The prevalence of a specific characteristic is the percentage of

individuals in the group presenting with the characteristic at a specific point in time (Cronje *et al*., 1997:16; Joubert, 2002:17).

According to Currier (1984:215) the purpose of a retrospective study approach is to uncover facts or information that already exists.

After considering the research title, aims of the study and taking the above noted definitions into consideration a **retrospective descriptive study design** was chosen.

3.3 STUDY POPULATION

The study population, or target population, is the total group on whom one wishes to gather information and draw conclusions. The study population shares a specific set of characteristics or criteria that has been established by the researcher. The criteria of a study population are determined from the literature review and the aims of the study. The population criteria are set before subject selection, and detailed information about the subjects are given later, after they have been recruited for the study (Bailey, 1997:83-84; Joubert & Katzenellenbogen, 2002:74b).

There are a number of factors that need to be considered before a subject may participate in a study. The population size, selection of subjects as well as the inclusion and exclusion criteria for this study are discussed hereafter.

3.3.1 Study population

The study population included all infants who were diagnosed with grade II or III asphyxia, admitted to the Pelonomi Hospital neonatal care unit, and who were subsequently followed up at the high risk/ paediatric specialist and physiotherapy out patient clinics following discharge.

The primary requirement from a physiotherapy perspective was that all infants had to have had a neurodevelopmental assessment between the ages of six

weeks and twelve months of age during the period January 2004 through May 2005.

3.3.2 Size of the study population

In previous studies where the neurodevelopmental outcome of moderate to severely asphyxiated infants was determined, population size varied between 26 and 251 subjects. In most of the studies done, cases of mild (grade I) asphyxia were also included in the study population. This was not the case in this study as it has been determined that 100% of mild cases have a normal outcome (Aurora & Snyder, 2004:552)

Table 3.1: Population size in studies on the monitoring of neurodevelopmental outcome of asphyxiated infants

Research study	Demographic location	Number of subjects with moderate to severe	Total number of subjects	Age followed up to
Robertson & Finer (1985)	Alberta, Canada	101	167	3.5years
Hull & Dodd (1992)	Derby, Great Britain	107	301	18 months
Thornberg *et al.* (1995)	Gotenborg, Sweden	39	227	18 months
Ellis *et al.* (1999)	Katmandu, Nepal	72	102	12 months
Thompson *et al.* (1997)	Cape Town, South Africa	?	40	12 months
Badwani *et al.* (2005)	Western Australia	32	276	5 yrs

Demographics, study duration, as well as inclusion criteria played an important role in determining the size of the study populations in previous studies. For the purpose of this study only population statistics and outcomes for moderately to severely asphyxiated infants were of interest.

Based on the statistical data available for the neonatal care unit at Pelonomi Hospital, moderate to severely asphyxiated infant's account for approximately 10% of the average 70 monthly admissions. The aforementioned statistics include all infants diagnosed with asphyxia, including those who subsequently may have been transferred from Pelonomi Hospital to other hospitals in the city, or have died. Calculated over a seventeen-month period in which the infants needed to have been assessed by the researcher, it would indicate a population of approximately fifty infants.

The original number of subjects with moderate to severe asphyxia aimed upon was 35.

A total number of 45 subjects were finally included in the study. Five of these subjects were subsequently lost to follow up as they failed to arrive for scheduled follow up visits or relocated to other provinces.

The population size was thus comparable to the size in studies by Thompson *et al*. (1997) and Ellis *et al.* (1999) regarding number of subjects, demographics and period of follow up.

3.3.3 Inclusion criteria

The sample included subjects whose MEDITECH electronic neonatal discharge report, patient file and physiotherapy file met the following criteria:

- Infants diagnosed with asphyxia and subsequent grade II or III hypoxic ischemic encephalopathy (HIE) using the Sarnat and Sarnat grading system.
- Patients followed up at the paediatric high risk /paediatric specialist out patient clinics and physiotherapy out patient clinic at Pelonomi Hospital in Bloemfontein.
- Physiotherapy file with a documented physiotherapy neurodevelopmental assessment between the age of six weeks and twelve months.
- Infants with a gestational age $\geq$ 36 weeks.

3.3.4 Exclusion criteria

The sample excluded subjects whose MEDITECH electronic neonatal discharge report, patient file and physiotherapy file did not meet the following criteria:

- Infants who failed to have a physiotherapy file with a documented neurodevelopmental assessment between the ages of six weeks and twelve months.
- Infants diagnosed with neurological abnormalities other than HIE.
- Infants diagnosed with clinical syndromes e.g. genetic, metabolic or neurological syndromes to name a few.
- Infants diagnosed with congenital abnormalities.
- Infants diagnosed by a physician as having clinical signs of full-blown acquired immune deficiency syndrome (AIDS). Human immunodeficiency virus (HIV) status of mother and/or child is not routinely determined.

The exclusion criteria are noted as such as they may all give rise to neurological symptoms or abnormalities. Deviations from normal neurological functioning will then not be clearly attributable to the asphyxial insult in such cases.

3.4 DEVELOPMENT OF THE DATA FORM

The aim of the study was two-fold. Firstly to determine the prevalence of neurodevelopmental sequelae in infants who suffered moderate to severe asphyxia, and secondly to describe the associated risk factors in the study population.

Data collection would thus comprise of two distinct aspects, namely neurodevelopmental assessment, and the description of the risk factors associated with asphyxia. The neurodevelopment assessment needed to be quantifiable and gauged with a standardized measure to ensure the reliability and validity of the results. Risk factors were for descriptive purposes only, and did not need to be quantified.

There are numerous developmental screening tests available such as the Denver developmental screening test (1967), Bayley scales of infant development (1969) and the Griffith scales of mental development (1976). These screening tests are well documented, and widely used abroad. Simon (1999:774) states that the use of only a developmental screening tests in the follow up of asphyxiated infant populations proved inadequate. He advises that a comprehensive neurodevelopmental evaluation is indicated, to ensure the early identification of problems.

The decision of choosing a suitable objective measure is further complicated by the fact that there is no worldwide uniformity in the method of developmental monitoring, screening or assessment. Current recommendations are based on limited research and clinical experience (Dworkin, 1989:1000).

The format in which the data had already been collected by the physiotherapy department (namely the START program checklists) at Pelonomi Hospital played a vital role in the choice of objective measure, in that they had to be compatible.

Considering all of the above the researcher decided upon the Neurodevelopmental Assessment Score (NDS) as the objective quantifiable measure for this study.

Due to the data collection requirements for this study the researcher was unable to use any existing data collection tool or form. The researcher had to developed a data form that specifically met the requirements of the study.

The data form developed for this study was comprised of two separate sections:

- Section one: risk factors associated with asphyxia
- Section two: neurodevelopmental assessment, including muscle tone, fine motor, perceptual and cognitive development, speech and language development and developmental assessment (NDS).

The data form used in the study can be found in Appendix D.

The various components of the data collection form are discussed hereafter in the order in which they appear in the form.

3.4.1 Description of the risk factors and measures of risk associated with asphyxia

The role of risk factors in neonatal asphyxia have been well described by both paediatricians and gynaecologists, including Oswyn *et al.* (2000), Osborn (1998), Woods and Malan (1996), Pattinson *et al.* (2005), Badwani *et al.* (1998), and Aurora and Snyder (2004).

The first part of the data form, the risk assessment section, served to describe the associated risk factors in the study population, and to compare them with those noted in other study populations.

According to Oswyn *et al.* (2000) risk factors can be grouped into three main categories, namely, maternal risk factors relating to the mother, neonatal risk factors relating to the infant and referral risk factors relating to the residency of the mother, location and the method of delivery, adequacy of the facilities and the availability of transportation. The risk factors were categorised similarly in this study.

For the purpose of this study the following maternal risk factors were identified by the researcher from the literature as the most prevalent maternal risk factors associated with asphyxia:

- Hypertensive disease of pregnancy or pre-eclampsia (PET)
- Maternal diabetes
- Maternal drug use
- Maternal vascular disease
- Intrauterine growth restriction (IUGR)

- Placentio abruptio
- Induced labour
- Malpresentation of the infant
- Maternal hypoxia
- Maternal infection

For the purpose of this study the following neonatal risk factors were identified by the researcher from the literature as the neonatal risk factors associated with asphyxia:

- Gestation
- Birth weight

In addition for purpose of this study the following measures of risk were identified:

- Five minute Apgar score
- Ten minute Apgar score
- Number of mechanical ventilation days

For the purpose of this study the following referral risk factors were identified by the researcher from the literature as the referral risk factors associated with asphyxia:

- Residency of mother
- Location of delivery
- Method of delivery

Residency per se is not a referral risk factor in itself, but in a South African context, and for the purpose of this study residency of the mother was considered a risk factor for the reasons discussed below.

Health services in South Africa are divided into three levels of care namely primary or district level, secondary level and tertiary level in order of the level of specialization of the services provided. The referral policy of the Department of Health in South Africa is that uncomplicated pregnancies of ≥ 36 weeks duration are to be managed at a primary health care or district level. Patients are only then transferred to secondary or tertiary level services if complications should arise requiring specialist care.

Residency is therefore a referral risk factor when taking into account the distance of the towns in the Southern Free State and Northern Cape from Bloemfontein. Taking into account the fact that patients are only referred or transferred once complications arise, time in getting to specialist levels of care is of critical importance (Department of Health, 2005).

3.4.2 Neurodevelopmental assessment

The second section of the data form was the neurodevelopmental assessment.

Simon (1999:767) emphasized the importance that the neurodevelopmental assessment and follow up asphyxiated infants should include neurological as well as developmental testing.

The role of the neurodevelopmental assessment is to assess the integrity of the musculoskeletal system, searching for any abnormality in movement (Behrman *et al.,* 2004:1977). For the purpose of this study both neurological and developmental assessment was included in the data form.

3.4.2.1 Developmental assessment

An objective measure was identified for the developmental assessment. A discussion on the choice of assessment measure follows:

- **START assessment**

The physiotherapy department at Pelonomi Hospital currently makes use of developmental checklists, based on the START program checklists, as a developmental screening tool. The START program was developed in South Africa, for the purpose of neurodevelopmental assessment by the multidisciplinary team. Checklists are divided into three monthly age categories, namely 0-3 months, 3 –6 months, 6 –9 months and 9-12 months. Each age category contains a gross motor, speech and language, fine motor, perceptual and cognitive and activities of daily living checklists (Sunshine Centre, 1990).

The START program checklists are currently been utilized as they provide a comprehensive and global overview of the infant's development. In the light of the fact that there is no occupational or speech therapist available, it allows the physiotherapist to assess speech and language and fine motor, cognitive and perceptual development in the broader sense. The START program checklists are quick and easy to complete, which is important in a busy out patient clinic setting.

In addition to the START program checklists the physiotherapist also performs a neurological evaluation, assessing muscle tone, tendon reflexes and range of joint motion.

The START program checklist in itself could not be used as an objective measure for developmental status. The checklists are extensive and non-quantifiable. They also fail to assign the infant a score, quotient or a developmental category e.g. normal, developmentally delayed or developmentally impaired.

For the physiotherapist the focus of assessment remains gross motor function. The researcher wished to use a quantifiable measure that focused specifically on gross motor function, providing a clear description of the subjects' gross motor developmental status.

- **Neurodevelopmental assessment score**

It was vital that an objective measure that was chosen was compatible with the content of the START program checklists, ensuring that the available data could be utilized and be transcribed onto the chosen measure.

The neurodevelopmental assessment score (NDS) was decided on as the measuring instrument of choice. The NDS was developed in South Africa by local physiotherapists (Goodman *et al*., 1985:1327), taking into account the busy local clinic settings in South Africa. The NDS incorporating the neurodevelopmental features considered by physiotherapists to be the most important for identifying the need for early intervention, and is a gross motor measure (Potterton & Eales, 2001:11-15).

The NDS was suitable, as it has been developed and used in studies in South Africa, and in similar developmentally at risk populations such as very low birth weight infants, and HIV infected infants (Goodman *et al*., 1985; Potterton & Eales, 2001). Taking contextual factors into account it was felt that it would be an adequate assessment tool to provide internal study population coherence.

The NDS as an assessment tool has been validated for infants between six weeks and twelve-months of age (Potterton & Eales, 2001:12). As far as could be determined there is no available validation quotient, but the NDS has been validated against the Griffith's Mental Development Scale (Potterton & Eales 2001:14).

The NDS is a standardized screening test. The scale assesses twelve areas of motor development namely: moro reflex, protective reactions, asymmetric tonic neck reflex (ATNR), eye contact, head control, hand function, neck and shoulder retraction, prone functioning, sitting, rolling, standing, horizontal and oblique suspension. A scoring sheet is available with the NDS and age categories for infants are six weeks then three monthly age group intervals at three months, six months, nine months and twelve months respectively.

A score of “0” is given if the infant is functioning at or above the age appropriate level and a “1” if the infant is functioning below the age appropriate level.

A score out of 12 is finally calculated and the infant is assigned a NDS or developmental category (Goodman *et al*., 1985; Potterton & Eales, 2001):

Category I Normal (NDS score 0 – 4)

Category II Developmentally delayed (NDS score 5 – 9)

Category III Neurologically impaired (NDS score of 10 – 12).

The outcome of the subjects’ performance in the area of gross motor function, as documented on the START program checklists, was easily transcribed onto the NDS due to the comparability of the measures.

The comparability of the NDS and START program checklists is shown in table 3.2.

Table 3.2: Comparison between the NDS and START program checklists

NDS	START program checklists
Developed by physiotherapists for use by physiotherapist	Developed for the use by the multi-professional team and infant caregivers/parents
Focus mainly on the aspects of development found to be important to physiotherapists i.e. namely gross motor function	Focus on all aspects of development including fine motor function, speech and communication and activities of daily living
Consists of a twelve item score	Consist of large numbers of items to be assessed under each category
Easy and quick to execute	More time consuming to execute due to the large number of items. Items not relating to a physiotherapist's field of expertise may be more difficult to perform and evaluate
Items are scored as developmentally on par for age (0) and developmentally behind for age (1)	Items are scored as a pass (√) or fail (X) for an item relating to being on par or developmentally behind for age
Quantifiable. A total score out of twelve is calculated. This is then used to allocate a NDS category: I - Normal (score 0 - 4) II - Developmentally delayed (score 5 – 9) III - Neurologically impaired (score of 10 –12)	Not quantifiable as no score or category is assigned

As cited by Katzenellenbogen and Joubert (2002:90-91) **validity** means that the objective measure measures what it is supposed to measure. The study by Potterton and Eales (2002) states that the NDS has been validated for children between the ages of six weeks and twelve months, and validated against the Griffith Scales of Mental Development. The NDS does measure all aspects of gross motor development as deemed important by physiotherapists. The content of the measuring tool may therefore be considered as valid.

As cited by Katzenellenbogen and Joubert (2002:90-91) **reliability** of the measuring tool refers to the degree of similarity of the information obtained when the measurement is repeated on the same subject or group. The reliability was ensured in terms of observer variation in that the same person (researcher),

experienced in the field of neurodevelopmental assessment, assessed all subjects in the study population.

Table 3.3 shows the validation of the comparability of the NDS and START programs

Table 3.3: Validation of the comparability of the NDS with the START program checklists:

NDS element	START program checklist reference
Moro reflex	Gross motor checklist, supine positioning
Placing Parachute reflex	Gross motor checklist, standing position
ATNR	Gross motor checklist, supine positioning
Eye contact Following	Fine motor and cognitive skills checklist: vision
Head lag Pull to sit Leg position	Gross motor checklist, supine positioning
Fisting Hands to midline Reach Transfer	Fine motor and cognitive skills checklist: grasp and release
Retraction of the neck Retraction of the shoulder	Gross motor checklist, prone positioning
Prone Head control Arms	Gross motor checklist, prone positioning
Sitting	Gross motor checklist, sitting position
Supine Rolling	Gross motor checklist, supine positioning
Automatic walking Astasia Weight bearing Walking	Gross motor checklist, standing position
Horizontal suspension Oblique suspension	Gross motor checklist, ventral and oblique suspension

The original data collection form of the NDS was converted by the researcher into a key card that served to assist in the transfer and transcribing of the data from the START program checklist onto the NDS.

The key card as used in the study is provided in appendix E.

Potterton and Eales (2001:15) noted that the NDS had a few limitations and shortcomings as a measuring tool. The NDS was used as an objective measure in their study to determine the prevalence of developmental delays in infants who were HIV positive. The shortcomings noted were that the NDS served to be a insensitive measuring tool for global developmental status, and as a purely a gross motor measure it failed to provide information on other aspects of development such as fine motor and speech development.

- **Fine motor, perceptual and cognitive development and speech and language development**

The NDS was developed from a physiotherapy perspective, the emphasis being on gross motor development. Some criticism leveled at the NDS has been that it does not include other developmental aspects such as fine motor, perceptual and cognitive, or speech and language development (Goodman *et al.,* 1985:1327; Potterton & Eales, 2001:12-15).

In clinical practice, the physiotherapist does not always have the services of an occupational therapist and speech therapist available. She/he should be able to grossly assess fine motor, perceptual and cognitive, as well as speech and language development, and be able to identify possible problems, and the need for referral and intervention (Brown, 2001). Development should be considered holistically, and it is important for the physiotherapist to be knowledgeable about all aspects of the individual child's development.

To ensure that the data form collected information on the global development of subject, fine motor, perceptual and cognitive development, and speech and language performance was described in addition to the NDS. Information on the subject's performance in these areas was available in START program checklists completed by the physiotherapy department at Pelonomi Hospital. These developmental aspects did not form part of the quantifiable score, but were described as being developmentally on par or delayed for age.

3.4.2.2 Neurological assessment

For the purpose of this study tone, strength, motility, locomotion and primitive reflexes were examined as part of the neurological examination (Behrman *et al.,* 2004:1987).

Deep tendon reflexes were not specifically examined, however muscle tone would give an indication as to the nature of the deep tendon reflexes (Behrman & Kliegman, 2002:774)

Assessment of muscle strength, motility and locomotion and primitive reflex are contained in the NDS. Muscle tone was thus described as a separate element, and did not form part of the quantifiable score.

Only muscle tone will be discussed under the section neurological examination.

- **Muscle tone:**

Muscle tone can be described as the resting tautness or laxity in a muscle–the normal state of elastic tension or partial contraction in a resting muscle. Muscle tone is a characteristic of a muscle brought about by the constant flow of nerve stimuli to the muscle (Free dictionary online, 2005; Anderson, 1994:1026).

Behrman and Kliegman (2002:773) suggest that two types of muscle tone can be assessed in an infant. Passive tone is referred to the resistance to stretch felt when a limb is moved in both directions, whilst active tone refers to the posture an infant adopts when placed in a specific position.

Shepard (1980:91) and (Davies 1994:28) agree that the assessment of muscle tone is essentially subjective, and largely dependant on the experience of the assessor. Clinical assessment of tone through passive movement and posture is not quantifiable (Shaw *et al.* 1999:3). For the purpose of this study muscle tone will be described only as being normal, hypertonic or hypotonic.

Normal tone is described as the appropriate amount of resistance, allowing movement to proceed smoothly and without interruption. The opposing or antagonistic muscles adapt instantly to new amounts of stretch, and respond accordingly. There may be a slight variation in the amount of resistance felt from individual to individual (Davies, 1985:28).

Hypertonicity, also referred to as spasticity, is described as increased resistance to passive movement. The resistance varies from a slight delay in giving way to considerable effort being required before a limb can be moved at all. When the limb is released it is pulled in the direction of the spastic muscle group.

Hypertonicity is the release of tonic reflex activity and manifests itself in stereotype patterns of either flexion or extension (Davies, 1985:28).

Hypotonicity, also often referred to as the “floppy child”, is described as too little or no resistance to movement. The limb and child feels limp or floppy. When released the limb falls in the direction of the pull of gravity (Davies, 1985:28).

Muscle tone can be assessed in several ways including through observation and handling of the infant (Shepard, 1980:90-91).

For the purpose of this study muscle tone was assessed by means of passive movement of the limb, assessing the degree of resistance when an individual joint was moved passively in both directions. Tone in the upper limbs was tested in supine by flexing and extending the arm and moving the arm across the chest. Tone is the lower limb was tested in supine by flexing and extending the leg. In addition tone in the abductors and an adductor muscle was tested through abducting and adducting the leg (Behrman & Kliegman, 2002:773).

Tone was tested in the head and trunk by means of pull to sit from supine, and observation of horizontal and oblique suspension and prone positioning (Behrman & Kliegman, 2002:773). Testing of tone in the head and trunk is contained in the NDS (Sunshine centre, 1990).

3.4.3 Summary of the developed data form

From the above discussion the researcher developed the data form in the following format:

Section one relating to maternal, neonatal and referral risk factors.

Section two relating to the neurodevelopmental assessment, comprising of:

- Assessment of muscle tone
- Assessment of fine motor, perceptual and cognitive development
- Assessment of speech and language development.
- Assessment of gross motor development in the form of NDS

The allocations of the data elements in the two categories are given in table 3.4.

Table 3.4: Data elements and category

Data element number	Category	Sub -category	Aspects
Data element 1 - 12	Risk factors		Maternal, neonatal and referral risk factors
Data element 13	Neurodevelopmental Assessment	Neurological Assessment	Muscle tone
Data element 14 - 15		Developmental Assessment	Fine motor, perceptual, cognitive Speech and language development.
Data element 16-28		Developmental Assessment	Gross motor assessment in the form of the NDS

3.5 STUDY PROCEDURE

A flow chart of the study procedure is given in figure 3.1

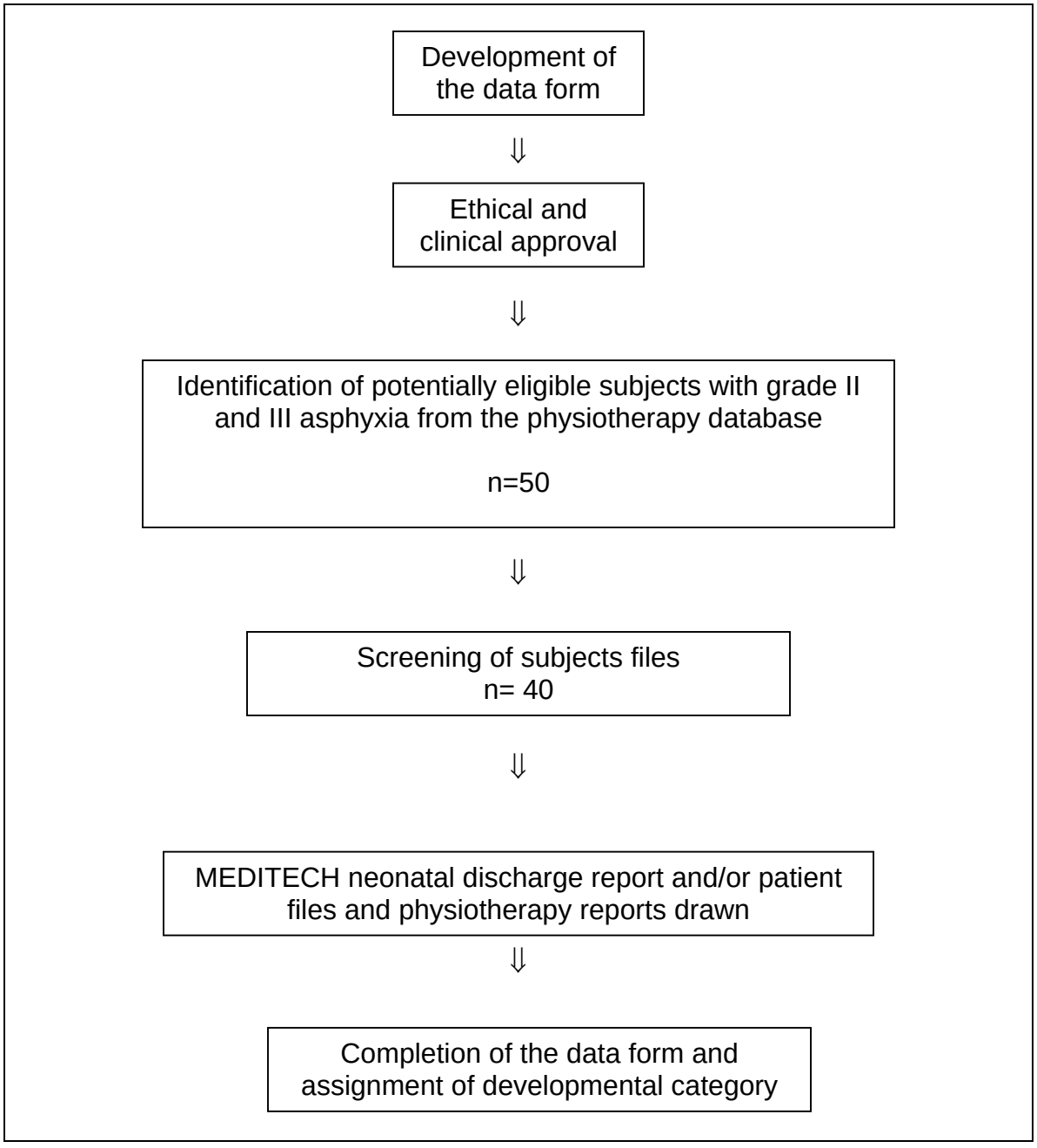

Figure 3.1: Flow chart of the study procedures

3.5.1 Ethical aspects and good clinical practice compliance

3.5.1.1 Mandatory approvals

Written approval for the study was gained from the ethical committee of the Faculty of Health Sciences at the University of the Free State. ETOVS number NR 92/05 was allocated to this study.

Following ethical approval, permission for the execution of the study, and access to the patient records was gained from the office of the Head of Clinical Services, Pelonomi Hospital, Bloemfontein.

As this was a retrospective study, and only made use of previously collected patient data, no parental consent was indicated.

3.5.1.2 Good clinical practice

The study was conducted in compliance with the protocol.

35.1.3 Data management, record keeping and storage

All data and information pertaining to the subjects was treated as confidential, and managed in accordance with ethical guidelines. All letters of permission and subject data forms were filed, and will be stored for a period of at least seven years.

3.5.2 Piloting of the data form

Following ethical approval the data form was piloted. Pre- testing or piloting of the data form served to test the logistics of the data form. Clarity of the data elements, availability of the required data and time frame for the completion of each data form was assessed.

The data form was piloted using the MEDITECH electronic neonatal discharge report, patient file and physiotherapy file of two subjects. Both subjects had

suffered grade II asphyxia, but were excluded from this study as a result of their gestation (prematurity).

The researcher found the data form to be simple to understand and quick to complete. Both infants had complete electronic discharge reports and physiotherapy files. All the relevant data was available as required in the data form.

No changes were made to the data form following piloting.

3.5.3 Subject identification

Using the physiotherapy statistical database the researcher compiled a list of all infants who were diagnosed with grade II or III neonatal asphyxia, and who were followed up at the physiotherapy out patient clinic between January 2004 and May 2005.

3.5.4 Screening

All subjects identified as having been diagnosed with grade II and III asphyxia, and who were followed up post discharge at the paediatric high risk/ paediatric specialist clinics and the physiotherapy department at Pelonomi Hospital following discharge were identified.

All identified subjects files were screened to determine if they met the inclusion criteria. Non-qualifiers were identified as such.

Subjects meeting the inclusion criteria were allocated a number on admission to the study. The subjects retained the number throughout the duration of the study.

3.5.5 Completion of the data form

In order to complete the data form the subject's MEDITECH electronic neonatal discharge report and/or patient record, as well as the physiotherapy file were accessed by the researcher.

For the purpose of this study only one data form was completed for a single assessment of the subject. If the subject had more than one assessment on his physiotherapy file, the data in the assessment at the oldest age ≤ twelve months was accessed.

The methods used for completion of the data form are discussed hereafter.

3.5.5.1 Risk factors associated with asphyxia

In order to complete data elements one to twelve on the data form, the researcher accessed the MEDITECH electronic neonatal discharge report and/or patient files of the subjects.

Information relating to the maternal, neonatal and referral risk were then completed on the data sheet. In each case the researcher controlled the accuracy of the transcription from the patient record onto the data form.

3.5.5.2 Neurodevelopmental assessment

In order to complete data elements thirteen to 28 on the data form, the researcher accessed the physiotherapy files of all the subjects.

- **Muscle tone**

To complete data element thirteen pertaining to the muscle tone of the subject, the physiotherapy file of the subject was accessed. Tone was described as being normal, hypertonic or hypotonic in the physiotherapy file.

The researcher then marked the corresponding option on the data form. In each case the researcher controlled the accuracy of the transcription from the physiotherapy file onto the data form.

- **Fine motor, perception and cognitive development, and speech and language development**

To complete data elements fourteen and fifteen, pertaining to fine motor, perceptual and cognitive development and speech and language development of the subjects, the physiotherapy file, and attached START program checklists were accessed.

After identifying the START checklists for fine motor, perception and cognitive development, and speech and language development, the researcher carefully reviewed them. After studying the outcome on the checklists, the researcher converted the outcome into a score. Both aspects of development were scored as being either developmentally on a par for age or behind for age.

The researcher then marked the corresponding option on data form. In each case the researcher controlled the accuracy of the transcription from the START program checklists onto the data form.

- **Gross motor elements and NDS score**

To complete data elements sixteen through 28, pertaining to the gross motor development of the subjects, the physiotherapy file, and attached START program checklist was accessed.

The NDS was then correlated with the gross motor START checklist. Corresponding items on the START gross motor checklist were identified and their outcome converted into a score. The key card was also used to ensure that the START item's outcome was correctly represented on the data form. A score of zero (developmentally on par for age) or one (developmentally delayed) was

given on the data form for each element based on the outcome documented on the START program checklist.

Considering the definition of developmental delay as discussed in the literature review, a delay in a single areas of development was considered as being at least 40% behind for chronological age. Leeway of a month (four weeks) was given when scoring infants as delayed.

The researcher then marked the corresponding option on the data form. In each case the researcher controlled the accuracy of the transcription from the START checklists onto the data form.

On completion of this portion of the data form, the twelve elements from seventeen through 28 were added together to provide a score out of twelve. A developmental category of either normal (score 0 - 4), developmentally delayed (score 5 - 9) or neurologically impaired (score 10 -12) was then assigned.

3.6 STATISTICAL ANALYSIS

Data was statistically analysed to provide descriptive statistics for namely frequencies and percentages for categorical data, and medians and percentiles for continuous data. The grades of asphyxia were compared, and the prevalence of neurodevelopmental delays was described using a 95% confidence interval. The statistical analysis was completed by the Department of Biostatistics at the University of the Free State.

3.7 PROBLEMS ENCOUNTERED DURING THE EXECUTION OF THE STUDY

3.7.1 Subject identification

A total of 50 subjects diagnosed with grade II and III asphyxia were identified from the physiotherapy database.

Five subjects did not meet the inclusion criteria due to prematurity or were of an age of greater than twelve months at first assessment. Five subjects were lost to follow up, in that they failed to arrive for their physiotherapy out patient appointments or relocated to other provinces.

Potential subjects were lost to follow up by the physiotherapist due to unexpected discharge from the neonatal unit, or transfer to other hospitals without a physiotherapy out patient appointment for follow up and neurodevelopmental monitoring being secured.

3.7.2 Completion of the data form

Collection of the data pertaining to the risk factors was impeded by the fact that the computer network at Pelonomi Hospital was frequently down during the months of June and July 2005. Access to the MEDITECH neonatal discharge reports could not be gained during these periods.

Eight subjects did not have a MEDITECH neonatal discharge report. In some cases both patient file and MEDITECH electronic neonatal discharge report provided incomplete information. In the case of one subject no history was available in the patient file or MEDITECH electronic neonatal discharge report.

This only affected the data gathering pertaining to the risk factors. In cases where data was unavailable for certain risk factors the size study population was marked accordingly.

3.8 SUMMARY

The methodology of the study is described in this chapter. The study population, including the selection and screening of subjects is outlined. Special attention was paid to the development of the data form, as well as the piloting and implementation of the form. The problems encountered during the study did not

influence the results in such a way that the goals of the study could not be achieved.

In chapter 4 the results of the study are discussed using amongst other, tables and figures.

CHAPTER 4

Results

4.1 INTRODUCTION

In order to ensure the maximum number of subjects meeting the inclusion criteria of the study, the researcher compiled a complete list of all the infants who were diagnosed with grade II or III neonatal asphyxia, and who had had a neurodevelopmetal assessment by a physiotherapist between the ages of six weeks and twelve months during the period from January 2004 until the end of May 2005. The study population was identified using the physiotherapy patient database. The same physiotherapist carried out all the neurodevelopmental assessments for the subjects during the period.

Data was statistically analyzed to provide descriptive statistics for namely frequencies and percentages for categorical data, and medians and percentiles for continuous data. The grades of asphyxia were compared, and the prevalence of neurodevelopmental delays was described using a 95% confidence interval. The statistical analysis was completed by the Department of Biostatistics at the University of the Free State.

In this chapter the results of the study are presented in the following order:

- Non–qualifiers and mortalities

Data from this point on will be presented per grade of asphyxia as follows:

- Distribution of the severity of asphyxia in the study population
- Gender distribution in the study population
- Maternal, neonatal and referral risk factors associated with asphyxia
- Neurodevelopmental assessment
- Neurodevelopmental categories
- Prevalence of neurodevelopmental sequelae
- Neurodevelopmental categories and risk factors

4.2 NON- QUALIFIERS AND MORTALITY

From the physiotherapy patient database 50 subjects were identified as having been diagnosed grade II or III asphyxia. Five subjects failed to meet the inclusion criteria due to prematurity, or that the first physiotherapy neurodevelopmental assessment only took place after the first year of life due to late referral.

Five subjects were lost to follow up, as two relocated to other provinces, and three failed to honour scheduled out patient appointments for neurodevelopmental monitoring.

According to the physiotherapy database no infants died following discharge.

Table 4.1. Shows the non-qualifiers and mortality using frequencies.

Table 4.1: Non- qualifiers and mortality

Category	Frequency
Non- qualifiers	5
Lost to follow up	5
Death following discharge	0

4.3 DISTRIBUTION OF SEVERITY OF ASPHYXIA IN THE STUDY POPULATION

All subjects were classified or graded by the attending clinician on admission to the Pelonomi Hospital neonatal care unit (NCU). Subjects were classified as either having grade II or III asphyxia using the Sarnat and Sarnat grading system (1976). Of the 40 subjects 31 were diagnosed with Grade II and nine with grade III asphyxia.

Table 4.2 shows the distribution of the severity of the asphyxia per grade in the study population using frequencies and percentages.

Table 4.2: Distribution of the Severity of asphyxia (n=40)

Grade	Frequency	%	Grade	Frequency	%
Grade II	31	77	Grade III	9	23

4.4 GENDER DISTRIBUTION IN THE STUDY POPULATION

40 subjects were included in the study. The study population was comprised of 22 male and eighteen female subjects. The grade II group was comprised of seventeen males and fourteen females, whilst the grade III group was comprised of five males and four females.

Table 4.3. Shows the gender distribution per grade of asphyxia in the study population using frequencies and percentages.

Table 4.3: Gender distribution (n=40)

Gender	Grade II (n=31)	%	Grade III (n=9)	%	Total (n=40)	%
Male	17	55	5	56	22	56
Female	14	45	4	44	18	44

4.5 RISK FACTORS AND MEASURES OF RISK ASSOCIATED WITH ASPHYXIA

For this study risk factors were noted in order to describe the study population. In the section below the risk factors will be described per grade of asphyxia, and where applicable compared per grade of asphyxia using a 95% confidence interval for the percentage or median difference.

4.5.1 Maternal risk factors

The attending clinician identified and noted if maternal risk factors were present in the patient record. Nine (23%) of the mothers were known to have had hypertensive disease of pregnancy or pre-eclampsia (PET). Hypertensive disease of pregnancy was also the most frequently noted maternal risk factor.

Intrauterine growth restriction (IUGR) was noted in three cases (8%), and two mothers (5%) were identified as having used drugs (in both cases alcohol) during pregnancy. In both cases where the mothers had used excessive amounts of alcohol during their pregnancy the infant suffered intrauterine growth restriction.

In the majority of mothers, 26 (65%), no risk factors or diseases were noted during pregnancy.

The values per grade of asphyxia were compared by means of a 95% confidence for the percentage difference, there was no statistical difference in the presence of maternal risk factors between the grade II and grade III subjects.

The percentage difference for maternal risk factors with a 95 % confidence interval comparing Grade II and III is shown in table 4.4.

Table 4.4: Maternal risk factors (n=40)

Maternal-risk factors	Grade II (n=31)	%	Grade III (n=9)	%	Total (n=40)	%	95 % confidence interval for the percentage difference *
Hypertensive disease	6	19	3	33	9	23	[-46.8%; 13.2%]
Maternal diabetes	0	0	0	0	0	0	
Maternal drug use	2	6	0	0	2	5	[-29.9%; 11%]
Maternal vascular Disease	0	0	0	0	0	0	
Intrauterine growth restriction	3	10	0	0	3	8	[-23.8%; 20.7%]
Placentio abruptio	0	0	0	0	0	0	
Induced labour	0	0	0	0	0	0	
Malpresentation of the infant	0	0	0	0	0	0	
Maternal hypoxia	0	0	0	0	0	0	
Maternal infection	0	0	0	0	0	0	
No diseases during pregnancy	20	65	6	56	26	65	[-22.1%; 41.2%]

* The wide confidence interval is due to the small study population.

In this study six (67%) of the mothers with hypertensive disease of pregnancy had growth restricted infants (weighing less than 2500g)

4.5.2 Neonatal risk factors and associated measures of risk

Data was collected regarding neonatal risk factors including gestation, Apgar scores at five and ten minutes, birth weight and number of mechanical ventilation days.

Median values and percentiles were calculated as the data was skewed.

Only infants with a gestational age of ≥ 36 weeks were included in the study. Gestational age ranged from 36 weeks to 41 weeks with a median value of 38 weeks for both Grade II and III subjects. No post term infants were included in this study.

Birth weight of the subjects ranged between 1 900g and 4 010g with a median value of 3060g for the grade II and 3000g for the grade III subjects respectively.

Apgar scores ranged from one to nine at five minutes with a median value at five minutes of three for the grade II and four for the grade III subjects respectively.

Apgar scores at ten minutes ranged from four and nine with a median value of six for the grade II and five for the grade III subjects respectively.

Five subjects required mechanical ventilation for a time period varying from two to eleven days for both the grade II and III subjects.

Data on neonatal risk factors was unavailable in two cases.

The median values per grade were compared by means of a 95% confidence for the median difference; there was no statistical difference in neonatal risk factors between the grade II and grade III subjects.

Values for the median difference for neonatal risk factors with a 95% confidence interval comparing grade II and III are given in table 4.5.

Table 4.5: Neonatal risk factors and associated measures of risk (n=38)

Risk factors	Grade II			Grade III			95% confidence interval for the median difference
	Median	25th percentile	75th percentile	Median	25th percentile	75th percentile	
Gestation	38	38	38	38	38	38	[0 ;0]
Birth weight	3060	2550	3450	3000	2430	3450	[-350; 570]
Measures of risk							
Apgar 5 min.	3	2	5	4	2	5	[-1; 2]
Apgar 10 min.	6	5	7	5	5	7	[-1; 2]
Ventilaton days	0	0	0	0	0	0	[0; 0]

4.5.3 Referral risk factors

Data was collected on referral risk factors including maternal residency, location of delivery and the method of delivery.

- **Maternal residency**

Of the 40 subjects 23 (59%) mothers resided in Bloemfontein, whilst sixteen (41%) resided elsewhere at the time of the subjects birth. The residency of one subject was unknown.

The values per grade were compared by means of a 95% confidence for the percentage difference; there was no statistical difference in residency between the grade II and grade III subjects.

The percentage difference for maternal residency with a 95% confidence interval comparing grade II and III is provided in Table 4.6.

Table 4.6: Maternal residency (n=39)

Maternal residency	Grade II (n=30)	%	Grade III (n=9)	%	Total (n=39)	%	95% confidence interval for the % difference
Bloemfontein	18	60	5	56	23	59	[-28.4%; 35.3%]
Other	12	40	4	4	16	41	

The sixteen mothers, who did not reside in Bloemfontein, resided in towns in the Free State and Northern Cape. The majority of the mothers (seven) resided in Thaba Nchu, a town located approximately 65 kilometres away from Bloemfontein. Two mothers resided in Colesburg, located approximately 220 kilometres away.

It can be estimated that on average mothers residing outside of Bloemfontein, resided approximately 106 kilometres away.

Table 4.7 below shows the residential demographics of mothers who did not reside in Bloemfontein

Table 4.7: Maternal residencies outside Bloemfontein (n=16)

Town	Frequencies (n=16)	Percentage %
Colesburg	2	13
Dealesville	1	6
Petrusburg	1	6
Reddersburg	1	6
Rouxville	1	6
Soutpan	1	6
Thaba Nchu	7	45
Wepener	1	6
Zastron	1	6

- **Location of delivery**

Data was collected regarding the location of subjects' delivery. Twenty-three (61%) of the infants were born at Pelonomi Hospital, a secondary level institution, whilst 14 (37%) were born in the periphery at a primary health care (PHC) level facility. Infants were later transferred to Pelonomi Hospital during the neonatal period. One (2%) home birth in Bloemfontein was also noted. The information on the location of delivery was unavailable in two cases.

The values per grade were compared by means of a 95% confidence for the percentage difference; there was no statistical difference in the location of delivery between the grade II and grade III subjects.

Table 4.8 below shows the percentage difference for the location of the delivery with a 95% confidence interval comparing grade II and III.

Table 4.8: Location of delivery (n=38)

Location of delivery	Grade II (n=29)	%	Grade III (n=9)	%	Total (n=38)	%	95% confidence interval for the % difference
Pelonomi Hospital	18	62	5	56	23	61	[-44.2%; 18.9%]
Periphery/ PHC	10	35	4	44	14	37	
Other (Home)	1	3	0	0	1	2	

- **Method of delivery**

Data was collected regarding the method of delivery of the subjects. Twenty-four (62%) of the subjects were delivered vaginally, and fifteen (38%) via a caesarian section. In the case of one subject information on the method of delivery was unavailable.

The values per grade were compared by means of a 95% confidence interval for the percentage difference; there was no statistical difference in the method of delivery between the grade II and grade III subjects.

Table 4.9 indicates the percentage difference for method of delivery with a 95% confidence interval comparing grade II and III

Table 4.9: Method of delivery (n=39)

Method	Grade II (n=30)	%	Grade III (n=9)	%	Total (n=39)	%	95% confidence interval for the % difference
Vaginal	20	67	4	44	24	62	[-11.8%; 51.4%]
Caesarian section	10	33	5	56	15	38	

Table 4.10 depicts the relationship between residency, location and method of delivery per residential area using frequencies.

Table 4.10: Relationship between residence and location of and method of delivery (n=39)

Residence (n = 39)	Location of deliver			Method of delivery	
	Pelonomi	Periphery/ Primary health care facility	Home	Caeserian section	Vaginal
Bloemfontein (n=23)	16	6	1	10	13
Thaba Nchu (n=7)	3	4	0	3	4
Colesburg (n=2)	2	0	0	1	1
Zastron (n=1)	1	0	0	0	1
Petrusburg (n=1)	0	1	0	0	1
Redderburg (n=1)	0	1	0	0	1
Rouxville (n=1)	1	0	0	1	0
Wepener (n=1)	0	1	0	0	1
Deallesville (n=1)	0	1	0	0	1
Soutpan (n=1)	0	1	0	0	1

4.6 NEURODEVELOPMENTAL ASSESSMENT

4.6.1 Age at assessment

Subjects who had had a physiotherapy neurodevelopmental assessment between the ages of six weeks and twelve months during the period January 2004 until the end of May 2005 were included in the study.

For the purpose of this study only information from a single assessment was used in the study. If the subject had more than one assessment on their file, the assessment at the oldest possible age ≤ twelve months was used. It is important to note that assessment at the oldest possible age may have hampered the earliest identification of any delay or impairment.

The distribution of the number of subjects per age group at assessment is shown in table 4.11.

Table 4.11: Age at assessment (n=40)

Age	Frequency (n = 40)	Percentage %
6 weeks	5	13
3 months	12	30
6 months	7	17
9 months	8	20
12 months	8	20

4.6.2 Muscle tone

Muscle tone formed part of the neurological assessment. Tone was described as normal, hypotonic or hypertonic. Of the sample 24 (62%) subjects had normal tone, whilst sixteen (40%) were found to have abnormal tone. Of the sixteen, twelve (30%) were hypertonic and four (10%) were hypotonic.

The values per grade of asphyxia were compared by means of a 95% confidence interval for the percentage difference; there was no statistical difference in muscle tone between the grade II and grade III subjects.

The percentage difference for muscle tone with a 95% confidence interval comparing grade II and III is given in table 4.12.

Table 4.12: Muscle Tone (n=40)

Tone	Grade II (n=31)	%	Grade III (n=9)	%	Total (n=40)	%	95% Confidence interval for the % difference
Normal	21	68	3	33	24	60	[-1.5%; 59.7%]
Hypotonic	3	10	1	11	4	10	
Hypertonic	7	23	5	56	12	30	

Figure 4.3 distribution of muscle tone in the total population in graphical form using percentages.

4.6.3 Fine motor, perceptual and cognitive development (n=40)

Fine motor, perceptual and cognitive development was assessed and expressed as being developmentally on par, or behind for age. Twenty-five (62%) of the subjects were developmentally on par for age, whilst fifteen (38%) were developmentally delayed for age.

The values per grade were compared by means of a 95% confidence interval for the percentage difference; there was no statistical difference in fine motor, perceptual and cognitive development between the grade II and grade III subjects.

Table 4.13 shows the percentage difference for fine motor, perceptual and cognitive development with a 95% confidence interval comparing grade II and III.

Table 4.13: Fine motor, perceptual and cognitive development (n=40)

Developmental status	Grade II (n=31)	%	Grade III (n=9)	%	Total (n=40)	%	95% confidence interval for the % difference
On par for age	21	68	4	44	25	62	[-10.5%; 52.3%]
Delayed for age	10	32	5	56	15	38	

4.6.4 Speech and language development

Speech and language development was assessed and expressed as being developmentally on par, or behind for age. Twenty-nine (73%) of the subjects were developmentally on par for age, whilst thirteen (27%) were developmentally delayed for their age.

The values per grade were compared by means of a 95% confidence interval for the percentage difference; there was no statistical difference in speech and language development between the grade II and grade III subjects.

Table 4.14 shows the percentage difference for speech and language development with a 95% confidence interval comparing grade II and III.

Table 4.14: Speech and language development (n=40)

Developmental status	Grade II (n=31)	%	Grade III (n=9)	%	Total (n=40)	%	95% confidence interval for the % difference
On par for age	23	74	6	67	29	73	[-20.0%; 41.0%]
Delayed for age	8	26	3	33	11	27	

4.6.5 Gross motor development

Gross motor development was assessed using the neurodevelopmental assessment score (NDS) as the objective measure.

4.6.5.1 Neurodevelopmental assessment score

The NDS, a standardized screening test, was used to assess twelve areas of gross motor development namely: moro reflex, protective reactions, asymmetric tonic neck reflex (ATNR), eye contact, head control, hand function, neck and shoulder retraction, prone functioning, sitting, rolling, standing, horizontal and oblique suspension.

The NDS assess the subjects' performance on each developmental item, scoring each item as developmentally on par, or delayed for age.

The percentage difference per NDS outcome per item with a 95% confidence interval comparing grade II and III is given in table in table 4.15.

Table 4.15: NDS outcome per developmental item (n=40)

Developmental item on NDS	Score	Grade II (n =31)	%	Grade III (n=9)	%	Total (n = 40)	%	95 % confidence interval for the % difference
Moro reflex	**0**	30	97	9	100	39	98	[-26.8%; 16.2%]
	1	1	3	0	0	1	2	
Placing foot Parachute	**0**	28	90	7	78	35	88	[-45.7%; 9.5 %]
	1	3	10	2	22	5	12	
ATNR	**0**	30	97	9	100	39	98	[-26.8%; 16.2%]
	1	1	3	0	0	1	2	
Eye contact Following	**0**	24	77	4	44	28	70	[-60.9%; 0.7%]
	1	7	23	5	56	12	30	
Headlag Pull to sit, legs	**0**	19	61	4	44	23	58	[-46.5%; 16.9%]
	1	12	39	5	56	17	42	
Fisting, hands to midline, reach and transfer	**0**	21	68	4	44	25	63	[-52.3%; 10.5%]
	1	10	32	5	56	15	37	
Retraction of the neck and shoulders	**0**	23	74	5	56	28	70	[-50.0%; 12.3%]
	1	8	26	4	44	12	30	
Prone Head control	**0**	18	58	4	44	22	55	[-43.5%; 20.1%]
	1	13	42	5	56	18	45	
Sitting	**0**	23	74	4	44	27	68	[-58.0%; 4.0%]
	1	8	26	5	56	13	32	
Supine Rolling	**0**	23	74	6	67	29	73	[-41.0%; 20%]
	1	8	26	3	33	11	27	
Automatic walking, astasia, weight bearing and Walking	**0**	23	74	6	67	29	73	[-41.0%; 20%]
	1	8	26	3	33	11	27	
Horizontal and oblique suspension	**0**	19	61	3	33	22	55	[-54.0%; 7.8%]
	1	12	39	6	67	18	45	

(Where a score of 0 = developmentally on par for age and 1 = developmentally delayed for age)

From the NDS summary above, it is evident that the developmental items subjects performed worst on were horizontal and oblique suspension, eye contact and following, pull to sit, prone, midline orientation and reaching with the arms and sitting.

A NDS score for the twelve items was then computed by summing the scores for each item. Subjects could attain a score ranging from one to twelve.

Table. 4.16 shows the distribution of the scores attained by the subjects using frequencies and percentages, where one is the lowest score (least delayed) and twelve the maximum score (most delayed).

Table 4.16: Distribution of NDS (n=40)

Score	Frequency (n=40)	Percentage %
1	19	49
2	2	5
3	2	5
4	3	8
5	1	2
6	1	2
7	1	2
8	2	5
9	4	10
10	4	10
11	1	2
12	0	0

Where a score of 0-4 (normal), 5-9 (developmentally delayed) and 10-12 (neurologically impaired)

The median values for the NDS were compared by means of a 95% confidence interval for the median difference. No statistical difference between the scores grade II and III subjects [-7,0] was found, but there was a tendency for the grade III subjects to have a higher score. This would imply that the grade II subjects faired better developmentally.

The median difference for the NDS with a 95% confidence interval comparing grade II and III are given in table 4.17.

Table 4.17: NDS outcome per grade of asphyxia (n=40)

Grade	Median	75 percentile	25 percentile	95% confidence interval for median difference
Grade II	0	8	0	[-7; 0]
Grade III	4	9	1	

4.6.5.2 Neurodevelopmental category

The NDS score was utilized to assign each subject to a developmental category ranging from normal, to developmentally delayed to neurological impaired.

27 (68%) subjects had a normal neurodevelopmental outcome. 32% had neurodevelopmental sequelae, of which eight (20%) of the subjects showed a developmental delay and five (12%) could be identified as having a clear neurological impairment.

Of the subjects nine had cerebral palsy, six with spastic quadruplegia, two with spastic hemiplegia and one with hypotonia.

Table 4.18 shows the developmental categories assigned from the NDS usingfrequencies and percentages

Table 4.18: Neurodevelopmental categories (n=40)

Developmental Category	Score range	Frequency (n=40)	Percentage %
Normal	0 - 4	27	68
Developmentally delayed	5 - 9	8	20
Neurologically impaired	10 -12	5	12

Neurodevelopmental performance was also stratified per age group; frequencies and percentages for the NDS score distribution per age group is given in table 4.19.

Table 4.19: NDS categories per age group (n=40)

Age	Normal (frequency)	%	Developmetally delayed (frequency)	%	Neurologically impaired (frequency)	%
6 weeks (n=5)	3	60	2	40		
3 months (n=12)	8	67	4	33		
6 months (n=7)	6	86	1	14		
9 months (n=8)	7	88			1	12
12 months (n=8)	3	38	2	24	3	38

From the above table it is evident that developmental delays are evident as early as six weeks. Neurological impairments were only identified from nine months of age.

It is important to note that the methodology of the study could possibly have resulted in the fact that impairments were only identified from nine months and onwards.

4.7 Risk factors and neurodevelopmental categories

Gestation was not included in this table as all infants had a gestation of ≥ 36 weeks. The risks factors categories and NDS are given below in tables 4.20, 4.21 and 4.22 using frequencies.

Table 4.20: Maternal risk factors and the neurodevelopmental category

NDS category	Frequencies		
	Hypertensive disease of pregancy (n=9)	Alcohol use (n=2)	IUGR (n=3)
Normal	4	0	1
Delayed	3	0	0
Impaired	2	2	2

Table 4.21: Neonatal risk factors and neurodevelopmental category

NDS category	Frequencies								
	Birth weight (n=39)		Apgar 5min. (n=37)			Apgar 10min. (n=36)			Mechanical ventilation days (n=5)
	LBW	NBW	0-4	4-6	7-10	0-4	4-6	7-10	
Normal	3	24	14	9	2	0	15	10	4
Delayed	4	3	3	4	0	0	3	3	0
Impaired	2	3	2	2	1	0	4	1	1

Table 4.22: Referral risk factors and neurodevelopmental category

NDS category	Frequencies						
	Residence (n=39)		Location of delivery (n=38)			Method delivery (n=39)	
	Bloem-fontein	Other	Pelonomi	PHC	Other	Vaginal	Caesarian section
Normal	18	8	18	7	1	17	9
Delayed	2	6	3	4	0	3	5
Impaired	3	2	2	3	0	4	1

A correlation between risk factors and neurodevelopmental outcome could not be determined in this study due to the fact that the entire population of infants were not assessed.

From the above tables 4.20 to 4.22 however it can be seen that in the presence of risk factors outcome was variable, ranging from normal to neurologically impaired in the case of all risk factors.

It can be concluded that despite the presence of several risk factors in the study population the majority of the subjects (68%) had a normal outcome to date.

4.8 SUMMARY

40 subjects out of the potential 45 were finally included in the study. Five subjects were lost to follow up, due to relocation or failure to arrive for scheduled physiotherapy follow-up appointments.

Data was statistically analysed to provide descriptive statistics for namely frequencies and percentages for categorical data, and medians and percentiles for continuous data.

Subjects were graded using the Sarnat and Sarnat grading system, 77% subjects were graded as having grade II asphyxia and 23% as having grade III asphyxia.

Risk factors in the study population relating to maternal, neonatal and referral factors were identified and described using frequencies and percentages and medians and percentiles. There was no statistical difference in the risk factors between the grade II and grade III subjects.

Neurodevelopmental status was described in terms of tone, fine motor, perceptual and cognitive development, speech and language development and gross motor function.

Tone was described as normal, hypertonic or hypotonic. Of the subjects 60% had normal tone, whilst 40% were found to have abnormal tone. Of the 40%, 30% had hypertonicity and 10% hypotonicity.

38% and 27% of the subjects respectively showed delays in fine motor and speech development. There was no statistical difference in fine motor and speech development between the grade II and III subjects.

The neurodevelopmental outcome per grade of asphyxia was compared, the median values for the NDS showed no statistical difference between the scores of the grade II and III subjects, but there was a tendency for the grade III subjects to have a higher score. This implied that the grade II subjects faired better developmentally.

The neurodevelopmental outcome per age group showed that developmental delays were evident as early as six weeks of age. Neurological impairments were only identified from nine months of age. It is important to note that the methodology of the study relating to the age of assessment (oldest possible age in case of multiple assessments) may have influenced the results of neurological impairments only being identified from nine months of age and not earlier.

The prevalence of neurodevelopmental sequelae in the study population was 32%, of which 20% showed developmental delays and 12% had neurological impairment.

Table 4.23 provides a summary of the results of the study to determine the prevalence of neurodevelopmental sequale in moderate to severely asphyxiated infants.

Table 4.23 also provides a summary of the results of the study.

TABLE 4.23: Summary of results of the study

Data section	Data component	Results
Risk factors and associated measures of risk	**Maternal**	The study found that hypertensive disease of pregnancy (23%); intrauterine growth restriction (8%) and alcohol use during pregnancy (5%) were the most common risk factors. 65% of the mothers had no identified risk factors.
	Neonatal	The study found that low five minute and ten minute Apgar scores to be most commonly noted item. Gestation of the infants varied between 36 and 41 weeks, birth weight ranged from 1900 –4010 g. Five infants required mechanical ventilation and the duration ranged from two to eleven days.
	Referral risk factors	Study found that 41% of the mothers resided in rural communities. 37% of the deliveries took place in the periphery in a primary health care facility and the subjects were later transferred to Pelonomi Hospital. 62% of the deliveries were vaginal compared with 38% via caesarian section.
Neuro-developmental outcome		The study population was comprised of 31 grade II and nine grade III subjects, and 22 males and eighteen females. 40% of the subjects had abnormal muscle tone, 30% with hypertonicity and 10% with hypotonicity On average 33% of the subjects had delays in areas of fine motor or speech development. 32% of infants had a neurodevelopmental sequelae, of this group 20% had developmental delays and 12% had neurological impairment. Nine were cerebral palsied with spastic quadruplegia being the most prevalent type of CP. Developmental delays were evident as early as six weeks of age. Neurological impairment were identified from nine months of age. NDS scores for the grade II and III subjects showed no statistically difference, but the Grade III subjects tended to have a higher score.

A discussion of the results will take place in Chapter 5.

CHAPTER 5

Discussion

5.1 INTRODUCTION

The study had two aims. Firstly to determine the prevalence of developmental sequelae in infants who suffered moderate to severe birth asphyxia. Secondly to describe the study population regarding risk factors associated with neonatal asphyxia. The study was done retrospectively using a descriptive study design. Data collection made use of information in patient records (MEDITECH neonatal discharge report, patient file and physiotherapy files to complete the data form. Forty subjects were included in the study.

In this chapter the prevalence of neurodevelopmental sequelae in infants who suffered moderate to severe asphyxia will be discussed. The maternal, neonatal and referral risk factors associated will also be described. The risk factors relating to neurodevelopmental outcome will also be discussed.

Furthermore the results of the study will be compared to similar studies, and possible explanations for results will be given.

5.2. DISCUSSION OF RESULTS

In this section a brief discussion of the research findings will be presented and discussed.

5.2.1 Risk factors associated with asphyxia

5.2.1.1 Maternal risk factors

Hypertensive disease of pregnancy (23%), Intrauterine growth restriction (8%) and alcohol use during pregnancy (5%) were the maternal risk factors identified in this study population.

Studies by Oswyn *et al*. (2000), Pattinson *et al.* (2005) and Badwani *et al.* (1998) on risk factors associated with asphyxia similarly PET and IUGR as being significantly associated with an increased risk of asphyxia. PETand IUGR were also the two risk factors most frequently reported throughout the literature reviewed, as summarised in Chapter 3, table 3.2.

In this study six (67%) of the mothers with hypertensive disease of pregnancy had growth restricted infants (weighing less than 2500g). The interrelatedness of these risk factors have been well described, as is frequently the case mothers with hypertensive disease of pregnancy present with infants that are growth restricted. This intrauterine growth restriction in these cases is due to acute or chronic uteroplacental insufficiency (Nadkarni *et al.*, 2001:177).

Much has been written about the consequences of excessive alcohol use during pregnancy and its negative effects on intrauterine growth. Peleg *et al.* (1998:3), Vandenbosche and Kirchner (1998:3) and Kromberg and Jenkins (1999:43) all reported that excessive use of alcohol during pregnancy resulted in intrauterine growth restriction. Similarly in this study both mothers who had excessive alcohol consumption during pregnancy had infants that were growth restricted.

5.2.1.2 Neonatal risk factors and associated measures of risk

Data on neonatal risk factors relating to gestation, birth weight and measures of risk namely, Apgar score and mechanical ventilation were gathered.

From the data persistent low Apgar scores was the most prevalent neonatal risk factor noted. This was to be expected in that most moderate to severely asphyxiated infants are neurologically depressed at birth, directly reflecting in their Apgar score.

- **Gestation**

Gestation as a risk factor will not be discussed, as only infants with a gestation from ≥ 36 weeks were included in the study.

Inclusion criteria for gestation in previous studies vary greatly. The average gestational age of subjects in studies done by Robertson and Finer (1985), Hull and Dodd (1992), Thornberg *et al.* (1995), Ellis *et al.* (1999), Thompson *et al.* (1997) and Badwani *et al.* (2005) was 37 weeks.

- **Birth weight**

The birth weights of the subjects ranged from 1 900g to 4010g. Nine (23%) of the subjects' birth weight fell in the low birth weight range. Six (67%) of these low birth weight subjects had associated maternal risk factors of either hypertensive disease of pregnancy or alcohol use during pregnancy with subsequent intrauterine growth restriction. This would explain the fact that they were small at birth. One (3%) of subject was macrosomic, and had a birth weight exceeding four kilograms.

Studies by Oswyn *et al.* (2000) and studies reviewed by Aurora and Snyder (2004) indicated that low birth weight and macrosomia are associated with an increased risk of neonatal asphyxia.

Thompson *et al.* (1997:760) in their study in Cape Town, South Africa also identified that in the South Africa population infants are naturally large, contributing to an increased risk of birth asphyxia.

- **Apgar score**

Apgar scores for the population ranged between one and nine.

Generally Apgar scores for the population at both five and ten minutes are to be considered low.

A study by Oswyn *et al.* (2000) and studies reviewed by Aurora and Snyder (2004) identified persistent low Apgar scores as a risk factor associated with asphyxia. Fox (1994:2) however warns that a low Apgar score should not be equated with asphyxia. In this study despite the presence of low Apgar scores at both five and ten minutes the majority (68%) of the subjects had a normal outcome.

The results thus support the view of Fox (1994:2) who indicated that role of the Apgar score is primarily to identify the need for resuscitation in an infant. It is not indicated to be a predictor for long-term outcome or intended to equate with the diagnosis of asphyxia.

Studies to date on the predictive value of the Apgar score have been of short duration, long-term predictive value is not really known (Blackman, 1988:206). It is suggested that the Apgar score at five minutes of life shows poor predictive value in determining neurological outcome (Hull & Dodd 1992:390), however the presence of low scores at ten minutes and even more so at twenty minutes of life is considered one of the most powerful predictors of long term adverse out come (Machado & Hill, 2003:3). In this study outcome of infants with low Apgar scores at 10 minutes (< 7) varied between normal and neurologically impaired.

From the results of this study one would have to conclude that the Apgar scores were not predictive of outcome.

- **Mechanical ventilation**

In this study, as in the studies by Hull and Dodd (1992:386) and of Robertson and Finer (1985:476), the need for intubation and mechanically ventilation following initial resuscitation is indicative that the infant failed to commence or maintain spontaneous respiration following initial resuscitation. This is often case especially in severely asphyxiated infants.

In the study by Robertson and Finer (1985:477) mechanical ventilation following initial resuscitation was indicated in 34% of cases of moderate to severe asphyxia. In this study mechanical ventilation following initial resuscitation was indicated in only 13% of the cases, and the number of ventilation days ranged from two to eleven. The lower figures in this may be due to specific ventilation criteria, the limited number of ventilation beds in the neonatal care unit (NCU) at Pelonomi Hospital (two) and the possible transfer of infants needing mechanical ventilation to the local tertiary neonatal care unit in Bloemfontein.

No documented studies could be found to determine the long-term outcome specifically of infants with asphyxia who required mechanical ventilation. Considering the fact that it is usually the more severe cases of asphyxia that would require respiratory assistance, one would perhaps consider a poorer outcome.

5.2.1.3 Referral risk factors

Data on referral risk factors relating to residence, location and method of delivery was collected.

Pelonomi Hospital is the only level II neonatal care unit in the Southern Free State. A large number of high-risk pregnancies and deliveries are managed at the hospital. The NCU manages high risk infants born at the hospital as well as infants transferred into the unit after birth as a result of complications.

Studies in developing countries such as those by Oswyn *et al.* (2000) and Pattinson *et al.* (2005) emphasize the role that residency, referral and facilities play in the risk of asphyxia.

- **Residency of mother**

Sixteen (41 %) of the mothers in this study resided in other towns in the Free State and Northern Cape.

The mothers of the subjects that resided outside of Bloemfontein at the time of the birth would similarly associate with risks related to rural residence as described in the studies by Khreisnat and Habahbeh (2005:1); Oswyn (2000:117-118), Pattinson *et al.*, (2005:2) Pattinson (2003:451–452) and the Department of Health (2005).

These studies indicate that mothers in rural settings often have no or infrequent antenatal care. Reduced utilization of antenatal facilities may also be attributed to charges or service fees that have recently been introduced at various levels of care throughout the country (Costello & Manandhar, 1994:F2; Department of Health, 2005).

If mothers or the infant should develop complications their residency puts them at risk due to the distance from Bloemfontein, and thus specialist care. The average distance from Bloemfontein of mothers residing outside the city was approximately 105 km.

- **Location of delivery**

Of the forty subjects 23 (61%) were born at Pelonomi Hospital and fourteen (37%) were born in the periphery at primary health care (PHC) facilities. One (2%) home birth also took place.

Pelonomi Hospital is the referral centre in the province for high-risk pregnancies. Late referral to this hospital, with often resulting prolonged labour and poor foetal

monitoring, may play a role in the development of asphyxia in infants born at there.

Although obstetric history was not specifically investigated in this study, one would expect similar problems to present as mentioned in studies by Khreisnat & Habahbeh, (2005:1); Oswyn, (2000:117-118); Pattinson *et al.* (2005:2) and Pattinson (2003:451– 452). Infants born in the periphery in this study were also at risk of developing asphyxia due to several factors, such as delays in mothers seeking medical management when in labour in rural areas, prolonged second phase of labour, poor foetal monitoring, inadequate facilities and lack of skilled service providers to deal with high risk situations of both mother and child.

- **Method delivery**

Of the 40 subjects 24 (62%) were delivered vaginally and fifteen (38%) via caesarian section. The data on the method of delivery is comparative to data portrayed in the study of Thompson *et al.* (1997:759) in Cape Town South Africa where 81% of the infants were delivered vaginally and 15% via caesarian section.

A concern noted is the large number of vaginal deliveries; especially in a population characterized by an inadequate pelvis and large infant (Thompson *et al.*, 1997:760). Vaginal deliveries in such cases often result in prolonged second phases of labour (Hull & Dodd: 1992:388) and emergency caesarian sections. The above may all contribute to the high rate of asphyxia in babies in South Africa and in this study.

Operative deliveries via caesarian section are associated with an increased risk of asphyxia (Khreisnat & Hababeh, 2005:8), as the indication for surgical intervention in most cases is foetal distress (Hull & Dodd: 1992:390). This would similarly be the case in this study population.

5.2. 2 Neurodevelopmental outcome

The neurodevelopment assessment aimed to measure the neurological outcome of the moderate and severely asphyxiated subjects.

- **Muscle tone**

The distribution of tone was described as normal, hypertonic or hypotonic. Muscle tone in 24 (60%) infants was normal, twelve (30%) was hypertonic and four (10%) hypotonic.

Tone was not described in any of the studies on neurodevelopmental outcome of asphyxiated infants as depicted in table 5.2. It may be assumed from the type of neurological impairments noted most frequently in the studies done on outcome (namely spastic quadruplegia), that in most cases where abnormal muscle tone was present that it was increased (hypertonic), as was the case in this study.

Muscle tone is an important component of the neurological examination. Describing the tone was deemed important, as there is a wide variation in normal tone. A subject may present with abnormal tone in the absence of other abnormal developmental signs.

- **Fine motor, perceptual and cognitive development**

Twenty-five (62%) subjects fine motor; perceptual and cognitive development was on par for age, whilst fifteen (38%) were delayed for age.

In the studies on outcome, development was described holistically. No study reviewed specifically reported on the outcome of fine motor, perceptual and cognitive developmental. It was deemed important for the purpose of this study to differentiate outcome in all three areas of development. This would also assist in identifying the areas of development that asphyxiated infants had most difficulty in.

- **Speech and language development**

Twenty-seven (73%) subjects speech and language development was on par for age, whilst thirteen (27%) were delayed for age.

In the studies on outcome, development was described as a whole. No study specifically reported on speech and language development.

The age limit of twelve months was deemed limiting with regards to speech development, it is important to bear in mind that speech and language development becomes more complex with age. Subjects that were developmentally on par for age at the time of this may develop delays with increasing age and over time.

- **Gross motor function**

Assessment tool

For the purpose of this study the Neurodevelopmental assessment score (NDS) was used as the objective measure for gross motor development. Calculation of the scores from the twelve items allowed each subject to be allocated a developmental category.

Comparison of neurodevelopmental outcome between studies is made difficult, as wide variety of screening and assessment tools were used. The NDS has been validated against the Griffith ‘s mental development scale (Potterton & Eales, 2001:15). This makes the measuring instrument in this study comparable to that of the studies by Thompson *et al.* (1997) and Badwani *et al.* (2005), who made use of the Griffith mental development scale.

Neurodevelopmental outcome

Of the subjects twenty-seven (68%) had a normal outcome and thirteen (32%) had neurodevelopmental sequelae.

The presence of neurodevelopmental sequale in the studies of Robertson and Finer (1985), Hull and Dodd (1992), Thornberg *et al.* (1995), Ellis *et al.* (1999) and Badwani *et al.* (2005) ranged from 13-25%. The prevalence of neurodevelopmental sequelae in the study of Thompson *et al.* (1997) done in Cape Town, South Africa, was 42%, but included cases of mild asphyxia. The prevalence of 32% in this study is comparable in range to the prevalence in studies by Ellis *et al.* (1999) and Thompson *et al.* (1997), done in the developing world.

There was no statistical difference between the scores attained by the grade II and III subjects; there was however a tendency for the grade III subjects to have a higher score and thus greater neurological involvement.

Neurodevelopmental outcome per age group identified developmental delays as early as six weeks of age. Neurological impairments were identified from nine months of age, this can be explained by the fact that the developmental abnormalities become more prominent with age, as the complexity of movement increases. It also needs to be considered that the methodology of the study may have been limiting in the earliest possible identification of a delay or impairment in that only a single assessment at the lasted possible age was included for the purposes of this study.

Age at assessment needs to be taken into consideration when considering the results of this study. Age of subjects in this study varied from six weeks to twelve months. Younger subjects in particular who at the time of the study appeared normal or only delayed, could later present with more severe impairment as their movement possibilities increase with age. In the light of the time constraints long-term longitudinal follow up was not possible.

Developmental areas in which subjects showed the greatest delay were oblique and horizontal suspension, eye contact and following, pull to sit, prone, midline orientation and reaching with the arms and sitting. These areas all require good

proximal control and co-ordination of movement. Areas of gross motor delay were not identified in any other studies.

The study by Robertson and Finer (1985) was the only study to have noted the involvement of a physiotherapist in the continued evaluation of the infant following discharge. In all other studies the paediatrician performed the assessment, and in older children a psychologist performed a psychological assessment.

It is also important to note that the HIV status of the subjects was not known. If subjects were HIV positive the virus may have impacted on the developmental outcome.

5.3 RISK FACTORS AND NEURODEVELOPMENTAL CATEGORY

Despite the numerous risk factors noted in this study population the majority of the subjects (68%) had a normal outcome. This predominantly normal outcome can similarly be noted in all the studies on outcome noted in table 5.2.

The study by Robertson and Finer (1985) was the only study that also attempted to relate risk to outcome, but found no association could be drawn between risk factors and neurological outcome. They did however identify a strong positive correlation between the severity of the asphyxia and outcome.

5.4 LIMITATIONS OF THE STUDY

The study population was small, despite this being a retrospective study. The number of subjects was directly limited by the fact that the physiotherapy service in the NCU was only started in January 2004.

The time limits placed on the duration of the study limited the age to which the subjects could be followed up. Ideally subjects would be followed up longitudinally over time up until school going age.

The prevailing time limits resulted in only a single assessment being included for each subject. Ideally subjects should be assessed regularly over a period of time.

The large portion of seventeen subjects (43% of the study population) below the age of six months was limiting in that a large number of false negative results, may have been attained.

Transfer of patients to other hospitals, relocation and failure to arrive for follow up resulted in the entire population not being included in the study.

The methodology of the study regarding the age at which subjects were assessed was also potentially limiting in that the subjects who had multiple assessments data was included at the oldest possible age. This may have resulted in delays and impairments not being identified at the earliest possible time.

5.5 SUMMARY

The prevalence of developmental sequelae in this study sample was 32%, which is similar to the prevalence figures in other developing countries. Delays were most prevalent in areas of development requiring proximal control and co-ordination of movement.

20% of the subjects had developmental delays, whilst 12 % of the subjects exhibited neurological impairments. Nine subjects had definite cerebral palsy. The most prevalent type of cerebral palsy was spastic quadruplegia, which was seen in seven of the subjects, one subject presented with spastic hemiplegia and another with hypotonia.

There was no statistical difference between the scores of grade II and III subjects, but there was a tendency for the grade III subjects to have a higher score.

Developmental delays were visible on examination as early as six weeks, whilst neurological impairment become visible as the age of the subjects increased beyond nine months.

The age of the study population varied between six weeks and twelve months, with 43% of the subjects being younger than six months. This needs to be considered when interpreting the results. Younger infants at the time of the study may not have presented with neurodevelopmental delay, but could potentially develop delays with increasing age as movement possibilities become greater. Therefore there is the possibility of a high number of false negative results at the time of the study.

HIV status of the subjects was not determined, however it is important to consider the possible effects of the virus on the neurodevelopmental outcome in the case of an infected infant. Potterton and Eales (2001:14) similarly found that developmental delays most common in HIV positive children were those relating to proximal control and co-ordination of movement. In case of a HIV positive infant it would be difficult to determine whether the infants delay was due to the asphyxial damage or the effects of the virus.

Risk factors were also described relating to maternal, neonatal and referral risk. Despite the high prevalence of risk factors in the study population, the majority (68%) of the subjects had a normal outcome.

The study showed that a physiotherapist could play an important role in the accurate assessment of infant with moderate to severe asphyxia and assist in the early diagnosis and intervention of the neurologically impaired infant. Early identification of developmental problems will ensure early therapy intervention and ensure the best possible outcome for the child.

CHAPTER 6

Conclusions and recommendations

6.1 INTRODUCTION

The main aim of the study was to determine the prevalence of neurodevelopmental delays in moderate to severely asphyxiated neonates. Data was gathered from the patient record (MEDITECH electronic neonatal discharge report) and physiotherapy file of 40 subjects. This was the first study undertaken by a physiotherapist in South Africa to determine the prevalence of neurodevelopmental delays in moderate to severely asphyxiated neonates.

Significant conclusions can be drawn after this retrospective descriptive study only if the methods used were reliable and valid. The researcher used standardized methods throughout the study period as discussed in Chapter 3. It can thus be concluded that the results of this study are reliable and valid.

6.2 CONCLUSIONS

- A high prevalence (of 32%) of neurodevelopmental sequelae was present in this study population of moderate to severely asphyxiated infants. Of the 32% 20% presented with developmental delays and 12% with neurological impairments.
- Subjects with moderate to severe asphyxia did exhibit tonal abnormalities. Abnormal tone in the form of hypertonicity (30%) was more prevalent than hypotonicity (10%).

- Fine motor, perceptual and cognitive as well as speech and language delays were found on average in 33% of the subjects.
- Cerebral Palsy was common in those subjects who had severe neurodevelopmental delay or neurological impairment. Spastic quadruplegia was the most common type of cerebral palsy noted.
- Developmental delays were identified as early as six weeks of age, whilst neurological impairment were found in infants at an age of nine months and older.
- Despite the prevalence of numerous risk factors in the study population the majority (68%) had a normal outcome.
- A physiotherapist is able to provide accurate neurodevelopmental assessment on infants with moderate to severe asphyxia, and in conjunction with the attending paediatrician can identify areas of delay and impairment.

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6.3 RECOMMENDATIONS

Despite the limitations of the study the following recommendations can be made:

- Due to the high prevalence of neurodevelopmental sequelae, it is recommended that moderate to severely asphyxiated infant should be followed up by a physiotherapist post discharge from the NCU.
- It is suggested that physiotherapy follow up is commenced at six weeks of age to ensure the early identification of developmental delays, and throughout the first year of life.
- In the light of the high prevalence of on average 33% of fine motor and speech delays in the study population, it is suggested that infants who suffered moderate to severe asphyxia should also be routine assessed by an occupational and speech therapist.

For continued research in the field the following is suggested:

- It is suggested that children with moderate to severe asphyxia need to be studied longitudinally over a period of time in outcome studies.
- It would be suggested that infants be assessed from the neonatal period until school going age. Such studies will provided true data on actual long-term outcome, especially in areas of intellectual, perceptual and scholastic abilities.
- Research to determine which early signs during the neonatal period can be associated with later poor outcome will be valuable.
- Research to determine the association of risk factors, treatment and early therapeutic intervention and outcome are also indicated.

References

Adhikari, M. 1999. Care of the sick newborn. In Coovadia, H.M. & Wittenberg, D.F. (Eds). *Paediatrics & child health: A manual for health professions in the third world.* 4th ed. Cape Town: Oxford University Press, pp.114 and 129-130

Anderson, K.E. 1994. *Mosby's medical, nursing and allied health dictionary.* 4th ed. St. Louis: Mosby- Year book Inc., pp.111, 135, 546, 800, 806, 983, 1026, 1055 and 1272

Andrews, J. 2003. Intrauterine growth restriction. *Virtual Children's Hospital,* p. 1-2
< http://www.vh.org/adult/provider/obgyn/intrauterinegrowth/>
Retrieved on 15 November 2005

Aurora, S. & Snyder, E.Y. 2004. Perinatal asphyxia. In Cloherty,J. P., Eichenwald, E.C. & Stark, A.R. (Eds). *Manual of Neonatal care.* 5th ed. Phillidelphia: Lippincott Williams & Wilkins, pp. 536-555

Badwani, N., Kurinczuk, J.J., Keogh, J.M., Allesandri, L.M., O'Sullivan, F., Burton, P.R., Pemberton, P.J. & Stanley, F.J. 1998. Antepartum risk factors for newborn encephalopathy: the Western Australia case-control study. *British Medical Journal* 317: 1449-1553

Badwani, N., Felix, J.F., Kerinczuk, J.J., Dixon, G., Watson, L., Keogh, J.M., Valentine, J. & Stanley, F.J. 2005. Cerebral palsy following term encephalopathy: a population based study. *Developmental Medicine & Child Neurology* 47:293-298

Bailey, M.D. 1997. *Research for the health profession. A practical guide.* 2nd ed. Medford: F.A. Davis Company, pp. 83-84

Behrman, R.E. & Kliegman,R.M. 2002. *Nelson essentials of Paediatrics.* 4th ed. Philadelphia: W.B. Saunders Company, pp. 195, 773 –774

Behrman, R.E., Kliegman, R.M. & Jenson, H.B. 2004. *Nelson textbook of Paediatrics.* 17th ed. Philadelphia: W.B. Saunders Company, pp 566 –567, 1977, 1987

Blackman, J.A. 1988. The value of Apgar scores in predicting developmental outcome at age five. *Journal of Perinatology* 8(3): 206

Bobath, B. 1967. The very early treatment of cerebral palsy. *Journal of developmental medicine & child neurology* 9(4):374

Buchmann, E.J., Pattinson, R.C. & Nyathikazi, N. 2002. Intrapartum-related birth asphyxia in South Africa–lessons from the first national perinatal care survey. *South African Medical Journal* 92(11): 899 –900

Brown, E. 2001. Neurodevelopmental therapy (NDT) course notes. *(*Unpublished). Bloemfontein.

Costello, A.M de L. & Manandhar, D.S. 1994. Perinatal asphyxia in less developed countries. *Archives of disease in childhood* 71:F1-F3

Copeland, M.E & Kimmel, J.R. 1989. *Evaluation and management of infants and young children with developmental disabilities.* Baltimore: Paul H. Brooks Publishing Company Inc., p 75

Cronje, H.S., Joubert, G. & Bam, R.H. 1997. *Navorsingsmetodiek. 'n Basiese inleiding vir beginners.* University of the Free State, Department of Biostatistics, p 16

Currier, D.P. 1984. *Elements of research in physical therapy*. 2nd ed. Baltimore: Williams & Wilkins, p 215

Davies, P.M. 1994. *Steps to follow. A guide to the treatment of adult hemiplegia.* Berlin: Springer-Verslag, p 28

Department of Health, South Africa. 2005. Paediatric neonatology work group report.
<http://www.doh.gov.za/mts/reprts/neonatology.html>
Retrieved on 01 October 2005

Department of Health, South Africa. 2005. Provincial problems and solutions: Free State Province. *Maternal mortality study in the Free State by Dr. M.G. Schoon.*
<http://www.doh.gov.za/search/index.html>
Retrieved on 23 November 2005

Drillien, C.M., Pickering, R.M. & Drummond, M.B. 1988. Predictive value of screening for different areas of development. *Developmental Medicine & Child Neurology* 30:294

Dunn, C.M. 2000. Paediatric PT grows up, p. 1-2
<http://www.rehabpub.com/features/10112000//asp>
Retrieved on 01 October 2005

Dworkin, P.H. 1989. British and American recommendations for developmental monitoring: the role of surveillance. *Paediatrics* 84 (6): 1000-1001

Ellis, M., Manandhar, N., Shrestha, P., Shrestha, L., Manandhar, D.S. & Costello, A. M de L. 1999. Outcome at one year of neonatal encephalopathy in Kathmandu, Nepal. *Developmental Medicine & Child Neurology* 41: 689 -695

Fox, H.E. 1994. Apgar: A commentary. *P & S Medical Review*, p. 1-3
<http://www.cumc.columbia.edu/news/review/archi…/medrev_vln2_00006.htm>
Retrieved on 01 November 2005

Free dictionary online. 2005.
<http/www.thefreedictionery.com/tone/webdefintions>
Retrieved 10 October 2005

Goodman, M., Rothberg, A.D., Houston-McMillan, J. E., Cooper, P.A., Cartwright, J.D.& Van der Velde, M.A. 1985. The effect of early developmental therapy in normal and at risk survivors of neonatal intensive care*. The Lancet* 2(8468): 1327 –1330.

Goldstein, P.J. 1980. Birth asphyxia. In Smith, G.F. & Vidyasagar (Ed.) *Historical review and recent advances in neonatal and perinatal medicine,* p.1
<http://www.neonatology.org/classics/mj1980/ch11.html>
Retrieved on the 24 October 2005

Hahn, J.S. 2002. Clinical manifestations of Hypoxic-Ischaemic Encephalopathy, pp. 1 –2, 4-10
<http://64.233.161.104/search?q=cache:NMtk3OPANSUJ:neuroresident.stanford.edu/Teaching/PediNeuro/HIE_clinical_chap_JH2001.pdf+clinical+manifestation+basal+ganglia+injuries+in+infants&hl=en&ie=UTF-8>
Retrieved on 10 October 2005

Henning, P.A. 1993. *Die ondersoek van die pasgebore baba.* Pretoria: Academica, pp. 4, 7, 132, 134, 135, 137.

Hull, J. & Dodd, K.L. 1992. Falling incidence of hypoxic-ischaemic encephalopathy in term infants. *British journal of Obstetrics and Gynaecology* 99:386-391

ICICI social initiatives organization. Early child health. 2005. The problem with birth asphyxia: nature and prevalence.
<http://203.199.32/111/icicisig/ihb/ihb_contenttasp?lvl=217&plvl=154>
Retrieved on 19 July 2005

Jenkins, G.C. & Newton, R.C.F. 1981. *The first year of life.* New York: Churchill Livingstone, pp. 118-119

Joubert, G. 2002. Key concepts in epidemiology. In Katzenellenborgen, J.M., Joubert, G. & Abdool Karim, S.S. (Eds). *Epidimiology: A manual for South Africa*. Cape Town: Oxford University Press, p. 17

Joubert, G. & Katzenellenbogen, J. 2002. Study design. In Katzenellenborgen, J.M., Joubert, G. & Abdool Karim, S.S. (Eds). *Epidimiology: A manual for South Africa*. Cape Town: Oxford University Press, p. 66

Joubert, G. & Katzenellenbogen, J. 2002. Sampling. In Katzenellenborgen, J.M., Joubert, G. & Abdool Karim, S.S. (Eds). *Epidimiology: A manual for South Africa*. Cape Town: Oxford University Press, p. 74

Katzenellenbogen, J. & Joubert, G. 2002. Data collection and measurement. In Katzenellenborgen, J.M., Joubert, G. & Abdool Karim, S.S. (Eds). *Epidimiology: A manual for South Africa*. Cape Town: Oxford University Press, pp. 90-91

Khreisat, W.H. & Habahbeh, Z. 2005. Risk factors of birth asphyxia: A study at Prince Ali Ben Al-Hussein Hospital, Jordan. *Pakistan Journal of Medical Science* 21 (1): 30 –32

<http://www.pjms.com.pk/issues/janmar05/article/article7.html>
Retrieved: 10 October 2005

Kromberg, J.G.R. & Jenkins,T. 1999. Evaluation, growth and development. In Coovadia, H.M. & Wittenberg, D.F. (Eds). *Paediatrics & child health: A manual for health professions in the third world.* 4th ed. Cape Town: Oxford University Press, p 43.

Lau, C.T. & Lao, T.H. 1999. Cerebral palsy and the birth process. *Hong Kong Medical Journal* 5(3): 251

Lee, K.G. & Clohery, J.P. 2004. Identifying the high-risk newborn and evaluating gestational age, prematurity, postmaturity, large-for-gestational-age and small-for-gestational-age infants. In Cloherty,J. P. , Eichenwald, E.C. & Stark, A.R. (Eds). *Manual of Neonatal care*. 5th ed. Phillidelphia: Lippincott Williams & Wilkins p. 44-45

Lekskulchai, R. & Cole, J. 2001. Effect of a developmental program on motor performance in infants born preterm. *Australian Journal of Physiotherapy* 47:169 -170

Lin, P.W. & Simmons, C.F. 2004. Fluid and electrolyte management. In Cloherty,J. P. , Eichenwald, E.C. & Stark, A.R. (Eds). *Manual of Neonatal care.* 5th ed. Phillidelphia: Lippincott Williams & Wilkins pp. 108-109

Machado, C.J. & Hill, K. 2003. Early infant morbidity in the city of Sao Paulo, Brazil. *Population Health Metrics* 1: 3
<http://www.pophealthmetrics.com/content/1/1/7>
Retrieved on 05 November 2005

Mc Guire, W. 2004. Perinatal asphyxia
<http://64.233.183.104/search?q=cache:2wMrjdXlbqkJ:www.clinicalevidence.com/ceweb/conditionpdf/0320.pdf+Asphyxia+incidence&hl=en&ie=UTF-8>
Retrieved on 31 April 2005

Memorandum by the Charted Society of Physiotherapy. 2003. Parliament of the United Kingdom.
<http://www.parliament.the-stationeryoffice.co.yk/pa/cm200203/cmselect/cmhealth/464/464w06.htm>
Retrieved on 01 October 2005

Mokhachane, M., Velaphi, S., Beck-Arnold, E., Mphalele, S. & Okudu, G. 2002. The incidence of perinatal asphyxia at the C. H. Baragwanath Hospital, can it be reduced? p.1.
<http:// www.wits.ac.za/fac/paediatrics>
Retrieved on 15 January 2005

M.S. London health services centre. Patient services and education. M.S. Definitions. Defining muscle tone.
<http://www.lhsc.on.ca/programs/msclinic/define/m.htm>
Retrieved on 05 April 2005

Murphy, N. & Such-Neibar, T. 2003. Cerebral Palsy diagnosis and management: the state of the art. *Current Problems in Paediatric Adolescent Health Care.* May/June:146 -147

Nadkarni, J., Bahl, J. & Parekh, P. 2001. Perinatal outcome in pregnancy associated hypertension. *Journal of Indian Paediatrics* 38:174, 177

Osborn, J. 1998. Royal Prince Alfred Hospital newborn care protocol book on Asphyxia, pp. 1-9
<http://cs.nsw.au/rpa/neonatal/html/newprot/asphyxia.htm>
Retrieved on 16 February 2005

Oswyn, G., Vince, J.D. & Fries, H. 2000. Perinatal asphyxia at the Port Moresby General Hospital: a study of incidence, risk factors and outcome. *Papua New Guinea Medical Journal* 43(1-2): 110-120.
<http://216.239.59.104/search?q=cache:I2uAU_IKUmkJ:www.pngimr.org.pg/Perinatal%2520asphyxia%2520at%2520POM%2520.pdf+Asphyxia+incidence+South+africa&hl=en&ie=UTF-8>
Retrieved on 30 April 2005

Palmer, F.B. 2004. Strategies for the early diagnosis of cerebral palsy. *Journal of Paedatrics* August: S8 –S10

Pattinson, R.C. 2003. Challenges in saving babies–avoidable factors, missed opportunities and substandard care in perinatal deaths in South Africa. *South African Medical Journal* 93(6): 451-452

Pattinson, R., Woods, D., Greenfield, D. & Velahpi, S. 2005. Improving survival rates of newborn infants in South Africa. *Reproductive Health* 2(4): 1-13
<http://www.pubmdcentral.nih.gov/articlerender.fcgi?articl=1198255>
Retrieved in 01 February 2005

Peleg, D., Kennedy, C.M. & Hunter, S.K. 1998. Intrauterine growth restriction: Identification and management. *American Family Physician* 58(2): 2-3 <http://www.aafp.org/afp/980800ap/peleg.html>
Retrieved on 01 November 2005

Potterton, J.L. & Eales, C.J. 2001. The prevalence of developmental delays in infants who are HIV positive. *South African Journal of Physiotherapy* 57(3): 11- 15.

Raju, T.N.K. 2003. Hypoxic-Ischaemic Encephalopathy. *EMedicine specialties,* pp. 1-3, 5, 6, 8
<http://www.emedicine.com/ped/topic149.htm>
Retrieved on 10 October 2005

Robertson, C. & Finer, N. 1985. Term infants with hypoxic-ischaemic encephalopathy: outcome at 3.5 years. *Developmental Medincine & Child Neurology* (27): 473-484

Sabrine, N., Singh, J. & Sinha, S.K. 1999. Medical management of birth asphyxia. *Indian Journal of Paediatrics* April: 369

Shankaran, S. 2002. The postnatal management of the asphyxiated term infant. *Clinics in Perinatology* (29) 679 -687.

Shaw, J., Bially, J., Deuvorst, N., Macfie ,C. & Brouwer, B. 1999. Clinical and physiological measures of tone in chronic stroke. *Neurology Report* ,March p. 3
<http://www.fond articles.com/p/articles/mi_qa395/is_199903/ai_n8836019>
Retrieved on 01 November 2005

Shepard, R.1980. *Physiotherapy in paediatrics.* 2nd ed. London: William Heinemann Medical Books Limited, p. 90-91

Simon, N.P. 1999. Long-term neurodevelopmental outcome of asphyxiated newborns. *Clinics in Perinatology* 26(3) 767-776

Sunshine Centre. 1990. *START Program.* Johannesburg

Tennessee Department of Education. 2005. *Tennessee early intervention systems (TEIS)*.
<http://child.estu.edu/program/teistech/definition-of-dd.htm>
Retrieved on 31 April 2005

Thompson, C.M., Putterman, A.S., Linley, L.L., Hann, F.M., van der Elst, C.W., Molteno, C.D. & Malan, A.F. 1997. The value of a scoring system for hypoxic ischaemic encephalopathy in prediciting neurodevelopmental outcome. *Acta Paediatrica* 86: 757-761

Thornberg, E., Thiringer, K., Odeback, A. & Milsom, I. 1995. Birth asphyxia: incidence, clinical course and outcome in a Swedish population. *Acta Paediatrics* 84: 927 -932

Thurley, J., Bell, K. & Greacan, J. 2004. Teaching Neonatal Skills in South Africa, p. 1
<http://72.14.207.104/search?q=cache:9yrPghcbM9oJ:www.abc.net.au/rural/events/ruralhealth/2005/papers/8nrhcfinalpaper00228.pdf+Neonatal+asphyxia+south+african+statistics&hl=en&ie=UTF-8>
Retrieved on 18 July 2005

Valdivia, R. 1999. The council for exceptional children-Information centre on disabilities and gifted education. The implications of culture on developmental delay
<http://ericec.org/digests/es589.html.>
Retrieved on 31April 2005

Vandenbosche, R.C. & Kirchner, J.T. 1998. Intrauterine growth restriction. *American family physician.* 58(6): 1-3, 9
<http://www.aafp.org/afp/981015ap/vanderbo.html>
Retrieved 01 November 2005

Van der Velde, M. A. 1983. A physiotherapist's holistic approach to an early intervention programme. (Unpublished paper). Johannesburg General hospital, Johannesburg, pp. 17-18

Venter, A. 2001. Etiology of CP. Physiotherapy NDT course presentation. (Unpublished paper). Bloemfontein.

Weindling, A.M., Hallam, P.,Gregg, J., Klenka, H., Rosenbloom, L. & Hutton, J. L. 1996. A randomized controlled trial of early physiotherapy for high-risk infants. *Acta Paediatrics* 85:1107-1111

Woods, D. & Malan, A. 1996. University of Cape Town: Notes on the newborn infant, p. 1
<http://web.uct.ac.za/dept/icn/teaching/undergraduate/6th year/nnh/nnhcp03.htm>
Retrieved on 15 October 2005

World Health Organization.1996. Mother-baby package: implementation of safe motherhood in countries.
<http://who.int/en/>
Retrieved on 15 July 2005.

World Health Organization. 1997.Basic newborn resuscitation:a practical guide
<http:/www.who.int/reproductivehealth/publications/MSM 98 1/MSM 98 1 introduction.en.html>
Retrieved on 31 April 2005

World Health Organization, 2005. Facts and figures on birth asphyxia <http://wwww.eho/int/entity/whr/2005/media_centre/facts_en.pdf> Retrieved on 31 April 2005

APPENDIX A

APGAR SCORE

APPENDIX A

APGAR SCORE

	2	1	0
APPEARANCE	PINK	PINK LIMBS BLUE	BLUE
PULSE	> 100	< 100	0
GRIMACE	REFLEX RESPONSE	SLIGHT CRY	NO CRY
ACTIVITY	ACTIVE MOVEMENTS	SOME ACTIVE MOVEMENTS	NO ACTIVE MOVEMENTS
RESPIRATION	STRONG	SLOW IRREGULAR	NO BREATHING

TEST IS PERFORMED AT 1 MINUTE, 5 MINUTES and 10 MINUTES AFTER BIRTH BY MEDICAL PERSONNEL

TOTAL SCORE OUT OF 10 IS CALCULATED

CLASSIFICATION IN ACCORDANCE WITH APGAR SCORE

7 – 10	NORMAL
4 – 6	MODERATELY DEPRESSED
< 4	SEVERELY DEPRESSED

APPENDIX B

SARNAT & SARNAT CLASSIFICATION SYSTEM

APPENDIX B

SARNAT & SARNAT CLASSIFICATION OF HYPOXIC ISCHAEMIC ENCEPHALOPATHY (HIE)

STAGE	STAGE 1 (MILD)	STAGE II (MODERATE)	STAGE III (SEVERE)
Level of consciousness	Hyperalert Irritable	Lethargic or obturned	Superous Comatose
Neuromuscular control	Uninhibited Overactive	Diminished spontaneous movement	Diminished or absent spontaneous movement
Muscle tone	Normal	Mild hypotonia	Flaccid
Posture	Mild distal flexion	Strong distal flexion	Intermittent decerebration
Stretch reflexes	Overactive	Overactive disinhibited	Decreased or absent
Segmental myoclonus	Present or absent	Present	Absebt
Complex reflexes: Suck Moro Occulo- vestibular Tonic neck	Normal Weak Strong Normal Slight	Suppressed Weak or absent Weak Overactive Strong	Absent Absent Absent Weak or absent Absent
Automatic functions: Pupils Respiration Heart rate Bronchial and salivary secretions Gastrointestinal motility	Generalized sympathetic Mydriasis Spontaneous Tachycardia Sparse Normal or decreased	Generalized papasympathetic Miosis Spontaneous, occasional apnea Bradycardia Profuse Increased diarrhea	Both systems depressed Midposition, often unequal, poor light reflex Periodic, pnoea Variable Variable Variable
Seizures	None	Common focal or multifocal (6 – 24 hours of age)	Uncommon
Duration of symptoms	< 24 hours	2 – 14 days	Hours to weeks
Outcome	About 100% normal	80% normal Abnormal is symptoms persist > 5 – 7 days	About 50% die Remainder with severe neurologic sequelence

APPENDIX C

CLASSIFICATION OF CEREBRAL PALSY

APPENDIX C

CLASSIFICATION OF CEREBRAL PALSY

Cerebral palsy can be classified into 5 main groups:

- Hypertonic or spastic
- Hypotonic
- Dyskinetic and dystonic
- Ataxic
- Mixed

Below will follow a short discussion on the definition and etiology of the groups of cerebral palsy.

A: The hypertonic or spastic group can furthermore be divided into quadruplegia, hemiplegia, double hemiplegia and diplegia.

- **Spastic quadruplegia** involves all four limbs. This is due to a holistic lesion that affects the entire cortex. A high percentage of cortical blindness is also found in this group. The etiology of spastic quadruplegia is asphyxia, anoxia, merconium aspiration, prematurity, abruptio placenta and fetal distress.

- **Spatic hemiplegia** usually affects one side of the body. In most cases the arm is usually more affected than the leg. The lesion occurs in the region of the middle cerebellar artery. If the arm and leg are equally affected the lesion is usually in the region of the anterior cerebellar artery. Dense hemiplegia is due to an injury in the region of the internal capsule resulting involves limb and facial involvement. The etiology of spaStic hemiplegia is as a result of thrombi/ emboli, artery malformations and prematurity with anoxia.

- **Spastic double hemiplegia** involves all four limbs. The upper limbs are usually more involved than the lower limbs. Occurs due injury in the region of

the cerebellar artery. Causes are anoxia and shock with impaired blood flow to both hemispheres.

- **Diplegia** refers to involvement of all four limbs, with the lower limbs having a larger involvement. This group is also known as the subcortical group. The causes are paraventricular pathology and hydrocephalus.

- **Monoplegia** refers to the groups of CP's with single limb involvement. Also often referred to as the " minimal hemiplegia". Monoplegia is due to pathology in the area of the middle cerebral artery.

- **Paraplegia** refers to cases where both lower limbs are affected. The lesion is usually in the region of the spinal cord. As per definition these cases are not classified as cerebral palsy.

B: The **hypotonic group** refers to the group of known as the "floppy child". Of this group 45% will eventually become hypertonic CP's within two years. The etiology is the same as for the hypertonic group. In 10% of the cases the cause of the lesion is unknown. The other 45% will become dystonic, dyskinetic or develop athetosis.

C: The Dyskonetic group is characterized by the presence of dystonia, chorea and athetosis. The lesion is in the area of the basal nuclei and is caused by asphyxia, rheumatic fever, kernicterus, metabolic disorders, degenerative brain conditions and meningitis/encephalitis.

D: The **ataxic group** is caused by lesions to the cerebellum due to asphyxia, cerebellitis, trauma, and poisoning/ toxicity e.g. epilum or lead and abnormal development of the cerebellum. Pure athetosis is very rare.

E: Mixed group of CP's refers to children who are hypotonic, dyskinetic and with or without ataxia. This usually refers to the most CP's. Causes of a mixed CP clinical picture are mainly neonatal asphyxia
(Venter, A. 2001)

APPENDIX D

DATA FORM

20. APPENDICES:

Appendix D: Data collection form

DATA COLLECTION FORM

For office use only

☐☐ **1-2**

Subject number ☐☐

Instructions
Mark the appropriate block with a X or write your answer in the space provided

1. Date of data collection (dd/mm/yy) _____/____/_____ ☐☐☐☐☐☐ (d d m m y y)

Maternal, birth and postnatal history

2. Date of birth (dd/mm/yy) _____/____/_____ ☐☐☐☐☐☐ (d d m m y y)

3. Gestational age in weeks ☐☐ weeks ☐☐ 15-16

4. Birth weight in grams ☐☐☐☐ grams ☐☐☐☐ 17-20

5. Apgar score at 5 minutes (out of 10) ☐☐ ☐☐ 21-22

6. Apgar score at 10 minutes (out of 10) ☐☐ ☐☐ 23-24

7. Method of delivery ☐ 25
- 1 Normal vaginal delivery
- 2 Caeserian section

8. Gender ☐ 26
- 1 Male
- 2 Female

9.Town of residence of mother ☐ 27
- 1 Bloemfontein
- 2 Other, specify _____

10. Location of delivery ☐ 28
- 1 Pelonomi Hospital
- 2 Periphery
- 3 Other, specify _____

11. Maternal risk factors/disease during pregnancy ☐ 29
- 1 Hypertensive disease of pregnancy or pre-eclampsia ☐ 30
- 2 Maternal diabetes ☐ 31
- 3 Maternal drug use ☐ 32
- 4 Maternal vascular disease ☐ 33
- 5 Intra- uterine growth restriction (IUGR) ☐ 34
- 6 Placentia abruptio ☐ 35
- 7 Induced labour ☐ 36
- 8 Malpresentation of the infant ☐ 37
- 9 Maternal hypoxia ☐ 38
- 10 Maternal infection ☐ 39
- 11 No diseases during pregnancy ☐ 40

12. Number of mechanical ventilation days ☐☐ ☐☐ 41-42

Neurodevelopmental data collected from physiotherapy assesement file

13. Tone ☐ 43

1	Normal
2	Hypotonic
3	Hypertonic

14. Fine motor function (general impression) ☐ 44

1	Developmentally on par for age of assessment
2	Developmentally delayed for age of assessment

15. Speech and communication (general impression) ☐ 45

1	Developmentally on par for age of assessment
2	Developmentally delayed for age of assessment

Neurodevelopmental assesmesment score for gross motor development:

16. Age at assesment in weeks ☐ 46

1	6/52 weeks
2	14/52 weeks (3 months)
3	26/52 weeks (6 months)
4	38/52 weeks(9 months)
5	52/52 weeks (12 months)

17 Moro reflex ☐ 47

0	Developmentally on par for age of assessment
1	Developmentally delayed for age of assessment

18 Placing foot ☐ 48
Parachute

0	Developmentally on par for age of assessment
1	Developmentally delayed for age of assessment

19 ATNR ☐ 49

0	Developmentally on par for age of assessment
1	Developmentally delayed for age of assessment

20 Eye contact ☐ 50
Following

0	Developmentally on par for age of assessment
1	Developmentally delayed for age of assessment

21 Head lag ☐ 51
Pull to sit
Legs

0	Developmentally on par for age of assessment
1	Developmentally delayed for age of assessment

22 Fisting ☐ 52
Hands to midline
Reach
Transfer

0	Developmentally on par for age of assessment
1	Developmentally delayed for age of assessment

23 Retraction of neck
Retraction of shoulder
0 Developmentally on par for age of assessment
1 Developmentally delayed for age of assessment

53

24 Prone
Head control
Arms
0 Developmentally on par for age of assessment
1 Developmentally delayed for age of assessment

54

25 Sit
0 Developmentally on par for age of assessment
1 Developmentally delayed for age of assessment

55

26 Supine
Rolling
0 Developmentally on par for age of assessment
1 Developmentally delayed for age of assessment

56

27 Automatic walking
Astasia
Weight bearing
Walking
0 Developmentally on par for age of assessment
1 Developmentally delayed for age of assessment

57

28 Horizontal suspension
Oblique Suspension
0 Developmentally on par for age of assessment
1 Developmentally delayed for age of assessment

58

APPENDIX E

KEY TO COMPLETING THE NEURODEVELOPMENTAL ASSESMENT SCORE

CORRECTED AGE	6/52	14/52 –3/12	26/52 –6/12	38/52- 9/12	52/52- 12/12
MORO	√	√	X	X	X
PLACING FOOT	√	√	√	√	√
PARACHUTE	X	X	X	√	√
ATNR	√	√	X	X	X
4. EYE CONTACT	√	√	√	√	√
FOLLOWING	90	180	180	180	180
5. HEAD LAG PULL TO SIT LEGS					

FISTING HANDS TO MIDLINE REACH TRANSFER	√ X X X	√ √ X X	X √ √ X	X √ √ √	X √ √ √
RETRACTION OF NECK SHOULDER	√ X	X X	X X	X X	X X
PRONE HEAD CONTROL ARMS	2- 3cm			PIVOTS	
SIT					COMES INTO SITTING
SUPINE ROLLING			PRONE → SUPINE		

AUTOMATIC WALKING	√	X	X	X	X
ASTASIA	X	√	X	X	X
WEIGHT BEARING	√	X	√	√	√ PUULS TO STAND
WALKING	X	X	X	X	? CRUISING
SUSPENSION HOROZONTAL					
OBLIQUE					

KEY TO THE NDS SCORING TABLE:

X/√ = ABSENCE OR PRESENCE OF A SIGN AT EACH VISIT
↓ D= DISSAPEARING SIGN
→ = STABLE SIGN
ATNR= ASSYMETRIC TONIC NECK REFLEX

APPENDIX E

KEY CARD TO THE NDS

APPENDIX F

ETHICAL APPROVAL

APPENDIX G

CLINICAL APPROVAL