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Early functional outcomes in children with traumatic brain injuries

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A dissertation submitted to the Faculty of Health Sciences, University of the Witwatersrand, in fulfilment of the requirements for the degree of a Master of Science in Physiotherapy

EARLY FUNCTIONAL OUTCOMES IN CHILDREN WITH TRAUMATIC BRAIN INJURIES

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ABSTRACT

Traumatic Brain Injury (TBI) is a common cause of disability in children and adolescents. Research in children and adolescents with TBI is still relatively scarce, particularly in low- and middle-income countries. The aim of this study was to determine the early functional outcomes in children with TBI at discharge from acute hospitalisation and at three months' post discharge.

The study included 84 children and adolescents, aged three to twelve, who were admitted to Chris Hani Baragwanath Academic Hospital (CHBAH) with a diagnosis of a TBI, however, the inclusion was not limited to solely children with isolated TBI and in addition included children with associated injuries. The TBI cohort was heterogeneous and included participants with mild (n=71), moderate (n=6) and severe (n=7) head injuries. Motor function was assessed using the Gross Motor Function Classification System (GMFCS); the Gross Motor Function Measure (GMFM-88) and the Movement Assessment Battery for Children – Second Edition (MABC-II). At the three-month follow-up, the primary caregivers completed two questionnaires; The Assistance to Participate Scale (APS) and the Pediatric Quality of Life-Family Impact Module (PedsQL-FIM) to ascertain the amount of assistance the participant requires from the primary caregiver to participate in the home, social and community setting and to determine the impact the TBI has had on the primary caregiver's health related quality of life (HRQOL) and family function.

At hospital discharge, the participants ranged from a level nought to a level four on the GMFCS, indicating that there were participants that required a wheelchair for ambulation. On the GMFM-88 the participants scored the lowest in Dimension E (mean: 87.54%, SD: ±30.12) which consists of running, hopping, and jumping skills. On the MABC-II, the participants scored the lowest in the throwing and catching component (mean: 7.75, SD: ±3.59). The MABC-II revealed that at hospital discharge, 54.76% of participants had no motor difficulties, 23.8% were 'at risk' for motor difficulties and 21.43% had a high likelihood of motor difficulties.

There was a statistically significant difference between the GMFCS levels ($p<0.00$), the GMFM-88 ($p<0.00$), and the MABC-II ($p<0.00$) scores of the participants at discharge and at the three-month follow-up, with the majority of the sample demonstrating an improvement in motor function. The participants ranged from a level nought to a level two on the GMFCS, indicating an improvement in ambulatory function. The mean total score on the GMFM-88 was

99.38% (SD: ±2.62) indicating almost perfect scores on this outcome measure. The MABC-II revealed that the majority of participants (76.06%) demonstrated no motor disabilities. However, a considerable percentage (23.95%) were still classified as 'at risk' of motor impairment or had a high likelihood for motor impairment.

There were statistically significant correlations ($p<0.00$) between the initial GCS score and the functional outcome on the three primary motor outcome measures at the three month follow-up period. There were also statistically significant correlations between the initial GCS score and the type of TBI ($p<0.00$), and the initial GCS score and the type of associated injuries ($p<0.00$). There was also a statistically significant correlation ($p<0.03$) between sex and associated injuries sustained. Although, there was no direct correlation between age and outcome, there was a statistically significant correlation ($p<0.01$) between the age group and the type of TBI sustained. Younger children were at higher risk of sustaining a TBI, yet the TBI sustained tended to be more mild in nature compared to the older age groups.

The majority of the participants were independent in the home, social and community setting at the three-month follow-up (mean APS score: 39.65; range: 19-40; SD: ±2.53). Primary caregivers also reported that the injury had negatively impacted their HRQOL (mean: 69.06; range: 17.92-100; SD: ± 20.44) and family functioning (mean: 64.75; range: 4.17-100; SD: ± 26.78).

In conclusion, motor function recovered in 76.06% of the participants of this study. Long term follow-up is warranted to determine residual implications of the injury on a variety of functional domains.

DECLARATION

I, **Dalya Rosen, Student number 459381**, declare that this dissertation is my unaided work, with the exception of those works indicated in the reference citation and acknowledgements. It is being submitted in complete fulfilment of the requirements of the degree of Master of Science (Physiotherapy) at the University of the Witwatersrand. It has not been submitted before for any other degree or examination in any university.

Signed on this day in Johannesburg, South Africa

Student Signature:  **Date:** 9 September 2021

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LIST OF ABBREVIATIONS

ADL	Activities of daily living
AIDS	Acquired immunodeficiency syndrome
APS	Assistance to Participate Scale
BBB	Blood brain barrier
BOT-2	Bruininks-Oseretsky Test of Motor Proficiency – Second Edition
BOTMP	Bruininks-Oseretsky Test of Motor Proficiency
BP	Blood Pressure
BSF	Basal skull fractures
CBF	Cerebral blood flow
CBV	Cerebral blood volume
CENTRE-TBI	Collaborative European Neurotrauma Effectiveness Research in Traumatic Brain Injury
CDC	Centre for Disease Control and Prevention
CHBAH	Chris Hani Baragwanath Academic Hospital
CNS	Central nervous system
CP	Cerebral Palsy
CPP	Cerebral perfusion pressure
CSF	Cerebrospinal Fluid
CST	Corticospinal tracts
CTB	Computed tomography of the brain
CTE	Chronic Traumatic Encephalopathy
DAI	Diffuse axonal injury
DCS	Diffuse cerebral swelling
DNA	Deoxyribonucleic acid
DTI	Diffusor tensor imaging
EDH	Epidural haematoma
EMS	Emergency services
EVD	External ventricular drain
FA	Fractional anisotropy
fMRI	Functional magnetic resonance Imaging

GCS	Glasgow Coma Scale
GMFCS	Gross Motor Function Classification System
GMFM	Gross Motor Function Measure
HIV	Human immunodeficiency virus
HRQOL	Health related quality of life
ICC	Intraclass correlation coefficient
ICF	International Classification of Functioning
ICH	Intracerebral haemorrhage
ICP	Intracranial pressure
ICU	Intensive Care Unit
IED	Improvised explosive device
IVH	Intraventricular haemorrhage
K-ABC	Kaufman Assessment Battery for Children
LMIC	Low to Middle income countries
LOC	Loss of consciousness
MABC-II	Movement Assessment Battery for Children – Second Edition
MAP	Mean arterial pressure
MANOVA	Multivariate Analysis of Variance
MD	Manual dexterity
MOI	Mechanism of injury
MRI	Magnetic resonance imaging
MTBI	Mild traumatic brain injury
MVA	Motor vehicle accidents
NAD	Nothing abnormal detected
NAI	Non-accidental injury
PANESS	Physical and Neurological Examination for Subtle Signs
PCS	Post-Concussion Syndrome
P-CTSIB	Pediatric Clinical Test of Sensory Interaction for Balance
PDMS-2	Peabody Developmental Motor Scales – Second Edition
PEDI	Pediatric Evaluation of Disability Inventory

PedsQL-FIM	Pediatric Quality of Life – Family Impact Module
PI	Principal investigator
PICU	Paediatric Intensive Care Unit
PMTS	Pietermaritzburg Metropolitan Trauma Service
PSAW	Paediatric Surgical Admission Ward
PSOPD	Paediatric Surgical Outpatient Department
PTBI	Paediatric traumatic brain injury
PVA	Pedestrian vehicle accident
RCWMCH	Red Cross War Memorial Children's Hospital
RTA	Road traffic accident
SAH	Subarachnoid haemorrhage
SAP	Systemic arterial pressure
SD	Standard deviation
SDH	Subdural haematoma
SES	Socio-economic status
SPSS	Statistical Package for the Social Sciences
TBI	Traumatic Brain Injury
UK	United Kingdom
USA	United States of America
WHO	World Health Organization
WM	White matter

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CHAPTER ONE – INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

Traumatic brain injury (TBI) is caused by an external force to the brain resulting in transient or permanent neurological dysfunction (Khan et al., 2003). TBI can affect multiple body systems causing impairments of body structure and function which can lead to decreased participation in society and a reduced quality of life (Linder-Lucht et al., 2007, McGuire et al., 2004).

Annually, at least ten million people, including children, are either hospitalised or die from a traumatic brain injury (Vavilala et al., 2016). Paediatric traumatic brain injury (PTBI) is a worldwide critical health problem as it results in premature mortality and disability amongst children and adolescents (Norman et al., 2007). The burden of TBI is manifested in all regions of the world, however it is particularly prominent in low- and middle-income (LMIC) based regions, such as Sub-Saharan Africa (Hyder et al., 2007). In South Africa the large number of paediatric TBI is predominantly related to the high incidence of road traffic accidents (RTA) (Levin, 2004).

According to a study conducted by Schrieff-Elson et al. (2017), TBI requires careful surveillance as it is responsible for most long-term disabilities and deaths resulting from injury. Furthermore, whilst the goals and guidelines for rehabilitation within the adult age group have been fairly well established, it is not the case for the younger population (Yen and Wong, 2007). Research in children and adolescents with TBI is still relatively scarce and data from the adult population is often extrapolated to determine the medical management and rehabilitation of children and adolescents with TBI (Saatman et al., 2008). However, according to Yen and Wong (2007), the simple transference of data between the age groups poses several issues, many of which can be extremely detrimental and dangerous. There are distinct differences between the anatomy and physiology of the adult and paediatric brain which can directly impact numerous factors such as the type of brain injury and its age-related consequences (Araki et al., 2017, Saatman et al., 2008). Moreover, children and adolescents have an immature nervous system at the time of injury and are still in the process of skills acquisition and development (Chaplin et al., 1993, Anderson et al., 2011). Understanding the complexities of the aforementioned differences is vital for the appropriate management of the paediatric population post cerebral insult in order to optimize recovery (Kolb et al., 2003, Araki et al., 2017).

The functional outcomes after a traumatic brain injury are inconsistent. The available studies mostly contain relatively small sample sizes, are conducted in high-income countries, and often take place after the children and adolescents have spent a considerable time in an in-patient rehabilitation facility. Moreover, the majority of the studies do not focus on a combination of all three TBI classifications (mild, moderate, and severe) and the mild TBI's are often isolated from the moderate and severe TBI's, which are often grouped together. It is therefore difficult to compare and determine functional outcomes in a TBI cohort containing all three classification types.

This dissertation engages with numerous layers of the TBI pandemic. It is a human-centric discourse on the topic that delves into complex topics such as neural-plasticity and neural-vulnerability. The multifaceted anatomical and physiological differences between the adult and the paediatric brain and how they relate to injury and potential recovery post cerebral insult are explored. The complicated pathophysiology and TBI classifications are also discussed. The available research pertaining to functional outcomes after a traumatic brain injury in the paediatric and adolescent population will be critically explored and analysed. This is a South African story that can be impactful in the fight against PTBI and the gaining of knowledge around the subject.

1.2 PROBLEM STATEMENT

Currently, there is limited data regarding the epidemiology of paediatric traumatic brain injuries in Sub-Saharan Africa. The epidemiological studies undertaken at the Red Cross Memorial Hospital in the Western Cape have highlighted the great need for further research in this topic (Schrieff et al., 2013).

In addition, most studies exploring the functional outcomes in children with TBI are conducted in high income countries where the children receive extensive inpatient rehabilitation (Anderson et al., 2005b, Kramer et al., 2013). These results are not entirely transferable to the South African context as access to inpatient rehabilitation centres is limited. It is estimated that only two percent of people with disabilities living in LMIC countries have access to rehabilitation services (Hyder et al., 2007).

1.3 RESEARCH QUESTION

What are the early motor functional outcomes in children with traumatic brain injuries with or without confounding injuries? To what degree do the participants require assistance by the

primary caregiver to participate in activities of daily living three months after a traumatic brain injury? To what extent is the primary caregivers' quality of life impacted by the child's traumatic brain injury in the early stages of recovery?

1.4 AIM OF THE STUDY

To determine the early functional outcomes in children with traumatic brain injuries at discharge from acute hospitalisation and at three months' post discharge.

1.5 OBJECTIVES

1. To evaluate the gross motor function in children with TBI at discharge using the Gross Motor Function Classification System (GMFCS) classification system.
2. To determine the gross motor function in children with TBI at three months' post discharge using the GMFCS classification system.
3. To evaluate the functional motor outcomes in children with TBI at discharge using the GMFM-88 and MABC-II.
4. To determine the functional motor outcome in children with TBI at three months' post discharge using the GMFM-88 and MABC-II.
5. To explore parents' perspectives on the amount of assistance that a child with a TBI requires to participate in play and leisure activities at home and in the community at three months' post discharge using the Assistance to Participate Scale (APS).
6. To describe the health-related quality of life and family functioning of parents of children with TBI at three month's post hospital discharge using the Pediatric Quality of Life – Family Impact Module (PedsQL-FIM).
7. To investigate clinical and demographic factors that may be associated with functional outcome of children with TBI at discharge and at three months' post discharge.

1.6 SIGNIFICANCE OF THE STUDY

Limited data has been published about the nature and severity of PTBI in South Africa, particularly outside of the Western Cape. Such data is critical to assess the outcome and the severity of PTBI in order to assist with appropriate resource allocation, rehabilitation, and intervention strategies. Despite paediatric TBI having higher incidence rates in low- and middle-income countries such as South Africa, there is far less literature emerging from these countries compared to high income countries (Schrieff et al, 2013). Moreover, the majority of

research investigating motor function in this population group pertains to long term functional outcomes and takes place in high income-based countries. This study is based in a LMIC and focuses on early functional outcomes (i.e., during the acute and subacute period following TBI) as a means of filling the gaps and contributing to evidence-based recommendations for future management, particularly in this vulnerable population group.

1.7 CONCLUSION

Paediatric and adolescent TBI is a worldwide problem. It is known to be prominent in LMIC such as South Africa, yet appropriate surveillance of the condition is lacking. There is a paucity of data available regarding the demographics of PTBI in South Africa, particularly the Gauteng region. Furthermore, motor function recovery in the acute and subacute period following cerebral insult is minimally researched in this population group. Early and accurate predictors of outcomes post paediatric and adolescent TBI are vital for streaming resources, community re-entry, long-term treatment planning, family adjustment and coping techniques (Kramer et al., 2013, Medrano et al., 2013a).

CHAPTER TWO – LITERATURE REVIEW

2.1 INTRODUCTION

This literature review will serve to provide an overview of the following areas. Firstly, the definition and global incidence of paediatric traumatic brain injury, with a specific focus on African, South African and Gauteng statistics. Secondly, the anatomical and physiological differences between an adult and child brain will be analysed which leads into the complex discussion of neural plasticity and its effect on functional recovery. The most common patterns of paediatric TBI, the complex pathophysiology and associated medical management of the condition will subsequently be explored. Thirdly, the classification of TBI will be explained which then guides the in-depth analysis of each type of brain injury and the related research on functional recovery. Lastly, an overview of outcome measures used in this study to assess early motor impairments and their effect on family function and participation will be presented.

Literature dating from 1967 to present was searched using PubMed and Google Scholar search engines. Articles were also physically sourced from the Health Sciences library at the University of the Witwatersrand. The following key words were used when searching traumatic brain injury, paediatric neurotrauma, functional outcome, children and adolescents, motor recovery and outcome measures.

2.2 DEFINITION

The term ‘head injury’ has been replaced with ‘traumatic brain injury’ (Roozenbeek et al. (2013) as it better encapsulates the importance of the brain and the subsequent damage to it as a result of the traumatic event.

The World Health Organisation (WHO) and the United States of America’s (USA) Centre for Disease Control and Prevention (CDC) have provided similar definitions for traumatic brain injury (TBI), or cranio-cerebral trauma as it is often referred (Thurman, 2014). TBI results from a brain injury that is caused by an external physical force. The traumatic event causes the brain to move rapidly within the skull, leading to damage (Prins et al., 2013). The event may be classified as either impact or non-impact. Impact refers to the direct contact that the head makes with an object and non-impact refers to an injury that results from a non-impact force such as rapid acceleration and deceleration or blast waves (Prins et al., 2013). A TBI may include the

following findings or symptoms: 1. decreased or altered level of consciousness or amnesia; 2. neurophysiological or neurological changes; 3. skull fractures; 4. traumatic intracranial lesions; or 5. death (Thurman, 2014).

This definition is broad and thus includes brain injuries that may have several manifestations, ranging from transient and mild disruptions of cerebral function (e.g. a concussion) to more severe pathologies (e.g. diffuse axonal brain injury) that may result in long term disability and death (Thurman, 2014).

2.3 EPIDEMIOLOGY

In a 2016 study conducted by Wong et al. (2016), it was estimated that by the year 2020, TBI would be the leading cause of mortality and morbidity worldwide, particularly in low- and middle- income countries (LMICs). TBI is a global critical public health and socioeconomic problem, hence, epidemiological monitoring of incidence, prevalence and outcome is critical (Peeters et al., 2015). The frequency of TBI is currently higher than that of any other disease, including those such as breast cancer, acquired immunodeficiency syndrome (AIDS) and Parkinson's Disease (Prins et al., 2013). Owing to this, trauma forms part of the three tier structure referred to as "the triple burden of disease", the other two being communicable and non-communicable diseases (Prins, 2006). In one of the most up to date qualitative studies reporting on paediatric TBI globally, it stated that TBI annually affects more than three million children worldwide. In contrast, human immunodeficiency virus (HIV) affects approximately two million children per year and meningitis accounts for 500,000 new cases every year (Dewan et al., 2016).

Many countries have acknowledged that TBI is a critical healthcare issue and that further research in this field is necessary to quantify the incidence and mortality rates, risk factors, specific causes and longer term outcomes of these injuries (Thurman, 2014). Results have yielded and continue to yield vital information, particularly amongst the younger population, which can assist with implementing better safety regulations to reduce this burden (Roozenbeek et al., 2013). Some of the epidemiological studies and continued surveillance of TBI in the paediatric and adolescent populations have therefore been conducted in various countries and continents such as: The United States of America (USA) by Faul (2010), Langlois et al. (2005); in Estonia by Ventsel et al. (2008); in the Netherlands by Daniëlle van Pelt E (2011); in Australia by Crowe et al. (2009); in Norway by Olsen et al. (2019) and in Asia by Dewan et al. (2016). There have been a few reports from Africa such as that done by Wong et al. (2016),

including those focused on South Africa by Naidoo (2013), Buitendag et al. (2017), Schrieff et al. (2013), Buitendag et al. (2017). These efforts have all been focused on an attempt to curb the "silent epidemic" (Hyder et al., 2007). A detailed breakdown per region highlights a focused worldwide effort.

2.3.1 THE UNITED STATES OF AMERICA

In a research study conducted in the USA, the results revealed that a TBI occurs every 15 seconds which results in approximately 1.7 million new people affected by TBI per year, resulting in 50,000 deaths. Moreover, 80 000 people are left with permanent disabilities, costing the USA more than $77 billion on average per year (Faul, 2010). This research was further strengthened by a study conducted by Thurman (2014), whose epidemiological study focused on the young population of North America. His study estimated that in the year 2014, in the under-20 age group of the USA, there would have been approximately 630 000 children and youths treated in emergency departments, 60 000 hospitalised and 7500 deaths as a result of traumatic brain injuries. This is further compounded by the fact that these numbers are likely to be much greater than those estimated as the data described in the study only involved brain injuries that were medically attended to or fatal. This leaves a substantial portion of brain injuries unaccounted for. Patients often do not seek medical assistance for mild head trauma such as a concussion (Thurman, 2014). However, these unattended injuries are potentially consequential as they are prone to repeat, leading to adverse long term outcomes (Torres et al., 2019). This is particularly prevalent in sports amongst adolescents and falls amongst the younger age groups.

In the USA motor vehicle accidents (MVA's) still account for the majority of severe TBI's in children despite improved road safety regulations. This is often due to the ineffective use of child restraints such as car seats and safety belts. The leading cause of fatal traumatic brain injuries amongst older children and youths is firearms. It is important to note that this finding is less likely to repeat in other high-income countries owing to different gun law policies and availability of firearms. The majority of the less severe TBI's among younger children in North America are caused by falls, closely followed by sports and recreation (Thurman, 2014).

2.3.2 EUROPE

In Europe, one of the very first comprehensive systematic reviews of the epidemiology of TBI was conducted by Tagliaferri et al. (2006). This was followed up by research involving the systematic reviews and meta-analyses of articles conducted by Peeters et al. (2015) in which 28 epidemiological studies on TBI from 16 European countries published between 1990 and 2014 were reviewed. A living systematic review on the epidemiology of TBI in 23 European countries was then set up in 2015 as part of the Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) project with a primary aim of improving outcomes for people with TBI through improved surveillance and management (Brazinova et al., 2018). The studies included and reviewed TBI's sustained across all age ranges and not merely the paediatric or adolescent population. The lowest reported crude incidence rate was 47.3 per 100,000 population per year and the highest was 849 per 100,000 population per year. The reported crude mortality rates ranged from 3.3 to 28.10 per 100,000 population per year. These results are remarkably similar to those depicted in the 2006 study by Tagliaferri et al., and the study by Peeters et al., (2015). Hence, the results from the above studies do not suggest decreasing trends in incidence of TBI in Europe. Although a change in epidemiological patterns over time can be noticed, as prior to the year 2000 the main cause of TBI was RTA's which has now shifted to falls. This shift may indicate success of previous public health initiatives to reduce road related traumatic brain injuries, but it also indicates the need to better understand fall related TBI's particularly amongst young children and the elderly. In spite of the shift, RTAs remain the primary cause of moderate and severe TBI's amongst the European population.

2.3.3 OTHER COUNTRIES

Epidemiology of paediatric and adolescent TBI has also been documented in other countries. Studies have demonstrated that paediatric TBI contributes to more than half the injuries amongst children in Iran. It accounts for approximately 20% of trauma admissions in India and around 30% of paediatric injuries in Korea. Moreover, adolescent TBI affects more than 486 per 100,000 adolescent population per year in Australia. Although there are hundreds of reports from dozens of countries describing traumatic brain injuries in children and adolescents, one should assess general epidemiological overview of the condition as it relates to the global population with caution (Dewan et al., 2016).

It is clear from the above information that TBI amongst all age groups, and particularly amongst the paediatric and adolescent population, is a global health concern expanding across continents. It is now important to hone into the epidemiology of the condition that has been reported with regards to the African continent and particularly the South African region.

2.3.4 AFRICA

The exact extent of paediatric trauma in Africa is difficult to ascertain as there is limited reporting regarding this health issue. The majority of the available records are from hospital based data and interpretation of such reports is difficult to extrapolate to the general population (Ademuyiwa et al., 2012). Owing to the lack of information regarding this significant public health issue, Wong et al. (2016) conducted a study which was aimed at providing estimates of TBI in 2050 for the African population. The study had various limitations. Most of the studies that were included for review included RTAs with the assumption that RTAs translated to TBI's and therefore the study excluded any other causes of TBI's such as falls. These authors used information from a Kenyan based study that only included the RTA rate in the country. It was assumed that this Kenyan data could be extrapolated to Africa in general. Furthermore, two other studies were selected from high income countries that included New Zealand and the USA and this information was used to develop a model to estimate what the future burden of TBI would be in Africa in 2050, assuming Africa would develop in a way that resembled New Zealand or the USA today. Even with these study limitations, the researchers still expected that there will be approximately 10 million or more TBI cases in Africa by the year 2050.

In a Nigerian study, 127 children were admitted and managed for head injuries between October 2006 and December 2011 within a teaching hospital that deals with neurosurgery. Paediatric TBI's accounted for 13% of all head injuries managed over the five-year period. This number is likely to have been higher if there were not such strict inclusion criteria which did not allow for all mild TBI's to be included. Thus most of the data collected in this study represents moderate and severe TBI's which represents the smallest group in terms of the type of TBI sustained in the paediatric and adolescent population (Udoh and Adeyemo, 2013). The majority of children sustained their TBI's as a result of motor vehicle and motor-vehicle related accidents.

2.3.5 SOUTH AFRICA

South Africa has a population of approximately 59 million people, of whom 17 million are children and adolescents aged less than 14. The youth roughly constitute 28.8% of the South African population (Stats SA, 2019). In South Africa, trauma is reported to be the leading cause of death and disability in this vulnerable age group (van As and Millar, 2012). It is estimated that at least 6500 children between the ages of one to 14 years die annually as a result of unintentional injuries – TBI being included in this category. This rate is 10 times higher than that of any European country. Unpublished data by Childsafe South Africa shows that a child growing up in Cape Town is 25 times more likely to be admitted to hospital with an injury than a child growing up in Birmingham, UK (van As and Millar, 2012). In spite of these fear invoking figures, South Africa, just like the rest of Africa, currently has no national trauma registry to track the epidemic of TBI. Currently there are only a handful of local reports and audits which document the situation as it pertains to TBI in South Africa (Buitendag et al., 2017).

Despite limited data on this particular subject, Red Cross War Memorial Children's Hospital (RCWMCH) in Cape Town has consistently reported on paediatric TBI. A series of reports over the last four decades reveal an epidemic of TBI in children and adolescents that has been largely ignored (Buitendag et al., 2017). Schrieff et al. (2013) reviewed children admitted to RCWMCH over a five-year period who sustained a severe TBI. One hundred and thirty-seven children were admitted, all of whom required intracranial brain monitoring. The mortality rate was 14.6%. In the group of 117 survivors, 94.02% had a TBI as a result of blunt trauma/closed trauma and 5.13% as a result of penetrating/open trauma. Most of the injuries were as a result of pedestrian related MVA's (Schrieff et al., 2013).

Another South African study conducted by Buitendag et al. (2017) involves a retrospective review in the KwaZulu-Natal Province in an attempt to create a comprehensive overview of TBI among the paediatric and adolescent population and compare this with previous audits from South Africa . The study included all patients 18 years and younger who were admitted by the Pietermaritzburg Metropolitan Trauma Service (PMTS) with TBI between December 2012 and December 2016. During this four-year period, a total of 563 children and adolescents were treated by PMTS. This study included all types of TBI's unlike the RCWMCH study. Mild TBI constituted more than 80% of the injuries. This once again highlights the need for a nationwide trauma registry as the current reporting is not providing the South African

population with accurate numbers as all the studies are different and thus the scope of paediatric TBI as a national public health burden is being compromised.

In a retrospective record review of all patients admitted to the paediatric intensive care unit (PICU) at CHBAH between January 2011 and January 2013, there were a total of 919 admissions. Trauma accounted for 20% of all admissions, which was the highest percentage per category. RTA's accounted for 66% of these PICU admissions and 64% of the total mortalities (Patel et al., 2017).

2.3.6 SUMMARY

These epidemiological studies expose the extremity and extent of TBI and specifically paediatric and adolescent TBI globally. TBI appears to be prominent in low-middle income countries such as South Africa as well as in high-income countries such as the United States. The trends of incidence rates worldwide do not appear to be decreasing. This once again reiterates the importance of analysing the current situation, particularly in South Africa where the enormous burden of trauma is overwhelming (van As and Millar, 2012).

In order to understand the impact of TBI on children, a thorough understanding of the anatomical and physiological differences between the brain of a child and the brain of an adult needs to be explored. This is presented in section 2.4.

2.4 ANATOMICAL AND PHYSIOLOGICAL DIFFERENCES BETWEEN THE BRAIN OF AN ADULT AND THE BRAIN OF A CHILD

The central nervous system anatomy (CNS) and physiology in children is different to that of adults. These differences can be attributed to age-related structural changes. (Araki et al., 2017). The brain anatomy and physiology in children develops over several years to gradually assume the adult form. Some of the notable differences stem from the rapid development of cerebral metabolism in the early years (Takahashi et al., 1999). This is driven by cortical development, synaptogenesis, and rapid myelination. Furthermore, a child's anatomy is vastly different in early life and includes: the presence and disappearance of the fontanels; the presence and closure of the cranial sutures; the thickness and pliability of the cranium; the anatomy of the vertebra and the strengthening of the cervical ligaments and its associated

musculature. These differences increase a child's vulnerability to sustain a TBI (Kannan et al., 2014) and will be explored further in this section.

2.4.1 ANATOMICAL DIFFERENCES BETWEEN CHILDREN AND ADULTS

2.4.1.1 THE HEAD SIZE

One of the most obvious differences is the *head to body* ratio in the newborn and infant compared to adults. In the newborn and infant, the head is disproportionally large. The large head to body ratio leads to a high centre of gravity which predisposes the head to being a 'primary' target for trauma (Cameron et al., 2006). At birth, the newborn's brain is roughly 25% of its adult size while its body is only five percent of its adult weight. Furthermore, the heavy head is poorly supported by a neck that has weak ligaments and muscles. This results in the head carrying a greater weight relative to the child's body. The comparatively heavy head, on a weak supportive base, predisposes the child's head and cervical spine to injury when a child encounters external physical trauma (Cory et al., 2001). A fall is understandably the most generic form of head trauma in the nought to fours year age group (Haarbauer-Krupa et al., 2019).

2.4.1.2 THE SCALP

The scalp is highly vascularized in children which can result in a lethal amount of blood loss if injured. Even a small amount of blood loss can result in haemorrhagic shock in the newborn, infant and toddler. This can occur in the absence of external bleeding (Cameron et al., 2006, Kannan et al., 2014, Araki et al., 2017). The younger child has thinner skin and thus a poor ability to cushion the underlying structures against external forces (Cory et al., 2001).

2.4.1.3 THE SKULL

The skull undergoes various age-related changes with regards to the closing of fontanelles and sutures. The posterior fontanelle is usually closed by two months of age and the anterior fontanelle usually fuses between 12-18 months of age (Figaji, 2017). The lack of skull fusion in children assists with some buffering of increased intracranial pressure (ICP) – provided the increase is gradual. However, the subsequent increased compliance can only accommodate for brain swelling to a certain extent and can be exhausted rapidly if the intracranial volume rises, which is likely to happen in a traumatic event. It is also important to note that normal ICP and

blood pressure (BP) in young children are naturally lower than that of adults, resulting in significant adverse effects with small rises in ICP (Figaji, 2017, Prange and Margulies, 2002).

In addition to the delayed closure of the fontanelles and sutures in the skull, the calvarium is extremely thin, soft, and rich in bone marrow in young children. This allows for easy deformation when external pressure is applied even in the absence of a fracture. Nevertheless, these properties, together with the fact that the calvarium is securely attached to the bone cortex, provide a certain advantage during injury. The continuity of the skull tends to be well maintained and bone fragments are less likely to occur if a fracture is present (Margulies and Thibault, 2000, Ommaya et al., 2002, Prange and Margulies, 2002, Prange et al., 2004, Cameron et al., 2006).

2.4.1.4 THE CEREBRAL WHITE MATTER

Throughout a child's life there is a progression of myelination and not all areas of the brain undergo myelination at the same time. As a child develops, the amount of myelination of neurons within the cerebral white matter increases. This affects the functional outcome of a child post TBI – depending on which area of the brain is damaged and at what age. The degree of myelination results in varying absorption of traumatic forces, with an increased susceptibility to TBI in the unmyelinated regions (Cameron et al., 2006).

Myelination generally follows a pattern of progression which includes a caudo-cranial and posterior-anterior predominance. The frontal lobe is one of the last areas of the brain to undergo myelination, predisposing it to greater damage (Cameron et al., 2006). Furthermore, this problem is compounded by the protruding forehead in young children which places the frontal skull and its underlying parenchyma at risk to damage caused by an external force (Araki et al., 2017). This may explain why children that undergo a TBI often present with neurocognitive and behavioural problems post injury (Anderson et al., 2011).

2.4.2 PHYSIOLOGY OF EARLY BRAIN DEVELOPMENT

Brain development begins from the third week of gestation and continues into early adult life. The brain's maturation is complex and consists of various developmental spurts which are believed to impact the functional outcome following a paediatric TBI (Kolb et al., 2000b). The understanding of these physiological changes and how they are influenced by factors such as the age and developmental skill level of the child can assist in understanding recovery after a brain insult (Anderson et al., 2011).

2.4.2.1 NORMAL BRAIN DEVELOPMENT

Normal development is based on a variety of both exogenous and endogenous influences. Endogenous referring to the molecular events occurring through gene expression and exogenous referring to the environmental inputs (Stiles and Jernigan, 2010).

The major elements impacting brain maturation are dendritic growth, synaptogenesis, and myelination. These elements have overlapping timetables and sequences. These sequences begin in-utero and are critical for establishment of cerebral connectivity (Ismail et al., 2017). Whilst the prenatal period is primarily involved in the gross structural formation of the CNS, the postnatal development involves the elaboration of the CNS through differentiation and maturation processes (Anderson et al., 2011).

Rapid dendritic growth and synaptogenesis occur from eight months to two years resulting in higher levels of dendrites than those seen in adulthood. The rapid growth is then followed by selective elimination known as pruning which is a process that allows the CNS structures to be influenced by the environment and experience (Uylings, 2006).

Dendrites alone display their most intense growth spurts between the ages of 16 months and two-and-a-half years. Dendrites then continue to grow at a fast but less intense rate until five years of age. This is followed by a consistent period of regular growth up until the age of 27 years (Koenderink and Uylings, 1995). Pruning follows the initial overproduction of dendrites, allowing only the most functional dendritic branches to remain (Anderson et al., 2011). The pruning process of the CNS structures is highly influenced by the extent of exogenous input provided (Luciana, 2003, Uylings, 2006).

A similar timetable exists with regard to synaptic formation – Huttenlocher and Dabholkar in Krasnegor et al. (1997) suggested maximum synaptic density between 15 months and two to three years followed by a decline in formation over the next 16 years. With regards to myelination, research shows that peaks in myelination have been documented around the ages of two, 7-9 and 11-12 years (Levin, 2003). As mentioned above, the extent of myelination greatly impacts the absorption of external forces on brain tissue.

These overlapping stages may provide a window for learning and opportunity following a brain insult and they may underpin critical periods in development that are associated with better outcomes (Kolb et al., 2000b) which are discussed later on.

2.4.2.2 DISRUPTIONS ON EARLY BRAIN DEVELOPMENT POST TBI

Early brain lesions have been associated with disruptions in dendritic development and consequently synaptogenesis (Kolb et al., 2000b). A brain lesion can result in dendrites being thinner with fewer spines and shorter branches which consequently affects neuronal synapses, hence impeding brain function. Disruption to myelination periods can result in decreased conduction velocity, increased refractory periods after synaptic firing and frequent conduction failures which obstruct normal development (Kolb et al., 2000b). Unlike with damage to the mature CNS, the immature CNS has to contend with the injury itself as well as the fact that the normal developmental processes will be derailed. Thus, timing of the disruption may prove to be significant in terms of potential recovery post paediatric and adolescent TBI.

2.4.2.3 CRITICAL AND SENSITIVE PERIODS IN BRAIN DEVELOPMENT

The periods of overproduction of dendrites and the consequent synaptogenesis as well as peak periods of myelination, may provide a *window of opportunity* following a brain insult. These processes may underpin 'critical' and 'sensitive' periods in development (Anderson et al., 2011).

'Critical' and 'sensitive' periods in brain evolution are hallmarks of early development and any insult that occurs at these stages could result in either positive or negative outcomes as this is the period when the brain is the most amenable to change (Kolb et al., 2000b).

Within normal development 'critical' and 'sensitive' periods are times when the neural networks are most sensitive to environmental influences such as learning and instruction. An insult during these periods can either cause cessation of development or alter its course. Brain development appears to follow a set-sequence and if its progression does not occur appropriately the following may happen: it may never occur; it may delay the development of damaged brain regions; or result in asynchrony of neural connections (Schneider and Koch, 2005, Johnston, 2009).

Previous literature has often referred to 'critical' and 'sensitive' periods synonymously, however, with research progression it appears as if the two are interlinked but are not the same. 'Critical' periods for neural circuits refer to a stage when the neural circuits are committed to a single pattern of connectivity that is largely established by the genetic blueprint. This pattern is consolidated by the presence of a preferred stimulus. In the absence of the preferred stimulus the normal connectivity is disrupted leading to permanent abnormal connections i.e., there are no alternatives available (Ismail et al., 2017).

Contrary to this, ‘sensitive’ periods are more broadly defined as windows during which the effect of experience on brain development is unusually profound and can thus modulate the neural circuits. During ‘sensitive’ periods the neural circuits are motivated to change and have the ability to choose which patterns to select based on the stimulus provided. In the absence of a preferred stimulus the network is still malleable and open to change if the stimulus is reintroduced. Therefore, all critical periods are sensitive periods but not all sensitive periods are critical periods, yet both represent a time of heightened capacity for change (Ismail et al., 2017). Animal research suggests that brain insults occurring during these ‘sensitive’ periods can result in optimal outcome, particularly if they occur during a developmental stage that is associated with periods of synaptic and dendritic growth (Kolb et al., 2000b).

The question remains: What property allows the brain to be influenced and undergo change?

2.4.2.4 NEURAL PLASTICITY

Neural plasticity refers to an intrinsic property of the central nervous system (CNS) that provides it with the ability to respond to changes in the environment and experiences in a dynamic manner via modification of the neural circuitry. This phenomenon occurs throughout the lifespan as an individual’s brain develops and functions (Anderson et al., 2011, Ismail et al., 2017). Neural plasticity is a widely used term, but it is not easily defined. What is known is that it is a complex process that is heightened during time sensitive periods of pre- and post-natal development and it allows the brain to be altered by a wide variety of experiences (Kolb et al., 2000b).

In the context of healthy development, research has demonstrated plasticity to be a beneficial property as it facilitates adaptive changes in response to environmental stimuli, such as routine learning or specific training. Plasticity allows for the establishment of both new neural connections and the modifications to the mapping between behaviour and neural activity (Ismail et al., 2017). Many clinical observations have led to the longstanding notion that the developing brain has greater plasticity compared to the adult brain. Children generally learn a second language more efficiently, display easier acquisition of complex motor skills such as learning a musical instrument and have demonstrated the capacity to recover gross motor skills after a hemispherectomy for intractable seizures (Ismail et al., 2017).

The above observations would allow one to argue that an insult to the developing brain should recover better than an insult to an adult brain as it allows for the re-networking of neural pathways. However, clinical observations suggest great variability in outcome from an early

brain insult. Even though a child's brain has greater capacity for plasticity, it is not directly proportional to the child's recovery (Prins, 2006). These inconsistencies frame the two contradictory schools of thought – 'cerebral plasticity' versus 'cerebral vulnerability' (Anderson et al., 2011).

2.4.2.5 CEREBRAL PLASTICITY VERSUS CEREBRAL VULNERABILITY

'*Cerebral plasticity'* and '*cerebral vulnerability*' are the two contradictory concepts in the discussion around recovery post TBI within a paediatric framework. Each recognises that the age at injury impacts the child's recovery. They essentially interpret a linear relationship between age at insult and functional outcome differently. The debate between the two concepts stems from the different understandings of how the brain is structured and the extent to which it can rehabilitate post injury (Anderson et al., 2011). The concept of 'cerebral plasticity' believes that the younger the age at the time of insult the better the functional outcome whilst 'cerebral vulnerability' believes the opposite true (Anderson et al., 2011).

2.4.2.6 CEREBRAL VULNERABILITY

The concept of 'cerebral vulnerability' stems from the theory that different cerebral areas, such as speech and memory, are innately specialized to particular brain regions. The ability to recover post insult to a specified region is therefore hindered, ultimately leading to a poorer functional outcome. Evidence gathered for this argument has largely focused on language outcomes. If one were to take the perspective of a localizationist then any damage to the left hemisphere, which is the 'pre-specified' region for language, would result in language impairment with minimal ability to regain the skill post injury. This undermines the substitution theory which suggests recovery via reorganisation and transfer of damaged tissue to healthy brain areas (Anderson et al., 2011).

2.4.2.7 CEREBRAL PLASTICITY

'Cerebral plasticity' believes that the immature brain has 'equipotential' with minimal functional localization happening in the early stages of development. This 'equipotential' is what allows the non-damaged brain tissue to subsume the functions previously performed by the newly damaged areas. Lenneberg (1967) provides evidence in support of this model by citing a lack of speech impairment in children who underwent a left hemispherectomy for the treatment of intractable epilepsy. This model essentially translates to good recovery potential post injury owing to the brain's ability to transfer and reorganize functions previously

performed by damaged brain tissue to undamaged brain tissue (Kolb et al., 2000b, Anderson et al., 2011).

If these two concepts were absolute, then why has recovery post brain injury eluded scientists for decades? How does one explain the child's ability to relearn language if the predetermined language region has been removed? How does one explain the child's inability to resume normal activities of daily living after a severe brain injury if the brain is equipotential?

2.4.2.8 THE RECOVERY CONTINUUM

The recovery continuum was termed by Anderson and Colleagues (2011), whereby a psychological approach is undertaken. The article acknowledges that 'cerebral plasticity', and 'cerebral vulnerability' are severely limited in explaining the functional outcomes observed after insult to the immature brain. The authors determine the plasticity and vulnerability theories to characterize extremes in the *recovery continuum*.

Animal and human research has broadened the framework of this debate to extend further than the brain itself (Kolb et al., 2000b). Evidence has suggested that the environment (parenting styles, social context, and access to interventions) and pre-morbid characteristics (gender, age at insult, adaptive abilities, temperament) play major roles as potential mediators of recovery after early cerebral injury. Anderson et al. (2011) argues that the individual child's recovery falls somewhere along a continuum that is influenced by a range of factors. Some of these factors include injury related factors such as the severity and nature; constitutional factors such as developmental stage at time of injury, cognitive capacity, gender etc.; and the environment of the child during recovery. The varied outcomes of recovery observed post early brain injury are likely a result of the dynamic interaction between all the above factors on the 'recovery continuum'.

How does one define and understand the complexity of 'recovery'?

When a brain undergoes an insult there is resultant destruction and disruption of neural networks. Within the human CNS the destroyed neurons are not replaced, and the abnormal or damaged axons struggle to spontaneously regenerate thus rendering areas of brain tissue dead or dysfunctional. The functional improvements that are observed post brain insult can be attributed to certain levels of compensation that the injured person has learned in order to navigate around the disability – be it physically or cognitively (Kolb et al., 2000b).

The concept of recovery is poorly understood as there are such a vast number of outcomes that have been clinically identified in children post early brain insult. An important development in the past 30 years has been the demonstration that it is possible to stimulate functional recovery after cerebral injury in laboratory animals. Scientists believe that the rodent models of cerebral injury have provided a necessary tool for developing rehabilitation programmes in humans with TBI (Kolb et al., 2000b).

Has the literature identified specific factors that can assist in recognising predictors of outcomes and functional recovery in children and adolescents post traumatic brain injury?

2.4.2.9 AGE AT INSULT AND TIME SINCE INSULT

Research has suggested that the age at which a child sustains a brain insult will influence their development and mastery of skills, although the relationship is not simple and investigating age at insult in isolation may be misleading (Catroppa et al., 2008). Another principal factor to consider is the time that has lapsed since injury onset. This is owing to: the rapid recovery that occurs post insult and the potential for children with early brain insult to struggle to keep up with their peers developmentally, particularly in the neurobehavioral domain (attention, executive skills, processing speeds etc.). This leads to two ideas: delayed development and emerging deficits. *Delayed development* refers to impairments identified in the acute stages of recovery that are likely to be transient and will improve with time whereas *emerging deficits* refers to the failure to identify impairments that are yet to develop as the environmental demands increase and the child is unable to make age-appropriate developmental gains (Anderson et al., 2011). For example, a toddler who experiences a brain injury may initially present without impairment, however, by adolescence when the environmental demands have increased, executive problems may 'emerge'. Several studies, both human and animal, provide support for this notion of the development of 'new' impairments with time (Kolb et al., 2000a, Westmacott et al., 2009). Delayed impairments and their effect on function is also highlighted by Koskiniemi et al. (1995) who studied 39 people, who sustained a severe TBI between the ages of one and seven years old, into adulthood. Although school performance was good in half the sample, only 36% went on to live independently at home and only 23% were able to work independently.

Furthermore, research has demonstrated that the age at which the insult occurs is relevant based on the previously discussed notions of 'critical' and 'sensitive' periods in brain development. It has been established that there is capacity for neural restitution either through neural regrowth or anatomical reorganization after early brain insult, however the 'window of opportunity' for

a good recovery is fairly restricted (Anderson et al., 2011). In the context of diffuse insults, vulnerability appears to continue through the first five or six years of life with infants and preschool children showing poorer outcomes than school aged children. Müller et al. (1998) used a sentence-generated task in their study which demonstrated weaker asymmetry in children aged less than six compared to those with later lesions (>10 years of age).

Moreover, research by Anderson et al. (2005a) demonstrated that in children who sustain TBI's, there appears to be a pattern in which better outcomes were observed in those that suffered a less severe insult at an early age and more severe insults at a later stage. Thus, there appears to be a link between age at insult and insult severity. A study by Kuhtz-Buschbeck et al. (2003a) revealed that young age at injury was not associated with better recovery and the study covered a fairly large age range which included children between four - 15 years old. Dumas and Carey (2002) and Dahl and Emanuelson (2013) also suggest that age had no impact on motor recovery in their research studies. Moreover, Costeff et al. (1985) stated that the degree of recovery for motor impairments in 31 children where the age at injury was between three -15 years old, was also not related to the timing of the traumatic brain injury. Klonoff and colleagues (1993), whose follow up period spanned more than 20 years, arrived at the same conclusion. Other authors have even reported a worse outcome in younger individuals who sustain a traumatic brain injury (Michaud et al., 1993, Koskiniemi et al., 1995).

2.4.2.10 DEVELOPMENTAL STAGE AND SKILL LEVEL AT TIME OF INJURY

Based on the study of language in children with TBI, Dennis (1988) highlighted that there is a link between acquired developmental skills at the time of injury and functional recovery. There appears to be a strong correlation between brain maturity, nature of skill (lower-or-higher order) and level of skill maturity (emerging, developing and established) and the subsequent functional outcomes post TBI. For example, an insult that occurs during infancy when skills are emerging, has widespread implications for the future development of *all* skills and may result in anomalies in timing or order of skill acquisition. Brain insults that occur when new skills are developing may influence the rate, proficiency, and strategy of these skills. Therefore, the developmental stage at which the TBI occurs can potentially alter the developmental processes resulting in: delayed development; lower quality skill acquisition and compensatory strategies for skill mastery (Anderson et al., 2011). According to Dennis' model which has gained traction in empirical research, the patterns of improvement observed post childhood TBI vary depending on the level of skill development at the time of insult. This theory may also provide some explanation as to why children recover gross motor skills better than neuro-behavioural skills

post injury as these skills are generally mastered at a younger age than higher order skills such as attention and social cognition. Various researchers such as Barnes et al. (1999) and Ewing-Cobbs et al. (2004) have suggested that both the age and the developmental level at the time of the TBI influences the outcome in educational areas. Children who sustained early brain insult during preschool years were at higher risk for developing reading difficulties over time when compared to children who were injured at an older age. Chaplin et al. (1993) further suggest that when a child undergoes a neurological insult and the child has not yet developed proficiency in the execution of fundamental motor skills, the child's ability to develop these skills can be impaired by that injury. The lack of skills then leads to the inability to keep up with peers which subsequently may result in avoidance and withdrawal from participation which further leads to the underdevelopment of motor skills.

2.4.2.11 NATURE, EXTENT, SITE OF INSULT

Injury-related factors are the best investigated recovery variables. Animal and human literature consistently report that larger lesions produce greater impairment and thus poorer functional outcomes post injury. There are others that speculate that the extent of the lesion and the outcome can be represented in a U-shaped curve, with small and large lesions having better outcomes than intermediate lesions, or that there may be no relationship between injury and outcome at all (Ismail et al., 2017). As one would expect, small, focal lesions appear to be the most 'plastic' as they demonstrate the best recovery. In humans, good recovery outcomes have been demonstrated in large, unilateral lesions with the hypothesis that interhemispheric transfer of function can be forced, resulting in minimal loss of function. One of the most consistent predictors of functional outcome in children is the extent of the brain damage, rather than the site of the lesion. When early brain insult is bilateral or diffuse, regardless of the age at insult, there is most often greater impairment observed. Thus, there needs to be the presence of some undamaged brain tissue for potential functional recovery. Literature suggests that injury severity has been identified as a predictor of functional outcome, with more severe TBI being associated with greater impairments (Catroppa and Anderson, 1999, Ewing-Cobbs et al., 2004, Catroppa et al., 2008).

2.4.2.12 SITE OF LESION

Human research has demonstrated that all cortical regions show plasticity but not all areas respond in the same fashion to a variety of experiences (Kolb et al., 2000b). The sensory and motor regions respond differently to the prefrontal or hippocampal regions. For example, the sensory and motor regions demonstrate large chronic changes in response to complex housing

(rodents with TBI are placed in complex environments with novel and changing stimulation and exercise for at least a month to investigate the neural response) whereas the prefrontal regions demonstrate transient changes that disappear after a few days (Robinson and Kolb, 2004). Although all cortical regions demonstrate plasticity, the location of the injury is less predictive of recovery outcome following early brain insult. This is thought to be due to incomplete functional localization of brain regions in the immature brain(Kolb et al., 2000b). Furthermore, diagnosis of lesion severity is difficult because conventional magnetic resonance imaging (MRI) is not sufficiently sensitive to detecting diffuse axonal injury (DAI) (Caeyenberghs et al., 2011). However, research conducted by Kuhtz-Buschbeck et al. (2003a) demonstrated that there was a correlation between Glasgow Coma Scores (GCS), the number of brain regions affected and sensorimotor outcome in children with moderate and severe TBI. Children that presented with lower GCS scores and a higher number of affected brain regions had poorer baseline function scores on all outcome measures used, indicating increased sensorimotor deficits. Accordingly, Emanuelson et al. (1997) found a significant correlation between CT score and clinical outcome of children with TBI at discharge from a rehabilitation unit.

2.4.2.13 SEX

Evidence is emerging supporting gender specific effects following an early brain insult. Animal studies reveal that cortical development and recovery post injury do not follow the same path in both males and females and this is largely due to hormonal factors in which the female brain develops more rapidly during early childhood (Kolb et al., 2003). These results are consistent with MRI studies done on normal children, which highlight that grey matter volume peaks at around 10 years in females and 12 years in males (Gogtay et al., 2004). Females have also demonstrated larger dendritic volumes than males and functional MRI studies have revealed that females exhibit more bilateral cerebral activation (Anderson et al., 2011). Several other researchers Strauss et al. (1995) and Vargha-Khadem et al. (1992) report that the male brain is less mature than the female brain and therefore more vulnerable to cerebral insult.

2.4.2.14 ENVIRONMENT AND EXPERIENCE

Within normal development it is a longstanding notion that stimulating and enriching environments are required for optimal development (Anderson et al., 2011). This is highlighted by research involving tactile stimulation in which healthy babies provided with a stimulus demonstrated faster growth and earlier hospital discharge (Field et al., 1986). Additionally, studies have suggested that when children from deprived backgrounds were placed in enriched

environments, they showed accelerated developmental growth (Fox et al., 2010). This highlights the importance of parent nurturing and specific training on normal childhood development (Williams et al., 2001).

Giza et al. (2005), reported that the environment may also have a role to play in recovery post brain injury. Several studies done on rodents have highlighted that the manipulation of the post injury environment has an effect on the injured brains' structure and its subsequent ability to learn (Kolb et al., 2000b). Animal researchers have detected environmentally linked CNS changes particularly in cortical thickness, the size of dendrites and axons as well as an increase in the number of synapse formation. Kolb and Gibb (2010) demonstrated that in young rats, brief exposure to enriched environments can decrease evidence of brain pathology and behavioural impairment.

Moreover, it has become evident that recovery post paediatric brain injury is largely influenced by family function, socioeconomic status and response to disability (Taylor et al., 2002). Research using the International Classification of Functioning (ICF) model has been able to identify that it is not merely the relationship between impairments in body structure and function that directly affects an injured child's capabilities but the environmental and demographic factors also play a major role (Mihaylov et al., 2004). The environment can sometimes have more of a dominating influence on the participation and outcome of children with disabilities than the physical impairments (McGuire et al., 2004). A review of research exploring influential factors in the environment identified in the ICF, found that the extent of the disability friendliness of physical and social environments around children with disabilities greatly influences what opportunities are available to those children (Mihaylov et al., 2004). Studies evaluating these factors suggest that environment and experience may become even more important with time, particularly in the context of injury severity. Children with severe traumatic brain injuries from disadvantaged backgrounds with limited access to appropriate resources demonstrate significantly greater impairment and slower recovery compared to those with better socio-economic status (Taylor et al., 2002). The family's role is often fundamental to the enablement of the child's participation and reintegration into the community post injury (Bourke-Taylor et al., 2009). Research by Mihaylov et al. (2004) highlighted that the restrictive or facilitative nature of the child's home life which includes: the physical; economic; and attitudinal environment directly affected parental availability and capability to support the participation of the disabled child.

Moreover, a study conducted by O'Flaherty et al. (2000) identified that there was a tendency for lower maternal education and maternal unemployment to be associated with those subjects with severe TBI. This suggests that the socio-economic status may not only affect the recovery post injury, but it can potentially predispose the children to a higher risk of sustaining a traumatic brain injury.

In light of the above, the role of the rehabilitation services offered to paediatric and adolescent patients post TBI in both the acute and later stages becomes imperative. Research has demonstrated that early rehabilitation programmes should consist of a multidisciplinary team, of which physiotherapy plays a pivotal role. Early rehabilitation has shown to improve functional outcome, particularly when the environment in which it is performed is based on real world demands and experiences and an 'enriched environment' is created. These experiences are necessary for stimulating the neuronal plasticity required for functional recovery. Owing to the fact that TBI is a heterogeneous condition, the rehabilitation programmes should be tailor made and should focus on allowing children to re-experience life and face life's challenges again. Evidence demonstrates that the greatest benefit from rehabilitation is seen in those who receive it early after the onset of injury (Yen and Wong, 2007).

Moreover, the family's role in the rehabilitation process cannot be over emphasized owing to the critical involvement of the family in the everyday lives of children. Physiotherapists and the other interdisciplinary team members, have a role to play in the education of the family and the primary caregivers of these children. Such education should include the nature and severity of the child's injury, the rehabilitation goals and the likely short and long term needs of the child. It is important that the family understand the condition and that they are motivated to participate in the programme. Early involvement of the family has been shown to reduce long term dependence on hospital based systems and subsequently reduce the cost of caring for children with disabilities. The reduction in costs and the decreased burden on the medical system are vital in all countries but specifically in LMIC such as South Africa, where the medical system is under strain and the level of trauma is high (Yen and Wong, 2007).

2.4.3 SUMMARY

Neural plasticity is a feature of the young brain that allows it to adapt and respond to environmental influences and experience. The extent to which the immature brain can recover post TBI is complex and appears to be reliant on numerous factors. However, evidence is suggestive of the brains' ability to develop compensatory strategies as a result of functional neural plasticity which can assist in guiding future rehabilitative programmes.

2.5 MOST COMMON PATTERNS OF TBI SEEN IN CHILDREN

The radiological pattern of PTBI demonstrates distinctive differences compared to an adult traumatic brain injury. Some of the notable differences will be discussed in this section.

2.5.1 SKULL FRACTURES

Research on paediatric skull fractures seems to have gained traction owing to their dire consequences should they occur. Skull fractures in children are generally a consequence of the skull's increased pliability (Bir et al., 2015, Muhonen et al., 1995, Singh et al., 2016). Linear fractures most commonly occur in the parietal bone followed by the occipital, frontal, and temporal bones respectively (Bonfield et al., 2014). A linear fracture (often considered a simple fracture and the mildest form of skull fracture) may represent significant underlying parenchymal damage which is generally caused by marked deformation at the time of injury. In spite of this cerebral insult there is often minimal evidence of brain damage on a CT scan. This makes skull fractures a unique feature of young children. At the moment of impact, the fractured bone and its edges tear the dura. This leads to soft tissue dispersing between the fractured edges interfering with bone healing and fusion of the skull fracture. The fracture size gradually increases with time as the brain and the cranium grow. This leads to a vicious cycle as this process then pulls the dural edges further away from the brain tissue. Surveillance for continuously growing skull fractures is therefore crucial as surgery is often required to rectify this problem in the paediatric population (Singh et al., 2016).

With regards to depressed skull fractures, the simple type is more common amongst the paediatric population and generally results from a localized external force. These fractures can often be treated conservatively as spontaneous reduction generally occurs but older children may require cranioplasty (Figaji, 2017). It is reported by Vitali and Steinbok (2008) that 11% of depressed skull fractures are accompanied by dural injuries that result in intracranial lesions. When these fractures occur above dural sinuses, the children should be monitored in the intensive care unit (ICU) for progression of epidural haematoma and posttraumatic venous sinus thrombosis (Figaji, 2017).

Another common skull fracture in children, particularly those under the age of three, is a diastatic skull fracture. This fracture causes separation of the unfused sutures owing to direct

trauma or deformation. These fractures are often accompanied by raised ICP making them a medical emergency should they occur (Figaji, 2017).

Basal skull fractures (BSF) are also common in children, particularly in crush injuries. These fractures can cause a cerebrospinal fluid leak or even an injury to the carotid artery that runs through the canal at the base of the skull. The injury to the carotid artery may be silent in children if there is adequate crossflow through the circle of Willis, making this type of fracture in children very dangerous (Lew et al., 1999). In age groups where facial bones are still developing, BSF can result in cranial nerve and vascular injuries (Araki et al., 2017). In a study conducted by Alhelali et al. (2015), BSF occurred in 26% of their patients and appear to be independent predictors of mortality.

2.5.2 INTRACRANIAL INJURY

2.5.2.1 EPIDURAL HAEMATOMA

Acute epidural haematoma (EDH) is relatively rare in young children owing to the dura mater being strongly adhered to the inner surface of the skull, especially in the region of the suture lines (Araki et al., 2017). In children the epidural bleeds are mostly caused by the fractured bone fragments piercing the underlying dura, whereas in adults the bleed is often due to damage to the middle meningeal artery which is more incorporated into the bone compared to children. An epidural haematoma in children often occurs in a wider variety of locations compared to adults owing to the haemorrhages being mostly venous and not arterial (Chowdhury et al., 2012).

2.5.2.2 SUBDURAL HAEMATOMA

A subdural haematoma (SDH) occurs between the dura matter and the arachnoid membrane. This type of injury is thought to occur as a result of vascular rupture caused by direct external force or a collision of a moving skull with a stationary object. The sudden deceleration results in a shearing force and rotational acceleration which causes vascular and cerebral parenchymal injury (Araki et al., 2017).

2.5.2.3 SUBDURAL FLUID ACCUMULATION

This is a major subject of research linked to paediatric TBI. The accumulated fluid in the subdural space can vary from a haematoma to a highly concentrated protein or a mixture of the

two. The fluid collection is often incidentally diagnosed on imaging and the treatment largely depends on the area of the accumulation – subdural or subarachnoid (Araki et al., 2017).

2.5.2.4 SUBARACHNOID HAEMORRHAGE

Subarachnoid haemorrhage (SAH) is caused by microvascular ruptures in the subarachnoid space or on the brain surface. Hochstadter et al. (2014) analysed 171 children who sustained a severe TBI (pre-sedation GCS of eight or below) and underwent a CT scan within the first 24 hours of hospital admission. The results demonstrated that a SAH was present in almost half of all the cases and its presence was indicative of TBI severity. Although the SAH was not independently associated with increased risk of mortality amongst the paediatric patients.

2.5.2.5 INTRAVENTRICULAR HAEMORRHAGE

An Intraventricular haemorrhage (IVH**)** is often caused by intraventricular perforations of intracerebral haematomas that are located next to the ventricles. It can also be observed in cases where there is subependymal vascular ruptures and damage to the paraventricular structures including the transparent septum, corpus collosum and the fornix. The shearing and rotational forces that occur in a DAI can also result in rupture of the blood vessels in the subependymal and ventral corpus collosum resulting in an IVH. ICU is highly recommended in paediatric IVH in order to monitor for secondary hydrocephalus (Araki et al., 2017).

2.5.2.6 CEREBRAL CONTUSIONS

This type of injury is relatively common in paediatric TBI and generally occurs just below the site of impact of the external force. Contusions are most often seen on the grey matter while the white matter is generally well preserved. Cerebral contusions tend to occur in the frontal and temporal lobe regions because of their anatomical makeup. Primary contusion can result in cerebral swelling which can subsequently result into an extensive hypoxic lesion that surrounds the original injury. A rapid increase in focal cerebral pressure can quickly progress to cerebral herniation and death (Figaji, 2017).

2.5.2.7 DIFFUSE AXONAL INJURY

DAI is more common amongst paediatric TBI compared to adults and its sequelae are the most frequent cause of poor clinical outcome (Caeyenberghs et al., 2011). DAI is characterized by widespread axonal damage due to shearing forces by acceleration, deceleration, or rotation of the brain. DAI mostly affects the white matter predominantly in areas which include the corpus

callosum, subcortical white matter structures and the brainstem (Caeyenberghs et al., 2011). Injuries to these areas of the brain could potentially result in a child presenting with a severe clinical presentation, such as a coma, even if typical neuroimaging may appear relatively benign. Typical neuroimaging in not sensitive to axonal damage making an accurate diagnosis of DAI in children challenging (Prange and Margulies, 2002).

2.5.2.8 INTRACEREBRAL HAEMORRHAGE

An intracerebral haemorrhage (ICH) caused by trauma is generally observed in the frontal and temporal white matter and can also be seen in the basal ganglia and the cerebellum in the paediatric population. It is often difficult to determine and should be considered as a differential diagnosis should there be a sudden neurological deterioration (Araki et al., 2017).

2.5.2.9 DIFFUSE CEREBRAL SWELLING

Diffuse cerebral swelling (DCS*)* is referred to as a secondary injury and is considered one of the most life-threatening complications of a TBI. It tends to develop more readily in children because of the relative lack of cerebrospinal fluid (CSF) available for displacement. Furthermore, children are vulnerable to cerebral hyperemia, which can result in intracranial hypertension, owing to an underdeveloped auto-regulatory mechanism for cerebral blood flow (CBF) (Araki et al., 2017).

2.5.2.10 PNEUMOCEPHALUS

A pneumocephalus is defined as the presence of air in the epidural, subdural or arachnoid space within the brain parenchyma or ventricular cavities. Trauma is the most common cause in which dura is opened or torn and air penetrates the cranial cavity(Dabdoub et al., 2015). Most of the cases reported involve skull fractures as they create a space for the air to enter the cranial cavity. A pneumocephalus can become a tension pneumocephalus in which case the air causes a rise in intracranial pressure. This can be a medical emergency, however, in 85% of cases a pneumocephalus gets absorbed within two to three weeks without any clinical manifestations and can be treated conservatively (Dabdoub et al., 2015)

2.5.3 SUMMARY

The specific anatomy and physiology of a paediatric brain results in common injury patterns. The pathophysiology of a TBI and the related complications will now be explored in the following section.

2.6 PATHOPHYSIOLOGY OF A TRAUMATIC BRAIN INJURY

2.6.1 PRIMARY INJURY VERSUS SECONDARY INJURIES

A TBI can be separated into *the primary* injury and *the secondary* injury. The *primary injury* refers to the immediate brain damage as a result of the initial impact (either impact or non-impact) causing displacement of the brain within the skull. *Secondary injury* represents consecutive pathological processes initiated at the moment of injury with delayed clinical presentation (Kinoshita, 2016).

2.6.2 THE TBI

Following a severe primary cerebral insult, a cascade of events amplifies the initial damage leading to secondary damage. Owing to the fact that the primary brain damage is mechanical in nature and therefore irreversible, therapeutic modalities are targeted at influencing and limiting the dire consequences of the secondary brain injuries which occur as a delayed consequence of the primary damage (Kinoshita, 2016). Cerebral ischaemia and cerebral hypertension are examples of conditions related to secondary brain damage. Both these conditions are sensitive to therapeutic modalities and interventions. Hence knowledge of pathophysiology post TBI is necessary for appropriate and patient-oriented treatment (Werner and Engelhard, 2007).

Secondary brain damage occurs as a result of changes in CBF, cerebral metabolic dysfunction, inadequate cerebral oxygenation, and impairment of cerebrovascular autoregulation. Moreover, excitotoxic cell damage occurs, resulting in inflammation and subsequent brain cell apoptosis and necrosis (Werner and Engelhard, 2007).

2.6.3 THE CASCADE OF EVENTS OCCURRING IN SECONDARY BRAIN INJURY

The first stages of cerebral damage after a TBI are characterized by direct tissue damage and impaired regulation of CBF and metabolism (Werner and Engelhard, 2007). The biochemical changes result in transient cell membrane disruptions which leads to redistribution of ions and neurotransmitters, consequently altering the meticulously controlled membrane potential making the membrane more permeable (Prins et al., 2013).

This disequilibrium causes an influx of sodium and calcium into the intracellular space and the efflux of potassium into the extracellular space. The ATPase pumps subsequently work overtime to restore membrane potential, however it leads to rapid energy expenditure and depletion of cellular energy stores. This leads to an initial increase in glucose uptake which is followed by a prolonged period of glucose metabolic depression (Prins et al., 2013). Research suggests that the longer the glucose metabolic depression, the more severe the TBI.

The second stage of the cascade takes place when there is terminal membrane depolarization and excessive release of excitatory neurotransmitters such as glutamate and aspartate (Werner and Engelhard, 2007). Within one-hour post injury (acute phase), the presynaptic terminals release large amounts of glutamate, resulting in disruptions of the ionic equilibrium on the postsynaptic membranes and glutamate excitotoxicity (Prins et al., 2013).

The influx of calcium and sodium into the intracellular space results in catabolic intracellular process which increases the concentration of free fatty acids and free radicals. This process, together with the activation of specific proteins involved in cellular deoxyribonucleic acid (DNA), initiates progressive structural changes of biological membranes and nucleosomal DNA. Subsequently this causes DNA fragmentation and inhibits DNA repair resulting in membrane degradation on a vascular and cellular level, ultimately causing necrosis and apoptosis (programmed cell death) to occur (Werner and Engelhard, 2007).

2.6.4 CEREBRAL BLOOD FLOW (HYPOPERFUSION AND HYPERPERFUSION)

The normal brain has several mechanisms for regulating volume and pressure (known as brain autoregulation). The purpose of these mechanisms is to maintain continuous CBF and adequate oxygen supply. Brain autoregulation occurs despite changes in systemic arterial pressure (SAP) and cerebral metabolic requirements as a result of the reaction of the small vessels in the brain to hydrostatic pressure changes and their regulation of vascular tone through vasoconstriction and vasodilation. CBF remains constant when mean arterial pressure (MAP) is kept between 60 and 160mmHg (Werner and Engelhard, 2007).

The severely injured brain alters this brain autoregulation resulting in poor reactivity to systemic and arterial pressure changes which consequently cause CBF changes. Changes in CBF can result in harmful and irreversible conditions such as hypoperfusion e.g. brain ischaemia or hyperperfusion e.g. hyperemia (Kinoshita, 2016). These changes to CBF may lead to raised ICP resulting in irreversible and catastrophic damage (Werner and Engelhard, 2007).

2.6.5 VASODILATION AND VASOCONSTRICTION IN CEREBRAL VASCULATURE

The cerebrovascular constriction or dilation cascade is autoregulated by the CBF. Vasodilation would be used to increase the blood flow to brain tissue and vasoconstriction would be used to limit blood flow to brain tissue. Within a normal brain, the autoregulatory system would vasoconstrict the blood vessels in an attempt to minimize cerebral blood volume (CBV) or vasodilate the vessels to maximize the CBV. This usually occurs in response to cerebral perfusion pressure (CPP). A lower CPP results in vasodilation and a higher CPP causes vasoconstriction (Kinoshita, 2016).

After a TBI the CBF autoregulation, in response to increases and decreases in CPP, is impaired or abolished in most patients (Hlatky et al., 2002). A drop in CPP in response to a drop in systemic arterial pressure (SAP) will trigger a vasodilation cascade of the cerebral blood vessels which will result in a subsequent increase in CBV in the brain (Rosner et al., 1995). Some causes for a drop in SAP could be dehydration, hypocapnia due to hyperventilation therapy, hypoxemia, and pharmacologic agents. Cerebral vasodilation can lead to a drop in SAP which subsequently leads to an increase in CBV and ICP. This leads to hyperperfusion of the brain tissue which can lead to hyperemia. Conversely a vasoconstriction cascade can be triggered with a drop in SAP. This could potentially drive a drop in CBV and CPP causing brain ischaemia (Hlatky et al., 2002).

2.6.6 CEREBRAL OXYGENATION

TBI is characterized by a mismatch between cerebral oxygenation consumption and delivery. As previously mentioned, this occurs as a result of several different haemodynamic and vascular mechanisms leading to poor oxygen supply to brain tissue and consequent brain tissue hypoxia. The critical threshold for brain tissue oxygen pressure in adults has been identified as 10-15mmHg. Anything below these values results in infarction of neuronal tissue (Rose et al., 2006).

2.6.7 OEDEMA

Cerebral oedema frequently occurs as a result of either the primary or secondary brain injury. Two types of oedema can occur – vasogenic brain oedema and cytotoxic brain oedema (Unterberg et al., 2004). The prior relates to the breakdown of the endothelial cell layer of brain vessels in response to mechanical, autodigestive, and functional collapse. This destruction of

the endothelial cell layer results in the disintegration of the blood brain barrier (BBB) as it forms part of the essential structure of the BBB. Damage to the endothelial cell layer allows for uncontrolled ion and protein transfer into the extracellular space within the brain compartments causing water retention and subsequent increase in extracellular space volume leading to vasogenic brain oedema (Werner and Engelhard, 2007).

Cytotoxic brain oedema is more common and occurs due to increased intracellular water accumulation of neurons, astrocytes, and microglia. This is induced by increased cell membrane permeability for ions and ionic pump failure. Irrespective of the type of oedema, increased brain tissue swelling can result in increased ICP and secondary ischaemic events (Unterberg et al., 2004).

2.6.8 INFLAMMATION

TBI induces an array of inflammatory tissue responses. Both the primary and the secondary insults lead to the release of cellular mediators including pro-inflammatory cytokines, prostaglandins, and free radicals. These processes induce chemokines and adhesion molecules. This subsequently results in the mobilization of immune and glial cells which infiltrate defective and intact endothelial cell layers causing disruptions in the BBB. Injured and adjacent tissue will undergo phagocytosis as a result of these inflammatory processes. Within hours, days, and weeks the astrocytes create scar tissue formation through the production of microfilaments and neutropines. The progression of tissue damage that occurs as a result of these inflammatory processes relates to the direct release of neurotoxic mediators or indirectly to the release of nitric oxide and cytokines. These processes lead to further reduction in brain tissue perfusion and consequently an aggravation of secondary brain damage (Potts et al., 2006).

2.6.9 NECROSIS VERSUS APOPTOSIS

Both necrosis and apoptosis refer to brain tissue cell death that can occur after a TBI. Necrosis occurs in response to severe mechanical or ischaemic/hypoxic tissue damage with the excessive excitotoxicity of amino acid neurotransmitters and brain metabolic failure. Conversely, apoptosis refers to programmed cell death. This type of brain cell death occurs to neurons that are initially morphologically intact post injury and are able to maintain a normal membrane potential and adequate ATP-production. Hence, apoptosis occurs hours or days after the primary insult owing to negative occurrences discussed above. Apoptosis is thus clinically

significant as it provides a potential window of opportunity for anti-apoptotic therapeutic interventions (Eldadah and Faden, 2000).

2.6.10 SUMMARY

TBI causes mechanical stress on brain tissue (primary injury), which leads to a cascade of negative events (secondary brain injury) resulting in an imbalance between CBF and metabolism, excitotoxicity, oedema formation, inflammatory responses as well as brain tissue cell death. Understanding the pathophysiology assists in the management of TBI, yet the individual's brain response is unpredictable with every TBI, making medical management of the condition extremely challenging (Werner and Engelhard, 2007). However, the common medical management protocols will be discussed in section 2.7.

2.7 MEDICAL MANAGEMENT IN THE PAEDIATRIC POPULATION WITH TBI

Children are a vulnerable population group which results in scarcity of research and subsequent data available for the appropriate management of paediatric traumatic brain injuries. This has led to the lack of normative data for children which has subsequently resulted in the inappropriate generalization from adult studies on how to correctly treat children following a TBI (Figaji, 2017). At best these generalizations can be inappropriate or at worst they can be extremely dangerous. Children cannot be treated as a homogenous group especially given the marked changes in brain development and patterns of injury, nevertheless, some of the main medical management principles will now be discussed.

2.7.1 SURGICAL MANAGEMENT

The current guidelines for surgical management of TBI in the paediatric and adolescent population is recommended in the following cases (Araki et al., 2017):

1. A CSF leak
2. Detection of a foreign body
3. The necessary debridement of a local wound
4. Infected wounds
5. The necessary evacuation of a haematoma
6. Cosmetic reasons

The majority of paediatric skull fractures can be managed conservatively. When skull fractures occur in a paediatric TBI, the injury generally involves two or three fractured bones. Frontal bone fractures are more likely to require repair in children (Bonfield et al., 2014). Hospitalisation is not usually necessary in children with non-displaced skull fractures provided there is no change in the mental status; additional injuries or suspected non-accidental aetiology (Arrey et al., 2015).

Osteogenic potential in childhood bone also has its pros and cons. If the dura is intact following a small skull fracture, the fracture generally heals well. Yet, if a bone flap replacement is required the resorption rates of the bone are higher in young children, especially if there is a delay in bone replacement (Figaji, 2017).

Furthermore, cranioplasty using foreign material poses a risk in the young brain owing to the growing head and the pulsatile nature of the brain. Split calvarial grafts are usually advised but are difficult to use in children under the age of three owing to the underdeveloped medullary layer (Figaji, 2017).

Decompressive craniectomy is performed in the paediatric population to control intracranial hypertension and has proven to be effective in ICP reduction. Bifrontal craniotomy is likely to be selected in children, however, more studies are needed to determine its effect on mortality and long term outcomes, particularly those pertaining to higher cognitive functions (Araki et al., 2017).

Cerebrospinal fluid drainage is used as another method to control ICP by reducing the volume of the contents of the intracranial vault. An external ventricular drain (EVD) is commonly used but this does increase the risk of complications from haemorrhage and infection (Araki et al., 2017).

2.7.2 INTRACRANIAL PRESSURE

ICP monitoring is an invasive procedure yet it is the only scientifically proven method for early detection of raised ICP in children with severe TBI (Araki et al., 2017). In a report by Alali et al. (2015), the use of ICP monitoring resulted in reduced in-hospital deaths of children with severe TBI. The thinner skull in the paediatric population poses a challenge for ICP monitoring as surgeons are reluctant to use bolt systems and prefer not to measure ICP. Nevertheless, there are various procedures that can be performed such as tunnelling the monitor and adapting the

bolt thread based on the thickness of the skull. Monitoring ICP in children is critical and the young age should not be a deterrent to its measurements (Dixon et al., 2016).

2.7.3 CEREBRAL PERFUSION PRESSURE

Contrary to the adults, the effect of ICP and CPP on outcomes of TBI are not well documented in the paediatric population. Management of ICP and CPP in combination has become standard practice for children with severe TBI based on the notion that uncontrolled ICP and CPP has negative effects on outcome (Araki et al., 2017). Chambers et al. (2005), proposed age stratified critical levels of CPP, specifically for the age groups of two to six, seven to ten and 11-16 years. The CPP values that were associated with good outcomes were 43, 54 and 58mmHg, respectively.

2.7.4 THERAPEUTIC TREATMENT

The most common therapeutic drugs used for anaesthetic purposes in paediatric TBI are sedatives, analgesics, and neuromuscular blockade. Neuromuscular blockade is utilized primarily to improve compliance with mechanical ventilation, reduce metabolic demand and eliminate shivering (Araki et al., 2017).

Intravenous mannitol and hypertonic saline are routinely used to control intracranial hypertension and hypovolemia in children with severe TBI. Moreover, children have lower seizure thresholds and are at higher risk for early seizures compared to adults. Thus immediate prophylactic administration of anticonvulsants is recommended for children with severe TBI (Kannan et al., 2014).

Hyperventilation is also utilized to reduce ICP. Hyperventilation reduces CBF by causing cerebral vasoconstriction of the arterioles. However, caution should be taken when severe hyperventilation is used as a treatment modality as it can lead to subclinical cerebral ischemia and should be avoided (Kannan et al., 2014).

Hypothermia has been proven effective at lowering ICP as an adjunct to standard medical treatment. The guidelines provide level II evidence to use hypothermia as a treatment modality for a duration of 48 hours, followed by slow rewarming. Slow rewarming is imperative as it prevents rebound intracranial hypertension over 12-24 hours in children with severe TBI. If hypothermia is not possible, it is recommended to at least avoid hyperthermia which can result in extensive secondary brain damage by increasing metabolic demands, excitotoxicity and lowering seizure threshold (Araki et al., 2017).

2.7.5 SUMMARY

The heterogeneity of paediatric traumatic brain injury adds to the complexity of the medical management of this population group. It is thus imperative that a thorough clinical examination is done on every individual and the appropriate treatment plan is formulated in order to achieve the best possible outcome.

2.8 CLASSIFICATION OF A TRAUMATIC BRAIN INJURY

Verified and validated classification systems form an essential element in the diagnosis and treatment of human disease. A classification system also assists with the subsequent guidance of neuro rehabilitation and is needed for reliable clinical research (Friedland, 2013). The classification of TBI is a complex and evolving medical problem. Progress in classifying TBI has lagged behind other diseases such as cancer and this is thought to have slowed down the progression of medical management in this field (Hawryluk and Manley, 2015). TBI is a heterogenous injury and therefore no two brain injuries present exactly the same. This heterogeneity is considered one of the most significant barriers to finding effective therapeutic interventions (Saatman et al., 2008).

In any two scenarios, the mechanism of injury and the anatomical location of the lesion are likely different. For example, two individuals sustain a TBI and lose consciousness yet one TBI may include a localized bleed to the left frontal lobe caused by a blow to the skull and the other TBI may be sustained by an MVA and include multiple skull fractures and brain bleeds. Yet, owing to the level of consciousness both TBI's may be recorded as 'severe' by certain classification systems (Saatman et al., 2008). This is when severity is used as the sole classification indicator. However, the injuries are comprehensively different and the medical management and prognostic outcome for both individuals is unlikely to be the same.

The above scenario is an indication of the complexity in the classification of TBI's. It highlights the difficulty in creating a uniform classification system for a condition that is so vast and different in every case.

Does one classify based on the severity of the injury, the anatomical location, or the mechanism of injury? *Even if all of the above are used how does one standardise a classification system to incorporate every different injury, the consequent management and the prognostic outcome thereafter?* (Saatman et al., 2008)

A workshop in 2007 was hosted by the National Institute of Neurological Disorders and Stroke to address the above complexities. The workshop was designed to outline the steps needed to develop a reliable, efficient, and valid classification system for TBI's. The aim was to modernize the current classification systems and create one that was able to link specific patterns of brain and neurovascular injury with appropriate therapeutic interventions (Saatman et al., 2008). The workshop predicted that with a sustained and coordinated effort, a new TBI classification system for targeted therapies could be achieved by the year 2012 (Saatman et al., 2008). Currently there appears to be no available research suggesting that a new TBI classification system, incorporating multiple indicators, has been developed since the workshop.

Mayo Classification System for TBI Severity

The most updated classification system appears to be the Mayo Classification System for TBI Severity (Friedland, 2013). This classification system is seen as innovative as it incorporates multiple indicators (GCS score, post traumatic amnesia score, neuroimaging and has included skull fractures) for classifying injury severity as opposed to relying on a sole indicator. However, this classification system also has its limitations as it fails to differentiate between severe and moderate TBI's, and it clusters the two together. This appears to be problematic as the outcome for a severe and moderate TBI can vary significantly. Therefore, it is advised to use this classification system in conjunction with other systems for a more accurate approach to prognostic outcomes following a severe and moderate TBI (Friedland, 2013).

2.8.1 SEVERITY OF THE TBI USING THE GLASGOW COMA SCALE

In 1974, Graham Teasdale and Bryan J. Jennett, both professors of neurosurgery at the University of Glasgow, developed the 15 score Glasgow coma scale (GCS) as a means to measure the level of consciousness of an individual (Teasdale and Jennett, 1974). This scale was designed especially for patients with head trauma.

Despite advances in the development of new and improved severity classification scales, such as the Brussels Coma Grades, Innsbruk Coma Scale, the Four Score scale and the Grady Coma Grades, the GCS is still the most widely used measure of injury severity following a TBI in both the adult and paediatric population (Ghaffarpasand et al., 2013). It is suggested that this is owing to its generally good prognostic capabilities and its high inter-observer reliability (Narayan et al., 2002). As there is no objective measure of *coma* such as temperature or blood

pressure, the level of *coma* has to rely on clinical scores – allowing room for error (Fischer et al., 2010).

The GCS uses a patient's clinical symptoms – resulting in overall scores – to classify the severity of the brain injury as either mild, moderate, or severe. The GCS comprises of three parameters: eye response, verbal response, and motor response. The GCS score is the sum of the assessment in each of these categories (Ciurea et al., 2008). The scoring system ranges from 3-15 and the score recorded relates to a classification of TBI severity. A score of 13-15 is classified as a mild TBI, a score ranging between 9-12 is classified as a moderate TBI and a severe TBI constitutes a score of 8 or less. This means that the lower a score on the GCS, the more severe the brain damage and a poorer prognostic outcome should be expected (Saatman et al., 2008).

There are several limitations with the GCS as a classification system. Some of these limitations include: the impracticality of assessing the verbal score in an intubated patient; the exclusion of brainstem reflexes; the predictive value in patients undergoing modern neuro-intensive care; and the inaccuracy of scores based on early medical interventions that can affect consciousness. Some of these may include the administration of paralyzing agents, sedation, intubation and facial injuries (Friedland, 2013).

Furthermore, the reliability of the GCS remains elusive in the paediatric population. The scoring system is based on consciousness and a level of understanding of orders and commands which is not always applicable in the paediatric population, particularly in the preverbal age group (Ciurea et al., 2008). Some adaptations have been made to the GCS scoring system for paediatrics (particularly those younger than two years of age) and neonates to improve suitability (Ghaffarpasand et al., 2013). Research (Lieh-Lai et al., 1992, Chung et al., 2006) has demonstrated that the more accurately the patients' GCS score is recorded, the greater the reliability the measure becomes in predicting the outcome post TBI, particularly in the paediatric population. This research suggests that the cut off value for measuring a severe paediatric TBI on the GCS should be a score of five rather than eight. Hence, the threshold for neurophysiologic dysfunction should be decreased in the paediatric population. This is highlighted by research conducted by Lieh-Lai et al. (1992) and Bruce et al. (1978) in which it was observed that the mortality rate was greater in children with scores of three to five than those with scores greater than five. Furthermore, children with scores below five developed severe disabilities compared to the improved outcomes observed in the children who scored five and above.

The majority of the clinical research studies tend not to alter the original GCS scoring system, but rather exclude the population group younger than two when using GCS as an outcome measure. Despite its shortcomings the GCS is still the most feasible, accessible and reliable predictor of TBI outcome in the paediatric population and it can be adjusted if needed (Ghaffarpasand et al., 2013).

The above limitations with the GCS as a classification system, reinforces some of the difficulties with the available TBI classification systems. These limitations assist in highlighting why the use of single indicators as a 'gold standard' for TBI classification during clinical research should be discouraged, particularly when it is being used as a prognostic outcome measure.

2.8.2 THE ANATOMICAL LOCATION OF THE BRAIN INJURY

The anatomical location of the brain injury provides insight into which part or parts of the brain are affected by the injury. The more widespread the damage, the more severe the brain injury is likely to be and thus a poorer predicted outcome can be expected for the individual (Saatman et al., 2008).

The importance of understanding the anatomic location and how it relates to function is highlighted in a study conducted by Gagnon et al. (2004) in which balance was assessed in children who had sustained a mild traumatic brain injury. Forty-two percent of the sample presented with a posterior site of impact. This result is thought to have some significance as there are a number of structures involved in postural control such as the visual cortex that are located in the posterior region of the brain. By noting the anatomic location of the injury and the associated functions of the region, one can be alerted to potential functional problems that may accompany such an injury which can guide assessment and rehabilitation protocols.

The anatomical location in both the adult and paediatric population groups is generally diagnosed using neuroimaging which assists in the diagnosis of the extent, multiplicity, distribution and location of the insult (Saatman et al., 2008). Computed tomography scanning (CT) remains the modality of choice in paediatric patients presenting with an acute TBI as it is fast, widely available and extremely sensitive in the detection of skull fractures and conditions that require emergency attention such as large space occupying haematomas or an acute intracranial haemorrhage (Suskauer and Huisman, 2009). CT scans of the head can easily be combined with cervical spine CT scans to rule out spinal injuries, particularly if the cause of injury is unknown. However, the CT scan cannot exclude ligamentous injury and it provides

limited information on injury to the spinal cord itself (Sledge et al., 2001). Although the value of the CT scan in the acute setting is firmly established, it is limited in identifying the exact extent of the diffuse axonal injury (Suskauer and Huisman, 2009).

MRI is generally only recommended in acute TBI patients in which the neurological deficits are unexplained by the CT scan (Saatman et al., 2008). However, in diffuse axonal injuries, the MRI has proven to be more useful in the diagnosis and detection of white matter lesions (Sheriff and Hinson, 2015). MRI is also superior to CT scans at detecting oedema and contusions. It has also proven superior in visualizing damage to the posterior fossa and brainstem (Cameron et al., 2006). Clinical correlation with conventional MRI findings in mild TBI cases is still lacking as the damage is often diffuse and microscopic. Neuroimaging often reveals no abnormalities on inspection and subsequently a TBI is excluded (Cameron et al., 2006, Eierud et al., 2014).

Since neuroimaging became routine for neuro-trauma patients in the 1980's, the correlation between the location of the injury and its effect on outcome has long been recognized (Saatman et al., 2008). This is owing to the fact that there is an intimate relationship between brain structure and function (Irimia and Van Horn, 2015). The majority of patients with more severe TBI's generally have more than one injury type when using the anatomical location of the injury as a classification. The medical staff usually work systematically from the outside of the head inwards to ensure accurate diagnosis. Such injuries may include scalp lacerations and contusions; skull fractures; haemorrhages (epidural, subdural and subarachnoid); brain contusion and laceration; intraparenchymal and intraventricular haemorrhages.

Furthermore, traumatic brain injuries are generally classified as focal or diffuse based on neuroimaging results (Saatman et al., 2008, Ciurea et al., 2008). *A Focal brain injury* usually appears in a specific location and generally occurs as a result of a contact or 'impact' brain injury. An example of a focal TBI may be a brain insult caused by a direct strike to the head such as a baseball bat. This type of injury generally results in local parenchyma damage, compression of surrounding structures or cerebral herniation. Some of these injuries may include: a brain contusion; laceration of the brain tissue; and/or haemorrhages such as an intracerebral, epidural, subdural and intraventricular haemorrhages (Werner and Engelhard, 2007). Focal injuries typically have symptoms that are related to the specific area of the brain that was damaged. For example, if the speech area of the brain known as the *Broca's area* is damaged, problems relating to speech are likely to be present. This once again reiterates the complimentary relationship that exists between brain structure and function and how structural damage relates to functional outcome (Irimia and Van Horn, 2015).

Diffuse brain injury, as its name suggests, occurs over a more widespread area, and often includes damage to blood vessels. Unlike focal brain injuries, much of the damage in a diffuse brain injury is microscopic making detection and accurate deductions from neuroimaging challenging. This type of brain damage is often as a result of non-contact or 'inertial' forces such as acceleration/ deceleration injuries and rotational forces which are common in high-velocity motor vehicle accidents (Suskauer and Huisman, 2009). Brain damage caused by rotational, shearing, tensile and compressive forces, usually result in diffuse axonal injury and brain ischemia/hypoxia caused by the pathophysiological changes secondary to the primary insult (Marshall, 2000). Diffuse axonal injury is thought to occur because of the heterogeneity in brain tissue consistency, particularly between the grey and white matter. Patients with DAI tend to have a severe TBI, and clinical findings are often a prolonged, deep coma. Diffuse lesions often correlate with poorer prognostic outcomes (Sheriff and Hinson, 2015).

Neuroimaging is accompanied by its own limitations in classifying TBI and using it as a functional outcome predictor. Neuroimaging can underestimate the extent of the brain injury, particularly when there is DAI owing to its decreased sensitivity into axonal damage detection as mentioned above. The timing of the neuroimaging has also proven to be somewhat crucial in providing an accurate TBI diagnosis (Friedland, 2013). Owing to secondary injuries such as brain swelling, the patient may initially present with an abnormal scan leading to a diagnosis of TBI. However, if the patient was not scanned within the acute phase of the injury and an MRI is only conducted 12-months post insult, once there has been brain tissue recovery, the scan may appear normal. This would subsequently suggest that the patient never experienced a TBI leading to a potential misdiagnosis (Friedland, 2013).

Moreover, neuroimaging in the paediatric population needs to be approached with caution owing to its high radiation exposure. Even though an MRI provides less radiation it is still widespread practice to use CT scan imaging in the acute setting for its advantages mentioned previously and should be performed without hesitation (Suskauer and Huisman, 2009).

Over the last two decades there has been great advances in neuroimaging and the scans are becoming increasingly more accessible and informative to the medical fraternity (Torres et al., 2019). Innovative neuroimaging design is now more focused on the study of microstructural injuries which have proven to have an increased sensitivity to recognizing and diagnosing DAI. As a result, a body of literature has and continues to emerge in which imaging-based biomarkers of tissue injury and predictors of functional outcome after paediatric TBI. It is hypothesized that with these technological advancements there should be a subsequent enhancement in the

predictability of long term injury sequela and a more focused rehabilitation approach for the child post injury – particularly in the physical, neurocognitive and behavioural domains (Suskauer and Huisman, 2009, Konigs et al., 2018).

2.8.3 THE MECHANISM OF INJURY

Understanding the aetiology of the injury is advantageous in that it allows one to somewhat predict the pattern of injury based on one's knowledge of how precise forces at specific magnitudes affect the brain tissue. This is determined by whether the head is struck by or strikes an object. This mechanism of injury (MOI) refers to a contact or 'impact' brain injury. The other type of MOI is when the brain tissue moves within the skull and this is referred to as a noncontact or 'inertial' brain injury (Saatman et al., 2008).

Classification by aetiology can further be divided into blunt closed head injuries, penetrating open head injuries and blast head injuries. The latter has recently become a separate category owing to the development of improvised explosive devices (IEDs) used in military warfare (Ellenbogen et al., 2017). The TBI's caused by explosions are not yet fully understood but it is believed that the blast waves cause the brain tissue to rattle within the skull resulting in tissue damage (Sheriff and Hinson, 2015).

Blunt head injuries are the most common type of TBI and are usually far less lethal than penetrating TBI in the paediatric population. Blunt or closed head injuries are often used to describe falls, MVA's and or assaults in which the brain or skull is not exposed as a result of the insult (Ciurea et al., 2008). A classic example of a closed TBI is a concussion. Penetrating or open brain injuries occur when something has broken the skull or scalp and entered the brain tissue itself. Gunshot or stab wounds are common examples of this type of traumatic brain injury (Ellenbogen et al., 2017). This type of head injury is generally associated with more severe TBI's and poorer prognostic outcomes.

There is a strong but not absolute correlation between physical mechanism of injury and the associated anatomical location. For example: the presence of a skull fracture may not necessarily indicate damage to the underlying brain tissue (anatomical location), but it does provide an indication that there was an impact force (MOI) that resulted in the injury and the patient should be investigated further. This point was also discussed above in which a focal brain injury (the type of injury) generally results from a direct strike to head (the mechanism of injury being an impact force) which highlights the correlation between the mechanism of injury and the classification thereof (Saatman et al., 2008).

2.8.4 SUMMARY

The classification of TBI's in both the adult and paediatric population has proven to be a grave challenge for the medical world for many years. Advances in technology, particularly in neuroimaging, are providing hope that we will soon be able to identify and classify the brain damage with greater accuracy and precision. Consequently, this will contribute to improved prognostic functional outcomes and a more focused rehabilitation approach particularly in the paediatric and adolescent population groups with traumatic brain injuries (Suskauer and Huisman, 2009).

2.9 MILD, MODERATE AND SEVERE TBI

As previously discussed, traumatic brain injuries are typically diagnosed as either mild, moderate, or severe depending on the classifications used.

2.9.1 MILD TRAUMATIC BRAIN INJURIES

2.9.1.1 DEFINITION

The terms Mild Traumatic Brain Injuries (MTBI) and concussion are commonly used interchangeably. The injury is most often diagnosed following a blow to the head with or without a brief disruption in consciousness (Eme, 2017).

Mild Traumatic Brain Injury is defined as 'any period of loss of consciousness; any loss of memory for events immediately before or after the accident; any alteration in mental state at the time of the accident (e.g., feeling dazed, disorientated, or confused); loss of consciousness of ~30 minutes or less; an initial Glasgow Coma Scale of 13-15; and post-traumatic amnesia not greater than 24 hours' (Andersson et al 2012, p. 26).

In addition to the signs and symptoms mentioned in the definition, there are further indications that a child may have sustained a MTBI and these include: nausea; vomiting; headache; irritability; sensitivity to light and sound; unsteadiness; diplopia; seeing stars; insomnia or sleepiness; impact seizure; slowed response time; decreased concentration; vacant stare, slurred speech; anxiety; depression and sometimes personality changes (Kozlowski et al., 2007). In the past, loss of consciousness (LOC) was the primary marker for a concussion diagnoses, however, with an increase in studies and their subsequent findings, a concussion can occur in the absence of loss of consciousness (Eme, 2017). Thus, a full history of the child's mechanism of injury and its subsequent symptoms should be recorded for an accurate diagnosis.

2.9.1.2 PATHOPHYSIOLOGY

The exact pathophysiology of MTBI is not yet completely understood, however it is likely to involve a series of multifocal axonal injuries triggered by the initial trauma. Advanced neuroimaging; as discussed in 2.8.2; have revealed both structural and functional abnormalities following a MTBI (Bodnar et al., 2019). Almost 90% of concussions are transient with symptoms usually resolving within four weeks. However, there are a minority of patients that remain symptomatic several months' post insult. Some of the most common symptoms include dizziness, headaches, decreased mental alertness, sleep disturbances, frustration, forgetfulness, and fatigue. Symptoms that continue for more than 28 days post insult are referred to as Post-Concussion Syndrome (PCS). PCS is a condition comprising persistent headaches; sensitive eyes; poor concentration; fatigue and drowsiness; and disturbed sleep patterns which can result in negative effects such as school absenteeism and impaired academic performance. Furthermore, other symptoms such as mood changes and depression can affect a child's interaction with family members and peers and subsequently result in a lower quality of life and loss of social activities (Torres et al., 2019).

In the last decade, there has been significant advances in research that has focused on the potential long-term consequences of recurrent and undiagnosed concussion. A condition known as Chronic Traumatic Encephalopathy (CTE) has been described. A link between recurrent concussion and CTE has been identified, however the progress from concussion to potential CTE is unknown and not all cases of concussion will result in the condition. Examples of famous athletes who have succumbed as a result of CTE are former England striker Jeff Astle and Bellini, who was Brazil's football World Cup winning captain in 1958 (McKee et al., 2012).

2.9.1.3 EPIDEMIOLOGY

According to research conducted by Yeates (2010), 80-95% of all traumatic brain injuries occurring in children and adolescents are considered mild, many of which go unreported. However, the number of children and adolescents seeking care post MTBI is rising dramatically in countries such as the United States owing to the increasing public awareness regarding concussion; improved training of clinicians in concussion diagnosis and a legislation in all 50 states that now requires clearance from a healthcare provider prior to returning to play (Torres et al., 2019). A study by the WHO highlighted that the mean annual incidence rate of MTBI at all ages is estimated to be at least 600 per 100 000 (Dahl and Emanuelson, 2013) with 14% of children experiencing some form of disability requiring specialised educational and medical

services (Rivara et al., 2012). These results are consistent with those reported in the studies conducted in South Africa as mentioned in 2.3.5.

Falls are the most common cause for MTBI in the younger population, whereas sport related concussions increase exponentially with the older age groups. Furthermore, the literature suggests that boys are twice as likely to sustain an MTBI compared to girls, particularly from sport-related injuries (Willer et al., 2004, Kozlowski et al., 2007).

A study conducted by Andersson et al. (2012), surveyed the places and activities where MTBI occurred in 358 children between 0-16 years of age. The most common causes of MTBI were falls from a height (44%) and falls from the same level (30%), most of which were sustained during 'play' activities. An interesting point to note is that the majority of the injuries occurred at home followed by school. These results highlight the alarming realisation that a child does not need to be in a high-risk environment and engaging in dangerous behaviour to sustain a concussion.

2.9.1.4 OUTCOMES POST MTBI

The impact of a MTBI on children and adolescents is variable and determinants of outcome are still poorly understood. However, in the last two decades the interest in people sustaining MTBI has increased which has led to substantial research development in the area. Because people with MTBI do not generally present with detectable neurological deficits to the extent seen after moderate or severe TBI, the investigation of gross motor abnormalities, particularly those that are subtle, have largely been neglected by the literature (Stephens et al., 2017). Previously, MTBI has been thought to cause more cognitive impairments as opposed to motor issues (Satz et al., 1997, Anderson et al., 2011). As a result, the physical impairments are largely ignored and few people with MTBI are referred for physiotherapy (Quinn and Sullivan, 2000).

Research conducted on children with MTBI presents inconstant findings. This is possibly owing to changing variables used within the studies such as different study designs, outcome measures, time frames, and age groups. However, the constant outcome that is present in the majority of the studies on children and adolescents with mild traumatic brain injury is balance deficits. Guskiewicz (2001) examined the cognitive and balance performance of 11 college athletes one, three, five and ten days after they had sustained a mild traumatic brain injury. The results yielded were surprising as the athletes demonstrated no difference to the matched control group on the cognitive performance assessments, however, they performed significantly poorer than the uninjured control groups with respect to motor performance up until the third day. The

findings were attributed to sensory interaction issues which were as a result of the injured individual's inability to utilize their visual systems effectively and their inability to resolve sensory conflict. The results of this small study contradict the previously mentioned notion that cognition is affected to a greater extent than gross motor abilities post MTBI.

Studies conducted by (Gagnon et al., 2004, Stephens et al., 2017) provide important findings because despite the children with MTBI being discharged from hospital without overt motor deficits, motor disturbances were observed over time. Stephens et al. (2017) acknowledged that many of the standardized outcome measures fail to identify motor deficits in children with MTBI, particularly those aimed at detecting fine motor problems. The study used the Physical and Neurological Examination for Subtle Signs (PANESS) as an outcome measure which is designed to examine subtle signs of motor impairment during gait, balance, and timed motor functions. The study used two assessment points which were at two and 12-months' post injury and included children 10 to 17 years old. The results suggested that the children had problems with gait and balance tasks particularly those pertaining to tandem walking and standing and hopping on one foot. The children in the TBI group had lower scores on the total PANESS score compared to the control group at two months compared to 12 months, however the gait remained poor throughout the study duration with no significant improvement in the TBI group.

Similarly, Gagnon et al. (2004) highlight that a significant number of children who sustained a MTBI present with some form of postural instability during the first three months post injury. Although the deficits lessened over the initial three-month period, they were still present at the three-month assessment mark. The children with MTBI performed poorer than the control group on the items that required more refined postural control and higher levels of anticipatory postural control such as walking on a narrow balance beam with their eyes closed. The children in this study struggled on all three outcome measures when vision was eliminated. Moreover, Rhine et al. (2017) investigated adolescents between the ages of 11 and 16 years who presented within six hours following a MTBI. The children were followed for one month in a prospective observational cohort study to determine the postural impairments in children with MTBI in the acute setting. The Nintendo WII balance board and the Romberg Test were used as outcome measures. It was concluded that following an MTBI, children acutely demonstrate significantly more rigid sway patterns with eyes closed compared to eyes open. These finding suggests that like the study that investigated the college athletes, children and adolescents may struggle to solely rely on their vestibular and proprioceptive systems to provide the necessary feedback required for good postural control post mild traumatic brain injury.

Dahl and Emanuelson (2013) also researched motor proficiency in children with mild traumatic brain injury. Twenty-seven children between the ages of four to 17 years' old who sustained a MTBI were compared with a control group of uninjured children. As with the study conducted by Gagnon and colleagues (2004), the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) was the primary outcome measure used. Tremor was also clinically evaluated in this study by a neurologist and a physiotherapist. The MTBI group demonstrated significantly poorer performance compared to controls with regards to balance. A statistical analysis was also conducted for children who performed below any of the norms in the sub-tests on the BOTMP. There was a significant difference between bilateral coordination and strength between the injured and the control groups. The children with MTBI did not differ from the norms with regards to fine motor and gross motor proficiency compared to the control group. The study also revealed that children with MTBI run an increased risk of developing tremor in their hands, particularly during fine motor activity, however, the tremor did not negatively affect fine motor performance. The authors deduced that tremor is rarely seen in children after MTBI but when it occurs it is generally non disabling, low amplitude, postural and kinetic and it may be a post-concussion symptom.

Furthermore, Howell et al. (2014) investigated the effect of cognitive task complexity on gait stability in adolescents following a concussion. The adolescents performed worse than the control group as the complexity of the task increased. These results may represent a way to identify motor recovery following a concussion.

Contrary to these findings, research by O'Flaherty et al. (2000) used functional outcome measure data in the two years after TBI in two groups of children to determine resource prioritization. The study compared functional outcomes between children with MTBI and severe TBI. The children in the MTBI group had no significant deficits at two years post insult. The virtual absence of functional disability in the MTBI group compared to the severe TBI group has led to the Westmead Hospital team altering their clinical practice. They no longer routinely perform diagnostic assessments on inpatients who are classified as sustaining a MTBI unless there are other reasons to do so, nor do they routinely follow-up these children. However, this appears to be the only study that failed to identify motor deficits in children post mild traumatic brain injury. This is potentially owing to the longer duration of follow-up compared to the other studies.

Children and adolescents are typically permitted to return to regular physical activity during the initial month post injury depending on the concussion grade and provided the symptoms

have resolved. The South African Sports Concussion Programme, which has the latest concussion management protocols and technology, is available to South African school children and amateur athletes. Research has demonstrated that balance deficits exist amongst children post MTBI (Gagnon et al., 2004, Dahl and Emanuelson, 2013, Stephens et al., 2017). This emphasizes the importance of testing balance in children and adolescents following a mild traumatic brain injury to ensure a safe return to sports and other demanding physical activities. Poor coordination, delayed reaction times, exercise induced headaches and dizziness, and compromised vision can affect daily function in these children, thereby greatly increasing the risk of recurrent head or other injury, particularly in the acute stage (Gagnon et al., 2004).

2.9.1.5 SUMMARY

Historically, mild traumatic brain injury was predominantly viewed as a relatively benign injury, but with the discovery of permanent negative sequelae and complications such as Post -Concussion Syndrome, and Chronic Traumatic Encephalopathy, the condition and its subsequent management has gained traction. Owing to the advances in research of the condition, gross motor deficits have been identified in this group. Balance disturbances appears to be the major issue following a mild traumatic brain injury in children and adolescents, regardless of the outcome measures used by the different researchers. The results underscore that recovery after MTBI in the paediatric population can be a lengthy process and it is important to consider how subtle, ongoing motor deficits might impact occupational performance in academic, athletic, and social engagement (Stephens et al., 2017).

2.9.2 MODERATE AND SEVERE TRAUMATIC BRAIN INJURY

Moderate and severe traumatic brain injuries are often grouped together in the research and as a result they will be discussed together in this section of the literature critique.

Approximately 10% of traumatic brain injuries in children and adolescents are classified as moderate and severe (Emanuelson et al., 1996). Children who sustain severe traumatic brain injuries usually require intensive rehabilitation owing to the multiple negative sequelae that accompany the condition. Some of these impairments can potentially affect the child's cognitive skills, memory, and academic performance. Furthermore, it is reported that approximately 65% of children with severe TBI exhibit spasticity resulting in functional limitations and disability (Linder-Lucht et al., 2007). Spasticity and other movement disorders such as ataxia and bradykinesia, may lead to long term impairments of motor proficiency in children and adolescents with TBI. In everyday situations children with TBI may not be able to

perform tasks as fast and as effortlessly as their peers thereby affecting their quality of life (Kuhtz-Buschbeck et al., 2003b).

Up to 80% of people who sustain a severe TBI present with some deficits in the standing position (Chaplin et al., 1993, Wade et al., 1997, Greenwald et al., 2001). Focal primary brain damage can lead to specific motor deficits that hinder balance (e.g., abnormal muscle tone) or affect single sensory systems (Shumway-Cook and Olmscheid, 1990, Ingersoll and Armstrong, 1992, Wöber et al., 1993). The balance deficits observed in severe TBI can generally be attributed to the extensive and diffuse nature of the axonal injury (Graham, 1996). Diffuse damage is thought to contribute to the disruption of mechanisms responsible for the appropriate sensorimotor integration required for the maintenance of balance. Research by Shumway-Cook and Olmscheid (1990) suggest that people with severe TBI have sensory integration issues which lead to an increased postural sway in scenarios of reduced or conflicting sensory inputs.

Kuhtz-Buschbeck et al. (2003a) investigated sensorimotor recovery in children after moderate and severe traumatic brain injury. The study included analysis of gait, gross motor, and fine motor skills over a five-month interval of inpatient rehabilitation after TBI. Twenty-three injured children were compared to healthy subjects that were matched for sex and age. The TBI group demonstrated reductions in gait velocity, stride length, cadence and impaired balance compared with the control group. The broad-based gait pattern and the increased double limb support indicate postural instability in children with brain injuries. The hand function tests (The Developmental Hand Function Test and the Purdue Pegboard test) revealed deficits in fine motor skills, speed, and coordination. The hand motor skills improved less than gait in the TBI group. The authors hypothesized that the differences in neuronal control of both functions may be the reason for the varying outcomes of fine motor control and gait. The basic pattern of walking is organized in neuronal circuits at the spinal and brainstem level (Patra, 1996) while fine motor control depends critically on the integrity of the cortical motor areas giving rise to corticomotoneuronal projections (Lemon, 1993). Moreover, the normal developmental rates of both systems differ with earlier maturation of the gait pattern compared to fine motor skills such as the precision grasp.

In contrast to the relatively short term study by Kuhtz-Buschbeck et al. (2003a), Chaplin et al. (1993) investigated long term motor outcome of children with TBI. The primary purpose of the study was to determine if motor impairments exist beyond one-year post injury. The study included 14 traumatically injured children between five to 15 years old who were matched for sex and age to a control group. The study compared gross and fine motor performance using

the BOTMP. The study revealed high differences on the gross motor composite for the TBI group compared to the cohorts. There were no notable differences between the injured and uninjured children on the fine motor composite. On further investigation of the fine motor subtest that involved response speed, there were significant differences between the groups. The difference in design between the gross motor and fine motor composites in the BOTMP may provide a possible explanation for the differing results between the gross motor and fine motor outcomes in this particular study. The authors hypothesized that response speed is a major factor affecting function in children post traumatic brain injury and perhaps the fine motor tests on the BOTMP are not sensitive enough as they fail to detect these problems. Similar findings reported by Bawden et al. (1985) demonstrated that children with severe TBI had significantly lower scores on highly speeded tests compared to lower speeded tests. Other studies by Chadwick et al. (1981a) and Chadwick et al. (1981b) revealed that children presented with specific deficits on short-timed tests that require fast motor responses. Thus, the authors deduced that speed of hand-eye coordination is particularly sensitive to the effects of traumatic brain injury.

Juxtaposed to the above studies that involved speeded tasks, Kuhtz-Buschbeck et al. (2003b) assessed functional motor behaviour of gait, reaching and grasping in children post moderate and severe traumatic brain injuries using quantitative and qualitative measures. The outcome measures used allowed more natural functional motor behaviour and permitted the children to move at their desired speeds. These measures allowed for greater variations in performance compared to the BOTMP which probed maximum speed and precision. This study examined 20 children with an age range of six to 13 years old and compared them to an uninjured control group. Kuhtz-Buschbeck et al. (2003b) incorporated both short-term and long-term assessment points, which included an assessment at two-months and one-year post injury. Prior to the research study, the children had been enrolled in a rehabilitation program that included special schooling, neuropsychological support, physiotherapy, and occupational therapy (three to five hours per week). In this study, the children with TBI displayed motor performances that were characterized by slowness, unstable motor patterns and coordination deficits. Furthermore, the study included a neuropsychological test, the Kaufman Assessment Battery for Children (K-ABC). Lower scores on the K-ABC which equated to lower cognitive scores were associated with prolonged reaction times in motor tasks. It was deduced that these results indicate that neuro-behavioural sequela of traumatic brain injury can involve functional domains.

Dumas et al. (2002) also studied children who had been enrolled in an inpatient rehabilitation programme in order to identify functional recovery in this population group.

Pediatric Evaluation of Disability Inventory (PEDI), functional skills and caregiver assistance domains of self-care, mobility and social function were assessed in 79 children and adolescents with TBI on admission and at discharge from the rehabilitation centre. Self-care levels were greater than mobility and social function on both PEDI scales on admission to the rehabilitation centre. At discharge, the children demonstrated a significant improvement in all three domains. The amount of change between the domains was significantly greater for mobility compared to the other two. Social function had the least recovery and was the lowest score on both admission and discharge, whereas self-care was the least affected. Comparably to the results by Kuhtz-Buschbeck et al. (2003a), children with greater functional deficits on admission, demonstrated greater functional gains after a period of inpatient rehabilitation. This particular study revealed that age was not related to the amount of recovery, although as mentioned in 2.4.2.9, age has been found to be a predictor of outcome in long term outcome studies (Michaud et al., 1993, Taylor et al., 2002, Ewing-Cobbs et al., 2004).

O'Flaherty et al. (2000) followed 51 participants during 1992-1994 between the ages of nought to14 years old. The children were separated into mild or severe categories based on specific criteria and compared to a control group of 30 non-TBI related admissions. There were three data collection points: the initial assessment; six months later and at two years post insult. As mentioned in 2.9.1.4, the children with MTBI demonstrated no significant deficits at two years post injury. Contrary to the findings of the MTBI group, the children in the severe TBI category demonstrated continued problems with fine motor performance; neurologic status; self-care and academic performance at the two year follow up mark. With regards to fine motor difficulties, up to half of the group had persisting fine motor issues. Thirty-six percent of the severe TBI group continued to have motor difficulties on standardised assessment tools. On the qualitative assessments, one fourth to half of the group displayed the following: muscle tone differences; arm and hand control difficulties; poor handwriting or required a keyboard; abnormal or delayed handwriting grasp and had difficulty with bilateral upper limb activity. Fifty percent of the severe subjects had impaired gross motor function at six months and remained that way at two years post injury. Fifty-eight percent of severe TBI subjects had persisting neurologic problems such as tremor and cranial nerve impairment at the two-year mark. With regards to self-care, 25 to 30 percent of the severe TBI group still had self-care dysfunction and the severe TBI group had between three to four times the rate of children who required extra educational support at two years compared to the MTBI group. However, it is important to note that 32% of the MTBI group and 27% of the severe TBI group had not yet begun school as they were too young, and this may have skewed some of the data. Both the mild and the control group (who

had been admitted with some type of injury), also had subjects who required additional educational assistance. Thus, children, regardless of the severity of the injury, whether it be a TBI or not, may struggle to reintegrate into society and assume regular activities of daily living.

Unique studies by Caeyenberghs et al. (2009) and Caeyenberghs et al. (2011) utilized advanced neuroimaging techniques to determine correlations between white matter integrity and motor function in children with TBI as an exploration of compensatory recruitment patterns. In the first study done in 2009, Caeyenberghs and associates aimed to compare brain activation patterns in typically developing children and children with TBI using functional MRI (fMRI). The primary focus of interest was the study of neural activation differences between both groups with emphasis on mechanisms of compensatory recruitment. Twenty-six children were included in the study, nine children with moderate and severe TBI were compared to 17 controls. The children were recruited from rehabilitation centres in Belgium and were assessed at least six months' post injury, when neurological recovery was stabilized. At the time of the study, the children were no longer in rehabilitation programmes. The interval between the time since injury and the assessment was on average three years and one month. The initial MRI or CT scan revealed neuropathological consequences in all patients typical of moderate and severe traumatic brain injury. Majority of the injured children showed signs of DAI as determined by a neuro-radiologist. The children were instructed to perform cyclical movements with their dominant and non-dominant hands and feet according to easy iso-directional and more difficult non-iso-directional mode. The Movement Assessment Battery (MABC) was also used to assess general motor performance. The TBI group scored on average worse than the control group on the total score of the MABC, however, performance between the two groups on the fMRI was similar. On analysis of the fMRI, the children with TBI showed enhanced activity in medial and parietal areas as well as the posterior cerebellum as compared to the control group. Furthermore, brain activation generally increased during the more difficult non iso-directional mode as compared with the easier iso-directional mode. Additional brain regions were involved when the degree of task difficulty increased. The findings of this study assist in supporting the notion of functional neural plasticity. The children with motor impairment, as a consequence of TBI, demonstrated changes in functional cerebral activity and exhibited compensatory activation. The results reflect increased recruitment of neural resources for attentional deployment and somatosensory processing.

Furthermore, Caeyenberghs et al., (2011) used diffusor tensor imaging (DTI) to investigate microstructure and motor impairments in young TBI patients. Similar to their previous study, the MABC was used to measure the degree of motor impairment in children with TBI when

compared to normal developing controls. Instead of using fMRI, another sensitive neuroimaging technique, DTI was used. DTI uses fractional anisotropy (FA) to measure microstructural changes in the white matter (WM) caused by neuropathology. The DTI revealed that the brain regions where the WM was most severely affected in children with TBI were the: corpus collosum; cerebellum and the cortico-spinal tracts. The TBI group demonstrated significant negative correlations between the manual dexterity sub-score on the MABC and the FA of the cerebellum. The ball skills sub-score correlated with mean FA in the fibres passing through the cerebellum. Decreased static and dynamic balance sub-scores were associated with a lower FA in the corticospinal tracts. Interestingly, none of the MABC scores were correlated with FA within the control group. The DTI findings also provide further evidence of abnormal motor processing in the TBI group. The brain regions with significant correlations, coincided with neural areas known to be important in specific motor areas. For example, the cerebellum is essential for the function of coordination and balance, whereas the corticospinal tract is associated with voluntary body posture adjustments. In most of the regions where FA values in the TBI group were significantly lower than the controls, there were high correlations with the MABC scores. The findings of this study emphasize the vulnerability of the cerebellum to traumatic brain injury. Abnormalities found within the corticospinal tracts (including the corona radiata) appear critically associated with their observed motor deficits. Patterns of abnormality found in this study are consistent with preliminary case reports on DTI of children with TBI (Lee et al., 2003). Moreover, FA abnormalities in this study are consistent with previous DTI studies that have shown decreased FA in the corpus collosum following acute and chronic TBI (Arfanakis et al., 2002, Huisman et al., 2004, Inglese et al., 2005). The WM damage in the cerebellum in this study is consistent with several clinical reports of cerebellar atrophy seen in children following a traumatic brain injury (Soto-Ares et al., 2001, Gale et al., 2005, Spanos et al., 2007). These types of studies, hold promise for future measurement of neural plasticity and repair following a traumatic brain injury in children which can lead to a way of monitoring therapeutic response.

Rossi and Sullivan (1996) used the same time interval as Caeyenberghs et al., (2011) of four years post TBI. The study examined motor performance including strength; agility; endurance and coordination. Their research revealed that the children and adolescents that had sustained a TBI had a lower level of performance which may affect the children's participation in sports and physical activities. Although most of the children regained independent ambulation post severe TBI, long term gait impairments, including compromised balance and speed, have been noted in this population group (Di Scala et al., 1992, Emanuelson et al., 1996).

Early recovery of walking in children and youths after TBI was also examined by Haley et al. (2003). This particular study also included subjects with lower-limb fractures. High ambulation recovery post TBI was reported in this research study. However, the definition of walking used in the study is on a basic level and quality was not assessed. More than 70% of children and adolescents who were admitted to acute rehabilitation achieved basic indoor ambulation with or without a walking device at discharge. Of the 106 children and adolescents: 60.4% walked independently; 12.3% required an assistive device and 27.3% were non-walkers at discharge. The study identified the following to be predictors of walking with an assistive device: the presence of spasticity (more than 85% of non-ambulators had lower limb spasticity); lower limb injury (48%); unconscious on admission to rehabilitation (55%) and a severe TBI (55%).

2.9.2.1 SUMMARY

Motor recovery after moderate or severe traumatic brain injury in children and adolescents is complex and dependant of a variety of factors. The recovery rate appears fastest in the first six months post insult and then slows considerably (Kuhtz-Buschbeck et al., 2003b). Advances in neuro imaging have assisted in identifying microstructural changes in the white matter of specific brain regions which have been translated to functional outcomes on gross motor outcome measures. This has allowed researchers to extrapolate potential reasons for the motor deficits that one can observe in children post TBI, with the damage that one cannot overtly see (within the brain structures itself). Although varying degrees of functional recovery are obtained post moderate and severe TBI, the children and adolescents are likely to be left with impairments that can lead to a decreased quality of life.

2.9.3. THE IMPORTANCE OF PAEDIATRIC REHABILITATION

Paediatric rehabilitation is vital in optimizing recovery in children and adolescents post TBI. As mentioned in 2.4.2.14., the greatest benefit from rehabilitation is seen in those patients who receive the rehabilitation early after onset of injury. The rehabilitation should include ‘enriched environments’ and include an interdisciplinary team, of which the family and the primary caregiver’s play a pivotal role. Patients that received rehabilitation early after insult were shown to have reduced levels of impairment, disability and secondary complications as well as better long- term functional outcome (Taylor and Alden, 1997). Paediatric rehabilitation is a process and involves many qualified personnel. It is generally divided into acute and post-acute rehabilitation. Acute rehabilitation generally involves: prevention of complications related to reduced mobility, sensory stimulation, improving awareness of the environment and daily

events, stabilizing the sleep wake cycle, prompting and shaping automatic behaviours such as feeding as well as promoting active participation in familiar daily activities. Post- acute rehabilitation involves discharge from acute hospitalization and participation in an outpatient rehabilitation programme. Continued rehabilitation in the later stages is vital to continue the neuronal reorganization, further optimize physical and functional recovery, assist in the child's transition to school and support the family's coping abilities (Yen and Wong, 2007).

2.10 OUTCOME MEASURES

Recovery of motor function and achieving mobility are among the primary therapy goals during the rehabilitation of TBI. Although various rehabilitation programmes have been designed to improve motor function in the paediatric population with TBI, there are no universally accepted outcome measures for this age group (Linder-Lucht et al., 2007). As discussed extensively in section 2.9., various authors used different standardized assessment tools for similar study designs and purposes. The two most commonly used outcome measures in the pTBI population is the BOTMP and the M-ABC. Studies by Chaplin et al. (1993); Gagnon et al. (2004); and Dahl and Emanuelson (2013) used the BOTMP whereas Caeyenberghs et al. (2011) and Caeyenberghs et al. (2009) used the M-ABC to compare motor function between children with TBI to a cohort. Some of the other outcome measures mentioned to assess function, participation and QOL in the paediatric TBI cohort include: the GMFM, the Barthel-Index and the Pediatric Evaluation of Disability Inventory (PEDI) (Dumas et al., 2002, Kuhtz-Buschbeck et al., 2003a). The researchers in this field very rarely use the same outcome measures to document motor recovery. This limited overlap in research makes it difficult to identify trends and to extrapolate concrete conclusions. Moreover, the outcome measures used often incorporate a combination of various functional domains such as: cognitive; self-care and physical dimensions which often fail to distinguish between mobility and pure motor skills. This lack of differentiation complicates the quantifying and interpretation of isolated motor recovery (Linder-Lucht et al., 2007). The outcome measures chosen for this study will be discussed in more detail.

2.10.1 GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM

The Gross Motor Function Classification System (GMFCS) was designed for children and adolescents with Cerebral Palsy. It is a five-level classification system (refer to table 2.1) that is based on self-initiated movement, with emphasis on sitting, transfers and mobility. Distinctions between levels are based on functional limitations, the need for handheld mobility

devices (such as walkers) or wheeled mobility. Quality of movement and prognosis for improvement is not the primary focus, but rather it is the individual's present abilities and limitations in gross motor function that are of particular interest. The emphasis of this measure is on the child's usual performance in the home, school and community setting rather than what they are able to do with their best efforts. The GMFCS was expanded in 2007 and includes an age band for youth aged 12-18 years. The GMFCS was designed with the World Health Organization's International Classification of Functioning, Disability and Health (ICF) as its primary focus. The user is encouraged to be aware of the impact that the environmental and personal factors may have on the disabled individual's functional ability (Palisano et al., 2008).

Table 2.1: Gross Motor Function Classification System (E&R)

Level I	**Walks without restrictions, limitations in more advanced gross motor skills**
Level II	Walks without restrictions, limitations walking outdoors and in community
Level III	Walks with assistance of mobility device, limitations walking outdoors and in community
Level IV	Self-mobility with limitations. Children are transported or use power mobility outdoors and, in the community,
Level V	Self-mobility is severely limited even with the use of assistive technology

(Palisano et al., 2008)

Advantages of the GMFCS

The tool is quick and easy to use. It includes detailed and age-appropriate descriptors which allow for a more accurate classification. It also includes pictorial representations for ages six through 12 which assists with easy identification and understanding of the differences between the classification levels (particularly, the subtle differences between level I and II). Research has demonstrated the GMFCS to have good inter-rater and test-retest reliability (Paulson and Vargus-Adams, 2017).

Limitations of the GMFCS

The classification system is ordinal but the distances between the levels must not be considered equal. For example, between a GMFCS level II and a GMFCS level III there is technically only a difference of one level. However, the difference between the levels is great in terms of an individual's functional ability and the subsequent impact the disabilities have on the individual's life. Therefore, one must be aware that the distances between levels is vast in terms of functional abilities and disabilities and that children are not equally distributed across the five levels (Palisano et al., 2008).

2.10.2 THE GROSS MOTOR FUNCTION MEASURE

The Gross Motor Function Measure (GMFM) is recognised in clinical practice and international rehabilitation research as the gold standard for evaluating quantitative changes in gross motor function (Linder-Lucht et al., 2007). There are two versions of the GMFM available, the GMFM-88 (Russell et al., 1989) and the GMFM-66 (Russell et al., 2000). The GMFM is designed to determine the quantity of gross motor function rather than the quality of movement. The GMFM-88 was primarily designed to detect clinically significant changes in gross motor function in children with cerebral palsy (CP) (Russell et al., 1989) but has since been validated for children with Down Syndrome (Gémus et al., 2001) and children aged five to 17 years with spinal muscular atrophy (Nelson et al., 2006). The GMFM was validated with children and adolescents from five months to 16 years of age and is appropriate for usage in children with gross motor function at or below the level of a typically developing five-year-old (McCauley et al., 2012).

There have been a few studies that have partially established the responsiveness of the GMFM-88 to changes in motor function after TBI (Kuhtz-Buschbeck et al., 2003a, Thomas-Stonell et al., 2006). A study conducted by Linder-Lucht et al. (2007) evaluated the validity of both versions of the GMFM for use as responsive measures of change in motor function in children and adolescents with TBI. The multicentre trial provided sufficient evidence of responsiveness and the validity to support the use of both versions of the GMFM in clinical and research settings in this population group. Furthermore, in a recent study conducted by McCauley et al. (2012), the GMFM was recommended as one of the outcome measures suitable for evaluating the physical functioning domain in paediatric traumatic brain injury research. Linder-Lucht et al. (2007) also confirmed that the GMFM is more sensitive to change in the acute period following TBI injury. The study revealed that the change in gross motor function becomes fewer as the interval between brain injury and the first GMFM assessment increased. The total GMFM-88/-66 score in children and adolescents with date of injury more than one year before the first GMFM assessment was only 1.8% whereas it was 12.8% in patients for whom the interval between the injury and the first GMFM assessment was less than 1 year. This reflects clinical observation that patients with TBI show the largest motor recovery during the first year of rehabilitation and the GMFM is a sensitive measure that is suitable to detect this change (Jaffe et al., 1995).

Advantages of the tool

The tool is freely available. Most of the equipment required is standard equipment in a physiotherapy gym (e.g., a mat, bench, toys etc.). No specific training is required to administer the GMFM-88 and the physiotherapist merely has to familiarise with the guidelines and score sheet prior to assessing the children. Both versions of the GMFM have been extensively studied and have sufficient validity, reliability, and responsiveness for the assessment of motor skills in both clinical practice and in research. The GMFM was shown to be highly reliable with an intraclass correlation coefficient (ICC) of greater than 0.98 as well as a high validity with an ICC of 0.99 (Alotaibi et al., 2013).

Limitations of the tool

The GMFM-88 can take long to administer (between 45-60 minutes) which may result in the child losing interest or becoming fatigued resulting in either inaccurate or uncompleted dimensions. The data derived from the GMFM-88 is ordinal. Ordinal data is ordered: i.e., scoring of individual items on the GMFM-88 is nought, one, two, three and equal credit is given for moving from nought to one, one to two and two to three. Although, the numbers imply that the distances between the numbers are equal, practically this is not necessarily correct as the difficulty between dimensions is not equal. Data from ordinal measures may actually under or over-estimate change over time. Because this tool was initially designed for children with CP, the scores can be compared to other children with CP of a similar age and similar GMFCS level at six and 12 months in order to gauge the child's level of improvement. However, there is currently no such comparison for children with traumatic brain injuries (Russell et al., 2000).

Furthermore, the test is performed in a controlled environment that does not necessarily translate to the child's motor responses in their daily life. Thus, making the measure less sensitive to detecting improvements in everyday activity (Linder-Lucht et al., 2007). Moreover, the test only examines gross motor function and should be used in conjunction with other outcome measures to provide a comprehensive assessment of the individual's activity and participation restrictions.

Details on the administration, scoring and interpretation of the GMFM-88 can be found in Appendix 1.

2.10.3 MOVEMENT ASSESSMENT BATTERY FOR CHILDREN – SECOND EDITION

The Movement Assessment Battery for Children – Second Edition (MABC-II) is a well-known standardized test for detecting movement difficulty in children (Brown and Lalor, 2009). It is a comprehensive measure of motor skills that does not assess gross motor function in isolation but rather the child's development as a whole (Griffiths et al., 2018). The MABC-II is a revision of the well-known Movement Assessment Battery for children (MABC) and it was designed to identify and describe impairments in motor performance of children three to17 years of age (Brown and Lalor, 2009).

The MABC-II was published in 2007 and the test and checklist were normed on a nationally stratified sample of 1172 children from the UK. The MABC-II test is used worldwide to detect movement impairments in children and adolescents (Jaikaew and Satiansukpong, 2019). It is a common outcome measure used in Western Countries but it has also been used in Asian and South American countries such as China, Japan and Brazil. Jaikaew and Satiansukpong (2019) studied the cross-cultural validity; content validity; and interrater reliability of the MABC-II in Thai children which proved to be successful. This demonstrates that the test can be used outside of the original country.

Moreover, Griffiths et al. (2018) conducted a systematic review on the psychometric properties of seven commonly used gross motor function assessment tools. The study revealed the MABC-II to be one of the most reliable tools for this population group. The tool also had one of the highest test-retest reliabilities and was one of two tests that demonstrated evidence of predictive validity.

Advantages of the tool

It covers a relatively broad age range which is in contrast to some of the other gross motor tools which use either a narrow age range (nought to five years old) such as the Peabody Developmental Motor Scales – Second Edition (PDMS-2) or an extremely wide age range (four -21 years old) such as the Bruininks-Oseretsky Test of Motor Proficiency – Second Edition (BOT-2). It is also less time consuming (20-40 minutes) to administer compared to other measures such as the PDMS-2 and the BOT-2 (Jaikaew and Satiansukpong, 2019). The test items are real life activities and appropriate for each child's age group. The kit is easy to carry, the performance test items are engaging for children and the scoring system is user friendly (Brown and Lalor, 2009). Moreover, it is more sensitive at detecting subtle motor deficits

making it a relevant tool for children with mild traumatic brain injuries that may not present with overt motor impairments.

Limitations of the tool

The primary weakness of the MABC-II is its lack of evidence on reliability and validity and therefore clinicians should be wary to base their clinical decisions solely on the results of the MABC-II (Brown and Lalor, 2009).

Details on the administration, scoring and interpretation of the MABC-II can be found in Appendix 2.

2.10.4 ASSISTANCE TO PARTICIPATE SCALE

The ICF instituted by the WHO has become a widely used guide for research, intervention and resource allocation for children and adolescents with disabilities (Majnemer, 2006). Research has highlighted that the participation of children with disabilities is hindered compared to their typically developing peers as they struggle to participate at the same intensity or in as many diverse activities (McGuire et al., 2004). Play and leisure activities provide children and adolescents with disabilities the opportunity to develop skills, social networks, and overall health. Therefore, the participation in such activities must be measurable so that efficacy research can be conducted (Bourke-Taylor et al., 2009).

The Assistance to Participate Scale (APS) was designed to measure the amount of assistance – from the perspective of the primary caregiver – that a child and adolescent requires at home and in the community in order to participate in enjoyable activities such as play, leisure or recreational pursuits. It is a brief, psychometrically sound instrument that was designed as an outcome measure and to predict the amount and type of additional assistance families with disabled children require to facilitate their child in an important aspect of the child's development and daily life: recreation and play (Bourke-Taylor et al., 2009).

Advantages of the tool

The tool is concise and easy to administer. It is free and readily available for download. Both subscales and the total on the APS showed good internal consistency and has demonstrated correlations with individual domains and overall scores for other validated measures such as the Pediatric Evaluation of disability Inventory caregiver scales and Pediatric Quality of Life Inventory (Bourke-Taylor et al., 2009).

Limitations of the tool

It was designed in a high-income country and therefore the activities such as attending a ballet class are not always transferrable to a low-middle-income country. It is only available in English and translation to other languages has not be validated.

Details on the administration, scoring and interpretation of the APS can be found in Appendix 3.

2.10.5 PEDIATRIC QUALITY OF LIFE FAMILY IMPACT MODULE

Research on families coping with paediatric chronic illnesses has established that parents/caregivers are directly affected (Medrano et al., 2013b). The impact the disease has on family functioning is a salient concern given the essential role that the family plays in assisting the child with the necessary adjustments post injury (Varni et al., 2004). As previously established, traumatic brain injury is often accompanied with negative sequela and permanent disability. The injury and subsequent functional outcomes often require parents and family members to adapt and make major changes to living with a newly disabled child. Thus, the psychological impact the injury has on the parent and family as a whole is tremendous and identifying how the child's functioning is affecting the family is imperative both clinically and from a research perspective (Medrano et al., 2013b).

The PedsQL Family Impact Module (FIM) gives a quantitative indicator of the parents self-reported health related quality of life (HRQOL) and family functioning as a result of their child's health. The PedsQL-FIM consists of multiple domains and therefore the authors propose that the measure is sensitive and able to capture the numerous ways a parent can be affected by having a child with a chronic illness (Varni et al., 2004). This is in contrast to a few other similar measures that tend to be one dimensional and not specific to children's health (Stein and Jessop, 2003).

Advantages of the tool

The tool is concise and easy to administer. It is free and readily available for download. The PedsQL FIM has been found to be highly internally consistent in all the research studies that have reported using the FIM as an outcome measure (Varni et al., 2004, Scarpelli et al., 2008, Hsieh et al., 2009, Jastrowski Mano et al., 2009, Panepinto et al., 2009, Anthony et al., 2010, Kunz et al., 2011, Limbers et al., 2011).

Limitations of the tool

It is only available in English and translation has not yet been validated. It was designed in a high-income country with people of different socio-economic status, therefore the questions may not be entirely relevant to this population group. Family function and parents HRQOL of this particular demographic could potentially be negatively impacted owing to social circumstances prior to the child's injury which may have exacerbated the situation (Houtzager et al., 2005).

Details on the administration, scoring and interpretation of the PedsQL-FIM can be found in Appendix 4.

2.10.6 SUMMARY

To summarise, motor impairment can negatively affect activity and participation levels of children and adolescents with a traumatic brain injury. Children with movement difficulties may struggle in performing activities of daily living (ADL's), academic and social activities (Jaikaew and Satiansukpong, 2019). Healthcare professionals and researchers require standardized assessment tools to identify, classify and diagnose motor problems in children (Griffiths et al., 2018). Although, there is no gold standard for the assessment of motor problems in children and adolescents with TBI, the GMFM-88 and MABC-II have proven to be highly reliable assessment tools (Linder-Lucht et al., 2007, Griffiths et al., 2018). Furthermore, identification of motor impairments is a crucial step towards support and intervention for the child and their family. The caregivers and family members are often the ones who experience the enormous burden of the disease which can severely affect family functioning and quality of life. The PedsQL FIM and the APS are two measures that are able to quickly detect the functional and psychological impact on those living with a disabled child (Bourke-Taylor et al., 2009, Varni et al., 2004).

2.11 CONCLUSION

It is not surprising that functional abilities may be compromised following brain injury at a critical developmental stage. Identified acute and long-term impairments in behaviour; attention; memory; education and adaptive deficits have been reported following paediatric and adolescent traumatic brain injury (Catroppa et al., 2008). Motor deficits in this population group have been studied, however, there is limited data available with regards to acute recovery amongst all three types of head injury classifications. Furthermore, the majority of the studies recruit children from rehabilitation units after they have received intensive therapy. Minimal

data exploring the untapped progression of motor recovery after a mild, moderate, and severe paediatric TBI is available, particularly from developing countries such as South Africa. This type of data is crucial in resource strapped nations where trauma forms part of the 'triple burden of disease' and resource allocation is imperative to optimize rehabilitation and functional re-integration of children and adolescents post TBI.

CHAPTER THREE – METHODOLOGY

The methodology that was used to conduct the research is presented in this chapter.

3.1 STUDY DESIGN

A descriptive cohort study was conducted. Assessments were performed at two time points by the researcher. Gross motor function was determined using specific outcome measures at discharge and at three months post discharge. Parent questionnaires were administered at three-month follow-up only.

3.2 ETHICAL CLEARANCE

Application for ethical clearance was made to the Human Research and Ethics Committee (Medical) of the University of the Witwatersrand and approval was granted prior to starting the data collection process. The study ethical clearance number is M1711107 (See Appendix 5).

3.2.1 PERMISSION TO CONDUCT RESEARCH

An application was made to CHBAH paediatric surgical department to conduct research on paediatric surgery patients. Permission was granted by Professor JA Loveland (Academic Head of Department of Paediatric Surgery) on 17 January 2018 (see Appendix 6). Participants and their primary caregivers were given information sheets with attached consent and assent forms prior to the commencement of the data collection (see Appendices 7 and 8). Written informed consent and assent (for children older than the age of six) was obtained from the participant and their relevant caregiver.

3.2.2 ETHICAL CONSIDERATIONS

The relevant informed consent or assent forms and information sheets which explained the purpose of the study and a detailed explanation of the research procedure were given to and completed by the study participants. For those patients who agreed to enrol in the research study, the Patient's Rights Charter was emphasized. The principal investigator (PI) was responsible for conducting all the procedures and the data collection. All data collected remained confidential, with only the PI and the primary supervisor having access to the raw data. All data collected was kept anonymous through numbers and coding. The results were made available to the participants and their caregivers and the appropriate referrals were made

based on the results obtained. There was no risk to the participants in this study. The participants were able to withdraw from the study at any point of the study duration. Their withdrawal would not prejudice them in any way. The appropriate remuneration was provided for transport.

3.3 LOCATION

This study was conducted at CHBAH in Johannesburg, Gauteng. All assessments were conducted in the Paediatric Surgical Admissions Ward (PSAW). CHBAH is the third largest hospital in the world and the largest in Sub-Saharan Africa (Patel et al., 2017). The hospital serves a population of approximately 4.5 million people. It has a maximum capacity of 3600 beds, and it is the referral centre for 17.3 million persons from Gauteng and the surrounding provinces.

Within the hospital 383 beds are dedicated to medical paediatrics and general paediatric surgery. Paediatrics in the hospital include the nought to 15 age group. The PICU is an eight bed facility that caters for all medical and surgical patients except for burns which has its own separate unit (Patel et al., 2017). CHBAH is situated in Soweto with an approximate population of 1.6 million people (StatsSA, 2019).

3.4 STUDY POPULATION

3.4.1 SAMPLE SIZE

The sample size was initially calculated using the M-ABC-2® as the primary outcome measure, a sample size of 31 children would have a 95% power to detect a three point change in the M-ABC scores, using a standard deviation of three. This allowed for a drop-out rate of 30%. Testing will be done at a level of significance of 0.05. As this sample size was considered small due to expected heterogeneity of the population it was recalculated using Raosoft sample size calculator. Based on a monthly intake of 35 children with TBI and three months of follow up, a sample of 86 children was generated . This allows for a 5% margin of error and a 95% confidence level. The outcome measures used are sensitive to change (section 2.10) making the study sufficiently powered to detect changes at three months.

3.4.2 INCLUSION CRITERIA

The children and adolescents were eligible to participate in the study if:

- They were between the ages of three to12 years.

- They were admitted to the Paediatric ICU and the surgical wards at CHBAH with a confirmed diagnosis of a TBI with or without other injuries.

3.4.3 EXCLUSION CRITERIA

- Children who had sustained a previous head injury.
- Children with known developmental delay, neurological or psychological disabilities prior to the traumatic brain injury
- Children who did not live in Gauteng.

3.5 OUTCOME MEASURES

3.5.1 THE GLASGOW COMA SCALE

The GCS uses a patient's clinical symptoms to classify the severity of the brain injury as either mild, moderate, or severe. The scoring system ranges from three to 15 and the score recorded relates to a classification of TBI severity. A score of 13-15 is classified as a mild TBI, a score ranging from nine to 12 is classified as a moderate TBI and a severe TBI constitutes a score of eight or less (Saatman et al., 2008).

3.5.2 THE GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM

The Gross Motor Function Classification System (GMFCS) is a standardized classification system of motor impairment. It consists of five levels, ranging from one to five and primarily focuses on ambulation. A level one equates to the least motor involvement and a level five equates to significant motor impairment. A level one includes children that are generally independent in ambulation but have some degree of impairment with higher motor tasks such as coordination, jumping, stair climbing etc. A level five refers to children that are severely disabled in ambulation and require maximum assistance such as a wheelchair. For the purpose of this study, any of the participants that did not present with any motor impairment in ambulation and did not fit the criteria of a level one, were awarded a GMFCS level nought.

3.5.3 THE GROSS MOTOR FUNCTION MEASURE

The Gross Motor Function Measure (GMFM-88) is a standardized assessment tool which is used to measure the gross motor function in children. It has been proven effective in children

and adolescents with TBI (Linder-Lucht et al., 2007). The GMFM has been extensively studied and has sufficient validity, reliability, and responsiveness for the assessment of motor skills in both clinical practice and in research. The GMFM was shown to be highly reliable with an intraclass correlation coefficient (ICC) of greater than 0.98 as well as a high validity with an ICC of 0.99 (Alotaibi et al., 2013).

3.5.4 THE MOVEMENT ASSESSMENT BATTERY – SECOND EDITION

The Movement Assessment Battery – Second Edition (MABC-II) is a well-known standardised test for detecting movement difficulty in children (Brown and Lalor, 2009). It is sensitive at detecting subtle motor deficits making it a relevant tool for children with mild traumatic brain injuries that may not present with overt motor impairments (Brown and Lalor, 2009).

3.5.5 THE ASSISTANCE TO PARTICIPATE SCALE

The Assistance to Participate scale (APS) is a brief, psychometrically sound instrument that was designed both as an outcome measure and to predict the amount and type of additional assistance families with disabled children require to facilitate their child in an important aspect of the child's development and daily life: recreation and play. The APS demonstrated excellent internal reliability on the current sample with a Cronbach's Alpha coefficient of α=0.98 (Bourke-Taylor et al., 2009).

3.5.6 THE PEDIATRIC QUALITY OF LIFE – FAMILY IMPACT MODULE

The Pediatric Quality of Life – Family Impact Module (FIM) gives a quantitative indicator of the parents self-reported HRQOL and family functioning as a result of their child's health PedsQOL-FIM demonstrated excellent internal reliability on the current sample with a Cronbach's Alpha coefficient of α =0.93 (Varni et al., 2004).

3.6 PROCEDURE

3.6.1 RECRUITMENT

The primary investigator screened the Paediatric Surgery Admissions book in PSAW, the PICU and the Paediatric Surgical Ward for patients with a diagnosis of TBI. If the patient fulfilled the

inclusion criteria, the primary caregiver was contacted either telephonically or verbally, if they were physically present in the ward and invited to participate in the research study. Caregivers were given the opportunity to read the letter of information and to sign the consent form. Children who were older than seven and cognitively able, provided assent to partake in the study.

For those participants that agreed to participate in the study, the assessments were conducted on the day of hospital discharge and a follow-up appointment was scheduled for three months later. The required number of 86 participants were recruited between March 2018 and April 2019. Of the 86 participants, one succumbed to his injuries and one was transferred to a private rehabilitation hospital rendering them ineligible for the study. The final study number thus consisted of a total of 84 participants. Of the 84 participants, 13 were lost to follow-up at the three-month mark for a variety of reasons (Figure 3.1.)

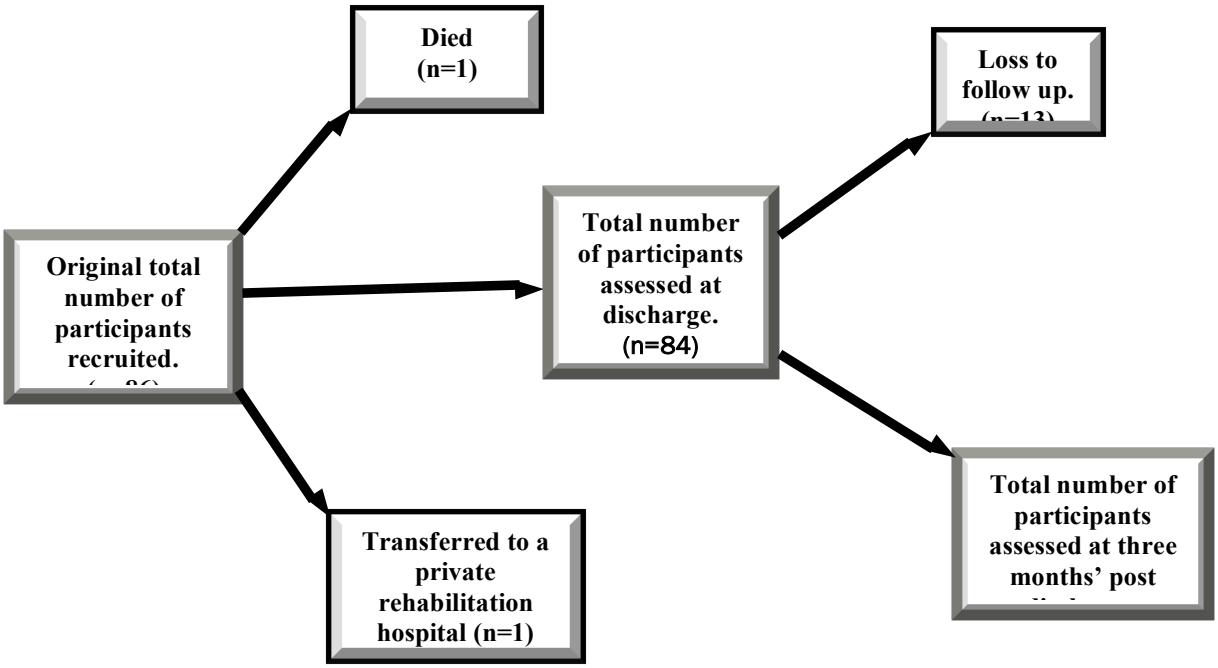


Figure 3.1: *Schematic summary of participant recruitment and loss to follow up.*

3.6.2 DATA FORM

The PI completed the data form based on medical information extracted from the hospital file and from the primary caregiver report. This information included relevant information such as history of the injury, medical and surgical management, and socio-economic demographic information (Appendix 9).

3.6.3 MEASUREMENTS

All measurements were conducted by the PI, an experienced paediatric physiotherapist. The assessments were conducted in the same room and the same environment in PSAW for each participant at discharge and at three-month follow-up. The room was quiet and free from distractions. Caregivers were present for the duration of the assessment.

The PI completed the process described below with every participant:

1. The GMFCS level was determined based on the GMFCS guidelines for each participant at discharge and the level was reviewed at three-month follow-up.
2. The GMFM-88 was completed according to the guidelines in the user manual (Gross Motor Function Measure (GMFM-66 & GMFM-88) User's Manual, Second Edition (2013)). Each child was allowed three attempts to complete an item, as per the instruction manual and scores were recorded on the scoring sheet (Appendix 10). The raw scores for each dimension were converted to a percentage out of 100 and entered into an Excel spreadsheet.
3. The MABC-II was completed according to the guidelines in the user manual (Movement Assessment Battery for Children – Second Edition (2007)). Each child was given two practice rounds for each item on the manual dexterity and balance subscales and five practice attempts for the throwing and catching subscale, prior to the formal assessment which included two attempts for the manual dexterity and balance subscales and ten attempts for the throwing and catching subscale. If the participant scored appropriately in the first formal attempt, then attempt number two was not required (for the two subscales), for the throwing and catching subscale, all ten attempts were recorded. The raw scores were documented on the scoring sheet (Appendix 11) and converted to standard scores as per the user's manual.
4. At the three-month follow-up, the parents were given two questionnaires to complete – the APS and the PedsQL-FIM, (Appendices 12 & 13). The PI first explained and demonstrated how each questionnaire was required to be completed and if the primary caregiver was able to complete it correctly then they completed it independently. However, if there was a problem with understanding then the Matron of PSAW would assist with translating and completing the questionnaires correctly.

3.7 STATISTICAL ANALYSIS

All data collected was analysed in consultation with a qualified statistician using IBM Statistical Package for the Social Sciences (SPSS) Version 26. Significance was set at $p<0.05$ and $p<0.01$. Cronbach's Alpha was used to determine the internal consistency of the outcome measures on the specific sample size.

3.7.1 DESCRIPTIVE AND INFERENTIAL STATISTICS

Descriptive statistics were used to summarise the data. The demographic information of the participants was analysed using means, medians, standard deviations (SD), percentages, frequencies, minimum and maximum values.

Inferential statistics were used to determine the statistical significance of relationships between the variables, and to statistically contrast these relationships. Normality assumptions were not met owing to the uneven distribution of data, thus a nonparametric equivalent of the dependent t-test; the Wilcoxon-signed rank test was used to determine whether there were statistically significant relationships between the motor scores at discharge and at three-month follow-up. This test was performed on the three primary motor outcome measures (GMFCS, GMFM-88 and the MABC-II).

3.7.2 CORRELATION STATISTICS

Table 3.1: Statistical tests used to determine relationships between factors affecting outcome.

	GMFCS	**GMFM-88**	**MABC-II**	**Sex**	**Type of TBI**	**Type of associated injuries**	**GCS**
GCS	Pearson correlation coefficient (r)	Pearson correlation coefficient (r)	Pearson correlation coefficient (r)	Pearson Chi-Square (X^2 2)	Fishers Exact Test (p)	Pearson Chi-Square (X^2 2)	
Sex	Point Biserial Correlations (r_{pb})	Point Biserial Correlations (r_{pb})	Point Biserial Correlations (r_{pb})		Pearson Chi-Square (X^2 2)	Fishers Exact Test (p)	Pearson Chi-Square (X^2 2)
Age group	Spearman's Rank Order Correlation (ρ)	Pearson correlation coefficient (r)	Pearson correlation coefficient (r)	Pearson Chi-Square (X^2 2)	Pearson Chi-Square (X^2 2)	Pearson Chi-Square (X^2 2)	Pearson Chi-Square (X^2 2)

A variety of correlation tests (as demonstrated in Table 3.1) were used to determine whether there were significant statistical relationships between a variety of factors effecting functional outcome. The statistical tests used were the following: Pearson correlation coefficient (r), Pearson Chi-Square test (X^2 2), Fishers Exact Test (p), Point Biserial Correlations (r_{pb}) and Spearman's Rank Order Correlation (ρ).

Pearson correlation coefficient (r) was used to measure the statistical relationship between two variables. The test is used to determine the degree of relationship between independent variables such as the GCS score and dependent variables such as the motor outcome. Two-tailed t-tests were employed to determine whether or not these relationships were statistically significant and in which direction. This test was used to determine the relationship between GCS scores to the three main motor outcome measures at three-month follow-up (GMFCS level, GMFM-88, and MABC-II scores) this test was also used to determine the relationship between age groups to the three main motor outcome measures at the three-month follow-up. The Pearson Chi-squared test was conducted on categorical data to determine if there is a relationship. This test was used to determine a correlation between GCS level to a variety of variables which included: sex of the participants; type of associated injuries; and age groups. It was also used to determine if there is a relationship between age group to several variables which included: sex; type of TBI; and type of associated injuries. It was also used to determine a correlation between sex of the participants and the type of TBI sustained. The Fisher's Exact Test was used to determine if there is a statistically significant relationship between categorical values. This test was used to determine a correlation between GCS level and the type of TBI and also if there was a correlation between sex and the type of associated injury. Point Biserial Correlations were used to determine if there is a relationship between the sex and the three main outcome measures (between the nominal and interval variables). The Spearman's Rank Order correlation was used to determine the relationship between age group and GMFCS level (two-ranked variables). The Multivariate Analysis of Variance (MANOVA) test was used to determine whether there are any differences between independent groups on more than one continuous dependent variable. In this case it was used to determine correlations between participants with isolated TBI's, and their motor outcomes, and participants with a TBI in conjunction with associated injuries , and their motor outcomes, at discharge and at the three-month follow-up, as well as, to compare the two groups at the corresponding two time points.

The results obtained in this study will be presented in the following chapter.

CHAPTER FOUR – RESEARCH RESULTS

4.1 INTRODUCTION

This chapter will present the data that were collected in an attempt to determine the early functional outcomes in children with traumatic brain injuries at discharge from acute hospitalisation and at three months' post discharge. Interpretation and discussion of the results will follow in chapter five.

4.2 DEMOGRAPHIC INFORMATION

This section of the results chapter will deal with describing and reporting on the demographic information of the sample population.

4.2.1 SEX, AGE AND SOCIO-ECONOMIC DEMOGRAPHICS OF THE PARTICIPANTS

The sex and age ranges of the participants are depicted in table 4.1 below.

Table 4.1: Sex and age of the participants (n=84)

	Frequency (n=84)	**Percent (%)**
Sex		
Female	30	35.7
Male	54	64.3
Age group		
3-6	46	54.8
7-9	31	36.9
10-12	7	8.3

n = number of participants

Of the 84 individuals, the majority were male as they comprised 64.3% of the sample size. The age range of the participants spanned from three to 12 years old with a mean age of 6.25 years (SD: ±2.302). There was an uneven distribution of ages as depicted in figure 4.1 with the majority of children between the ages of three to six years old (54.8%).

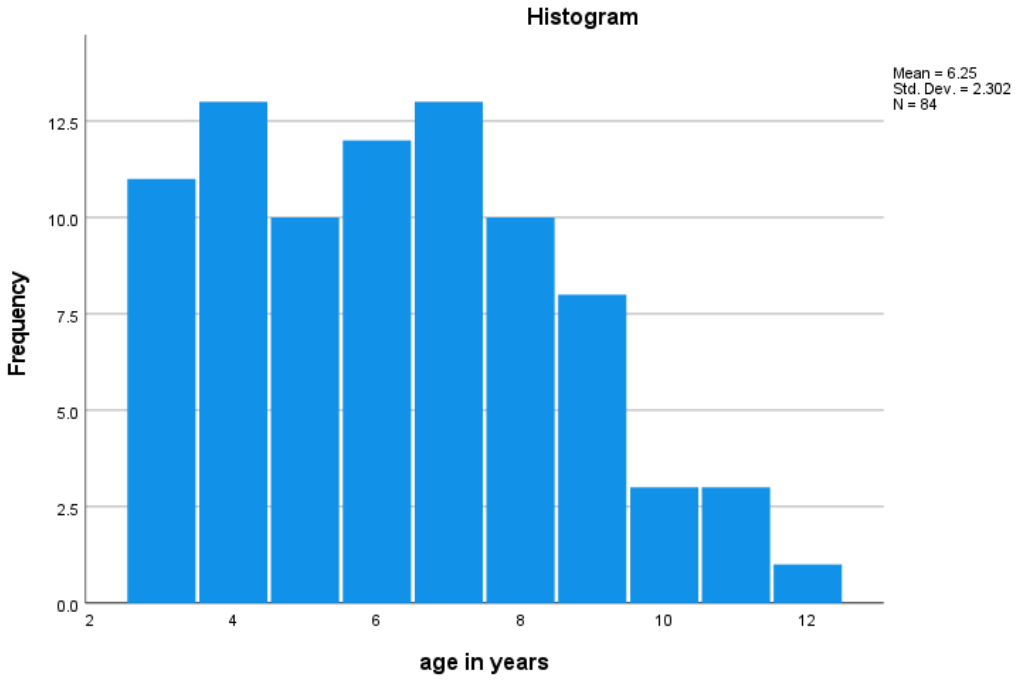


***Figure 4.1**: A histogram depicting age group distribution.*

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
age in years	.122	84	.004	.948	84	.002

a. Lilliefors Significance Correction



***Figure 4.2**: A line graph depicting test of normality for age group.*

The socio-economic demographics will be depicted in table 4.2. below.

Table 4.2: Socio-economic demographics

	Frequency (n=84)	Percent (%)		Frequency (n=84)	Percent (%)
Primary caregiver			**Marital status**		
Parent	70	83.3	**Single**	59	70.2
Grandparent	9	10.7	**Married**	23	27.4
Aunt	4	4.8	**Divorced**	2	2.4
Foster care	1	1.2			
			Number of dependants		
			1	10	11.9
			2	16	19.05
			3	23	27.38
			4	15	17.86
			5	10	11.9
			6	5	5.95
			7	3	3.57
			8	0	0
			9	0	0
			10	2	2.38
Living conditions			**Work status**		
House	47	56.0	**Employed**	36	42.9
Shack	24	28.6	**Unemployed**	48	57.1
Flat	4	4.8			
Room	8	9.5			
Missing data	1	1.2			
Transport			**Social grant**		
Taxi	73	86.9	**Yes**	65	77.4
Private Vehicle	11	13.1	**No**	18	21.4
			Missing data	1	1.2
Number of taxi's to CHBAH (return)			**Level of education**		
0	11	13.1	**Below grade 9**	14	16.7
1	2	2.38	**Grade 10-11**	36	42.9
2	43	51.2	**Matric**	27	32.1
3	1	1.2	**Diploma**	5	6.0
4	22	26.2	**Tertiary**	2	2.4
5	0	0			
6	5	6.0			

n=number of participants

The majority of the primary caregivers (83.3%) were parents (either a mother or father). The majority of the primary caregivers (70.2%) were single. More than half (57.1%) of the primary caregivers were unemployed with a large percent (77.4%) receiving a social grant from the Government. A taxi was the primary mode of transport to and from the hospital (86.9%), with more than half (51.2%) requiring two taxi's return (i.e., one taxi to the hospital and one taxi home). The majority (42.9%) of the primary caregivers had the highest level of education of either grade 10 or grade 11 with only 32.1% of them completing matric certification. Only 8.4% of those that completed matric furthered their studies (either diploma or tertiary studies).

All 11 official languages of South Africa are represented by the sample as demonstrated in figure 4.2.

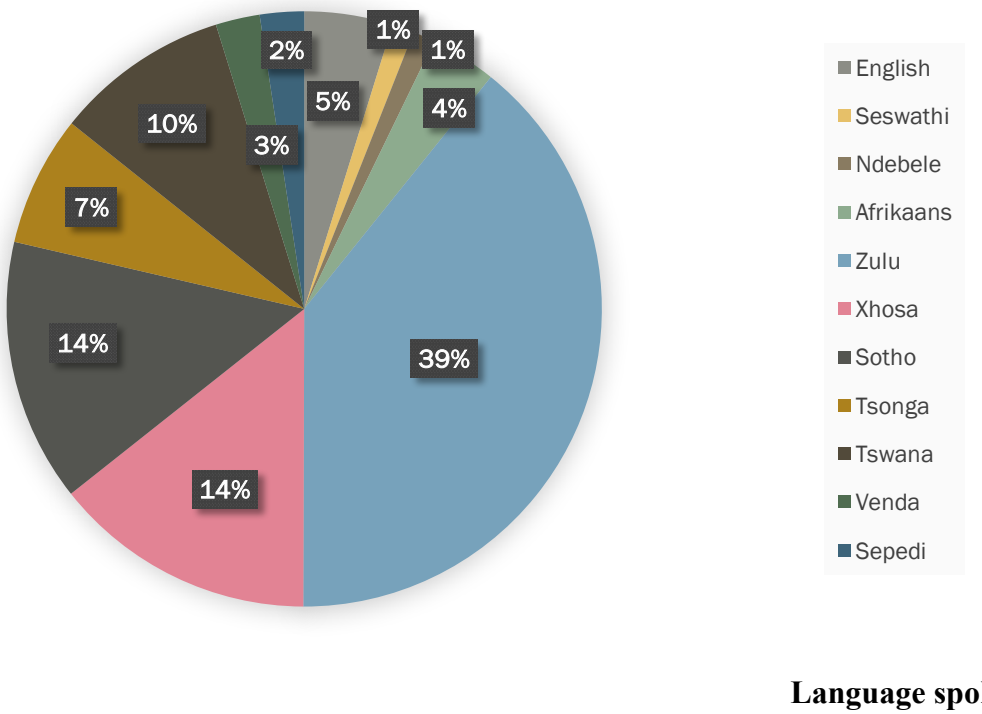


Figure 4.3: *Pie chart depicting the home languages spoken.*

IsiZulu was the dominant language (39%), followed by IsiXhosa (14%) and Sesotho (14%).

4.3 MECHANISM OF INJURY

All of the 84 participants sustained their traumatic brain injuries by a type of blunt force trauma as opposed to penetrating trauma. As can be seen below in Table 4.3. the majority of head injuries were caused by a type of road traffic accident (67.86%), where the participants were either passengers (13.1%) or pedestrians (54.76%). Of the participants that were passengers

(n=11) only 18.1% were restrained in the vehicle at the time of impact. An equal number of head injuries were caused by falls and objects striking the head (15.5%).

Table 4.3: Table depicting the Mechanism of injury

Mechanism of injury	Frequency (n=84)	Percentage (%)
Road Traffic Accident		
Pedestrian vehicle accident	46	54.76
Motor vehicle accident	11	13.1
Restrained	2	18.1
Unrestrained	9	81.82
Falls	13	15.5
Object striking the head	13	15.5
Non accidental injury	1	1.2

4.4 CLINICAL PRESENTATION ON SCENE

The clinical presentation of the participants at the scene of the injury as extrapolated from the emergency service (EMS) report, the parent and/or primary caregiver, the participant and the hospital file will be demonstrated in Table 4.4.

Table 4.4: Presentation of participants at the scene of injury

	Frequency (n=84)	Percent (%)
Altered LOC		
Yes	49	58.3
No	32	38.1
Undocumented	3	3.6
Vomiting		
Yes	26	31.0
No	51	60.7
Undocumented	7	8.3
Seizures		
Yes	12	14.3
No	62	73.8
Undocumented	10	11.9
Witness		
Yes	64	76.2
No	20	23.8

n=number of participants

LOC: Loss of consciousness

The majority of the children, (58.3%) were reported to have an altered LOC at the scene of the accident. Seizures were reported in 14.3% of cases.

4.5 TRANSPORT TO HOSPITAL

The participants were transported to CHBAH either via a private vehicle or the EMS. The number and percentages are depicted in Table 4.5.

Table 4.5: Transport of participants to hospital

	Frequency (n=84)	Percent (5%)
Private vehicle	39	46.4
EMS	45	53.6

n=number of participants

EMS: Emergency services

The majority of the sample (53.6%) were transported to CHBAH via EMS.

4.6 TBI SEVERITY

The TBI severity of the participants was determined using the Glasgow Coma Scale (GCS), by either the EMS on scene or the medical professionals on hospital admission. The GCS levels for all participants per age group is presented in Table 4.6.

Table 4.6: TBI severity per age group

	Mild (GCS 13-15) (n=71)	**Moderate (GCS 9-12) (n=6)**	**Severe (GCS 3-8) (n=7)**
Age group			
3-6 years (%)	47.62	3.57	3.57
7-9 years (%)	32.14	2.38	2.38
10-12 years (%)	4.76	1.19	2.38
TOTAL (%)	84.5	7.1	8.3

n=number of participants

GCS: Glasgow Coma Scale

As shown by the Glasgow Coma Scale (GCS) levels, the majority of the sample sustained mild head injuries (84.5%), followed by severe (8.3%) and moderate (7.1%) head injuries. The mean GCS was 13.49 (SD: ±2.4). The younger two age groups were admitted to hospital with more minor head injuries and the 10-12 age group sustained proportionately more moderate and severe head injuries.

4.7 TYPES OF TBI PRESENT IN THE PARTICIPANTS

The type of TBI as determined by the admission diagnosis and the CT brain results are depicted in Table 4.7.

Table 4.7: Types of TBI present

	Frequency (n=84)	Percent (%)
Unclassified head injury	36	42.9
Nothing abnormal detected on CT brain	24	8.6
Subarachnoid Haemorrhage	3	3.6
Intracranial Haemorrhage	1	1.2
Pneumocephalus	3	3.6
Multiple	10	11.9
Haematoma	7	8.3

n=number of participants

The majority of the sample (42.9%) were given a diagnosis of an unclassified head injury on hospital admission based on the medical history and the patient's signs and symptoms. Of the 57.1% (n=48) of children that had a CT brain post admission, 50% displayed no noticeable abnormalities and were given a diagnosis of nothing abnormal detected (NAD). A diagnosis of NAD was followed by 20.83% of these children sustaining multiple (more than one) types of TBI and this was followed by a haematoma (14.58%).

4.7.1 PRESENTATION AND DISTRIBUTION OF MULTIPLE TYPES OF TBI

Ten of the participants presented with multiple types of TBI on CT brain. The presentation and distribution of the type of TBI involved in the 'multiple' category is depicted in Table 4.8.

Table 4.8: Distribution of the types of TBI present in those subjects with multiple TBI (n=10)

	Frequency (n=10)	**Percent (%)**
Subarachnoid haemorrhage	6	60
Pneumocephalus	3	30
Intracranial haemorrhage	3	30
Base of skull fracture	1	10
Haematoma	5	50
Diffuse axonal injury	1	10
Epidural haematoma	4	40

n=number of participants

*the sum of the percentages does not add up to 100% as this table is a demonstration of the distribution of the TBI's present in the 'multiple' diagnosis.

Of the ten children that had a diagnosis of multiple TBI, a subarachnoid haemorrhage was present in six subjects; a haematoma was present in five subjects; an epidural haematoma was present in four subjects; pneumocephalus and intracranial haemorrhage were present in three subjects; diffuse axonal injury and base of skull fracture were each represented once on CT brain in the 'multiple' category.

4.8 ASSOCIATED INJURIES

The majority of the participants did not sustain isolated head injuries. Many of the head injuries were accompanied by soft tissue injuries, fractures and/or dislocations, medical and surgical complications, or combinations of the above. Medical and surgical management included the management of injuries relating to internal organs such as liver lacerations or lung contusions as well as those that required surgical intervention such as a tracheostomy or a craniotomy. The distribution and types of associated injuries will be depicted in Table 4.9.

Table 4.9: Distribution and type of associated injuries present in the participants.

	Frequency	Percent (%)
Associated injuries	**(n=84)**	
Yes	73	86.9
No	11	13.1
Type of associated injuries	**(n=73)**	
Soft tissue injuries	45	61.6
Fractures and soft tissue injuries	17	23.29
Fractures, soft tissue injuries, medical & surgical	5	6.85
Fractures	2	2.74
Fractures and medical and surgical	2	2.74
Soft tissue injuries and medical and surgical	1	1.37

n=number of participants

The majority (86.9%) of the participants had associated injuries in conjunction with the TBI. More than half (61.6%) of the associated injuries were isolated soft tissue injuries followed by a combination of fractures and soft tissue injuries (23.29%).

4.8.1 DISTRIBUTION AND TYPE OF ASSOCIATED INJURIES PER AGE GROUP

The distribution and type of associated injuries present in each age group is demonstrated in Table 4.10.

Table 4.10: Distribution and type of associated injuries per age group

	3-6 years n=46(%)	7-9 years n=31(%)	10-12 years n=7(%)
Associated injuries			
Soft tissue injury	52.17	58.06	42.86
Fractures and soft tissue injuries	15.22	25.81	28.57
None	19.57	9.68	0
Fractures, soft tissue injuries, medical & surgical	8.7	0	14.29
Fractures	2.17	3.23	0
Fractures and medical and surgical	2.17	0	14.29
Soft tissue injuries and medical & surgical	0	3.23	0

n=number of participants

Soft tissue injuries were the most common associated injury in all three age groups. The three to six age group had the highest number of no associated injuries (i.e.: they sustained isolated TBI's), and the 10-12 age group all had an associated injury accompanying the TBI. The three to six and 10-12 age groups displayed similar patterns of injury with regards to soft tissue, fractures, and medical and surgical injuries. The seven to nine age group displayed a slightly different picture.

4.8.2 ASSOCIATED INJURIES PER BODY REGION AND THE MEDICAL MANAGEMENT

Table 4.11. will break down the type of associated injury per body region and the subsequent medical management.

Table 4.11: Type of associated injury per body region and the medical management

	Percent (%)
Fractures/dislocations (n=26)	
Upper limb only	11.54
Lower limb only	3.85
Pelvis	3.85
Facial	3.85
Skull	42.31
Multiple	34.62
Fracture/dislocation management (n=26)	
Open reduction external fixation	19.23
Conservative	80.77
Soft Tissue Injuries (n=70)	
Pelvis	1.43
Chest	1.43
Facial	31.43
Skull	14.29
Eye/orbital region	1.43
Multiple	50.0
Soft Tissue Injury management (n=70)	
Debridement	2.86
Conservative	95.71
Debridement and split skin graft	1.43
Medical & Surgical (n=8)	
Multiple injuries	37.5
Craniotomy	1.43
Organ damage	1.43
Lung contusion	1.43
other	2.86

n=number of participants

Fractures and/or dislocations accounted for 30.95% of the associated injuries. Of the fractured areas, the skull region was the most common (42.31%), followed by multiple body areas (34.62%). The majority of the fractures and/or dislocations were managed conservatively

(80.77%), which included either a back slab, Plaster of Paris and/or skin traction, with only a small percentage (19.23%) requiring surgical intervention. The majority of the sample sustained some type of soft tissue injury (83.3%). Half of the sample (50%) sustained soft tissue injuries to multiple body regions. Of those that sustained a soft tissue injury, 95.71% of the cases required conservative management. The vast majority of the children (90.5%) did not sustain a medical and /or surgical injury but for those participants that did, 37.5% of them had multiple injuries.

4.9 MEDICAL MANAGEMENT

The following three tables (Table 4.12, Table 4.13, and Table 4.14) will demonstrate the medical and pharmacological management of the participants, their ventilation and neurosurgical management and will also include the length of relevant days and hours, including length of hospital and ICU admission.

4.9.1 MEDICAL AND PHARMACOLOGICAL MANAGEMENT

The most common medical and pharmacological management administered to the participants (n=84) on hospital admission are depicted in table 4.12. The full list can be found in Appendix 14.

Table 4.12: Medical and pharmacological management on hospital admission

	n=84 (%)
Neuro-observation	86.9
Antibiotics	15.5
Wound dressing	15.5
Anti-epileptic drugs	21.4
Analgesia	73.8
Anticoagulants	4.8
Inotropes	2.4
Sedation	3.6
Head up at 30 degrees	13.1
Blood transfusion	7.1
Oxygen	3.6

n=number of participants

The primary treatment prescription of the participants was neuro observation (86.9%). Analgesia was prescribed to 73.8% of the patients and anti-epileptic drugs were prescribed to 21.4% of the sample (either to treat seizures or as prophylaxis).

Table 4.13: Ventilation and neurosurgical management

	Frequency (n=84)	Percent (%)
EMS Ventilation		
No	84	100
Yes	0	0
Intubation on arrival		
No	78	92.9
Yes	6	7.1
ICP monitor		
No	82	97.6
Yes	2	2.4
Neurosurgery consult		
No	61	72.6
Yes	23	27.4

n=number of participants

Emergency services did not ventilate any of the participants at the scene of the accident. The majority of the children (91.7%) did not require ventilation post TBI and of the 7.1% of children that required ventilation, 100% of them were ventilated on admission to CHBAH. A neurosurgery consult was required for 27.4% of the participants.

Table 4.14: Length of in-hospital medical intervention (hours and days)

	Frequency of participants (n=84)	**Mean (median)**	**Range (SD)**
Length of neuroprotection (hours)	5	2.93 (0.00)	0-120 (16.07)
Length of ventilation (days)	6	0.41 (0.00)	0-13 (2.06)
Length of ICU stay (days)	4	0.75 (0.00)	0-21 (3.45)
Length of hospital admission (days)	84	6.51 (3.00)	2-58 (10.64)

The average length of hospital admission was 6.51days (SD: ±10.64). Ten participants required ICU admission and the longest ICU stay was 21 days. Six participants required ventilation on admission, the longest time an individual was ventilated for was 13 days (median:0.00, SD: ±2.06) and 120 hours was the longest period that an individual was placed on neuroprotection (mean: 2.93, SD: ±16.07).

4.10 MOTOR OUTCOME

The next section of the results chapter will describe the data obtained from the outcome measures used to determine motor function of the participants at discharge and at three-month follow-up, to determine significant changes in function in the preliminary period of recovery. GMFCS levels are presented as medians and range while GMFM-88 and M-ABC-II scores are presented as means, standard deviation (SD) and range.

Table 4.15: Motor outcome at discharge and three-month follow-up.

	Discharge (n=84)	**3-month follow-up (n=71)**	**P value (Z value)**
GMFCS (median (SD), range/IQR)	0.00 (1.24) (0-4/0)	0.00 (0.41) (0-2/0)	<0.00* (Z=2.99)
GMFM-88 (mean, (SD) range)	93.2 (18.04) (23-100/0)	99.38 (2.62) (84-100/0)	<0.00* (Z= -3.52)
M-ABC-II (mean, (SD) range)	7.75 (3.75) (1-16/4)	9.44 (2.86) (1-14/3)	<0.00* (Z=-4.49)

n=number of participants

*comparison was significant at the 0.05 level.

At discharge, on the Gross Motor Function Classification System (GMFCS), the greatest motor disability was a level four indicting that the child required physical assistance for ambulation (in most cases a wheelchair). The lowest score was a level nought, indicating no motor disability. At three-month follow-up, the maximum score was a level two indicating that the child could ambulate in most settings (sometimes with the use of a handheld device or physical assistance) and could climb stairs with the use of a railing. The Wilcoxon signed rank test demonstrated a statistically significant difference ($Z= 2.99$; $p<0.00$, correlation is at the 0.05 level) between GMFCS levels at discharge and at three-month follow-up. Significantly lower GMFCS scores were present at three-month follow-up, indicating improved motor ability.

On the Gross Motor Function Measure (GMFM-88), the mean at discharge was 93.20 (SD: ±18.04) and this improved to 99.38 (SD: ±2.62) at three-month follow-up. One hundred percent is the maximum that a child could achieve on this scoring system, thus at three months almost all of the children obtained perfect scores on this measure, indicating no motor disabilities. The Wilcoxon signed rank test indicated a statistically significant difference ($Z= -3.52$; $p<0.00$, correlation set at the 0.05 level) between the GMFM-88 scores of the participants at discharge and their scores at three-month follow-up. The scores of the participants were significantly greater at three months indicating improved motor function.

With the Movement Assessment Battery II (MABC-II), the mean score at discharge was 7.75 (SD: ±3.75) and 9.44 (SD: ±2.86) at three-month follow-up. The Wilcoxon signed rank test indicated a statistically significant difference ($Z= -4.49$; $p<0.00$, correlation set at the 0.05 level) between the MABC-II scores of the participants at discharge and their scores at three-month

follow-up. The scores of the participants were significantly greater at three months indicating improved motor function.

4.10.1 GMFCS, GMFM-88 AND MABC-II DISSECTED

The following three tables (Table 4.16, Table 4.17, and Table 4.18) will describe the motor outcome measures in greater detail and compare both the total and the subscales scores of the participants at discharge and at three-month follow-up. The bar graph (Figure 4.4.) will demonstrate the motor improvement in the participants based on the traffic light system of the MABC-II.

Table 4.16: Comparison of GMFCS levels at discharge and at three-month follow-up.

GMFCS Level	At discharge (n=84) (%)	At three months (n=71) (%)
Level 0	73 (86.9)	68 (95.77)
Level 1	0 (0)	0 (0)
Level 2	2(2.38)	3(4.23)
Level 3	1(1.19)	0 (0)
Level 4	8(9.52)	0 (0)
Level 5	0 (0)	0 (0)

n=number of participants

At hospital discharge the GMFCS levels ranged from nought to four (median: 0.00; SD: 1.24). Seventy-three participants (86.9%) were given a classification of nought, indicating that they were independent in ambulation with no difficulties. Two participants (2.38%) were classified as a level two, indicating difficulty with climbing stairs, running, and jumping. One participant (1.19%) was classified as a level three indicating the need for a handheld mobility device in most indoor settings. Eight participants (9.52%) were classified as a level four indicating that the participant required physical assistance or powered mobility in most settings. The data obtained from the GMFCS was thus skewed as the majority of the participants were

independent in ambulation at hospital discharge. Only three participants (3.57%) positioned somewhere between nought and four. The rest of the data skewed towards a level four indicating ambulatory difficulties at hospital discharge. The data suggests that the children were either discharged as independent in ambulation or the children required a fairly high degree of physical assistance, likely a wheelchair, for ambulation.

At three-month follow-up, the GMFCS levels ranged from nought to two (median:0.00; SD: 0.41), with only three participants (4.23%) scoring a level two and the remaining 68 participants (95.77%) scoring a level nought. The results indicate that during the three-month follow-up period, only 4.23% of the sample did not return to independent ambulation.

Table 4.17: Comparison of GMFM-88 scores at discharge and at three-month follow-up.

GMFM-88 scores at discharge (n=84)			**GMFM-88 scores at three months (n=71)**		
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**P value**
GMFM Total (%)	93.20 (18.04)	23-100	99.38 (2.62)	84-100	<0.00*
% Dimension A (Lying)	99.07 (4.88)	69-100	100 (0.00)	100	<0.16*
% Dimension B (Sitting)	97.37 (9.01)	48-100	100 (0.00)	100	<0.02*
% Dimension C (Crawling)	92.10 (24.79)	0-100	99.69 (1.84)	88-100	<0.01*
% Dimension D (Standing)	89.89 (26.09)	0-100	98.94 (4.07)	79-100	<0.00*
% Dimension E (Walking, running, jumping)	87.54 (30.12)	0-100	98.15 (7.85)	49-100	<0.00*

n=number of participants

*comparison was significant at the 0.05 level

The participants improved by a total of 6.18% over the three-month period. The participants improved in all five dimensions from discharge to three-month follow-up, with two dimensions (Dimension A and B) yielding perfect scores at three months post discharge. Dimension C (crawling) improved by 7.59% and Dimension D (standing) improved by 9.05% over the three-month period. At discharge, the lowest score was that of Dimension E (walking, running, and jumping). At three-month follow-up, this dimension had improved by 10.61% and was 1.85% away from being a perfect score of 100%. All the dimensions, except for dimension A, demonstrated statistically significant improvements over the three month period.

Table 4.18: Comparison of MABC-II scores at discharge and at three months

MABC-II scores at discharge (n=84)			**MABC-II scores at three months (n=71)**	
	Mean (SD)	**Range**	**Mean (SD)**	**Range**
MABC-II Total	7.75 (3.75)	1-16	9.44 (2.86)	1-14
Manual Dexterity (MD)	7.81 (3.11)	1-15	8.66 (2.89)	2-15
Throwing and catching	7.75 (3.59)	1-15	8.93 (2.48)	2-15
Balance	9.15 (4.39)	1-16	11.80 (3.84)	1-18

n=number of participants

The results depicted in Table 4.18. indicate that the participants improved in their total scores over the three-month period on the MABC-II. At discharge, the participants performed the worst in the throwing and catching component (mean: 7.75, SD: ±3.75) and performed the best in the balance component (mean: 9.15, SD: ±4.39) of the assessment battery. Furthermore, there was greatest improvement in the balance component over three months, followed by throwing and catching, with the least improvement in the manual dexterity component. The majority of children scored a mean standard score of 7.75 (SD: ±3.75) on the MABC-II, which is within one SD (one SD is a score of three), and is considered acceptable, indicating no significant motor impairment. However, the SD of the mean of the sample size is greater than three,

indicating that there were participants in the study that scored more than one SD from the mean standard score of 10 and would be considered 'at risk' for motor impairment and would require monitoring. At the three-month mark, the mean improved to 9.44 (SD: ±2.86) which is within one SD of the mean standard score of 10, indicating that the participants were unlikely to have significant motor impairment.

The MABC-II consists of a traffic light system which classifies motor function based on colour zones. The red zone implies significant movement difficulty (at or below the fifth percentile), the amber zone signifies that the child is 'at risk' for movement difficulties (between the 6th and 15th percentile) and the green zone signifies that the child is unlikely to have movement difficulties (above the 15th percentile). As depicted in the bar graph below (Figure 4.4.) at hospital discharge: 46 participants (54.76%) had no motor difficulties; 20 participants (23.81%) were 'at risk' of motor difficulties and 18 participants (21.43%) had motor difficulties. At three-month follow-up: 54 participants (76.06%) had no motor impairment, nine participants (12.68%) were 'at risk' of motor impairment and eight participants (11.27%) had a high likelihood of motor impairment. Based on the traffic light system, the majority of the sample had returned to motor function at three-month follow-up, however, 23.95% of the sample were still classified as 'at risk' of motor impairment or had a high likelihood of motor impairment. A total of 21 participants (29.58%) changed traffic light categories within the three month period.

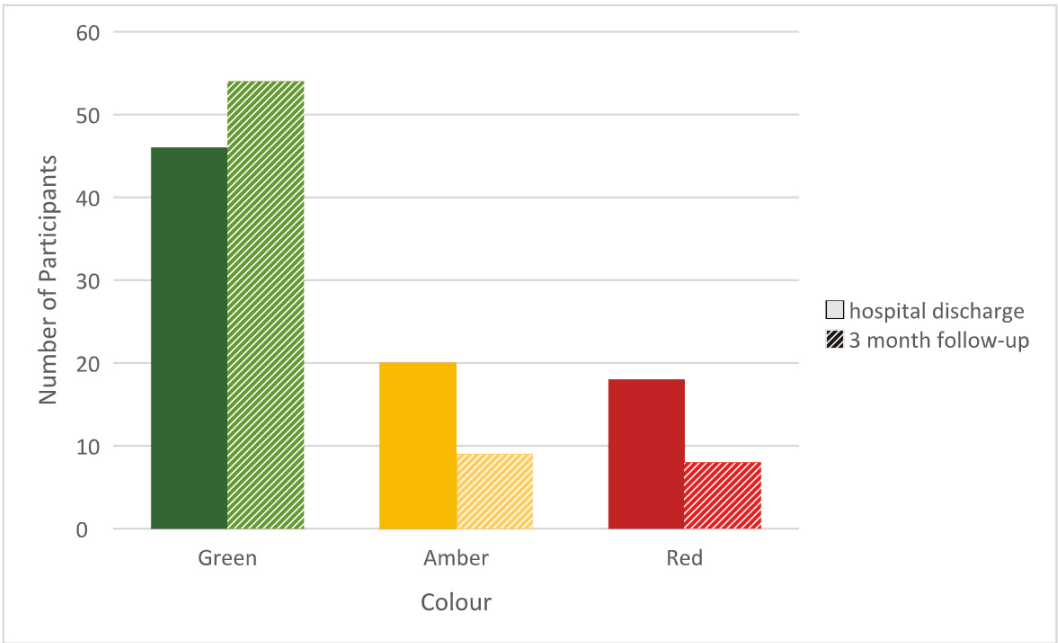


Figure 4.4: *Bar graph demonstrating motor improvement based on the traffic light system.*

4.11 QUALITY OF LIFE

The data from the two questionnaires that were administered to the parent and/or primary caregiver at three-month follow-up will be described below in an attempt to determine the extent of assistance the participant requires from the primary caregiver to participate in home, community, and social activities (Table 4.19). The impact the participant's injury has had on the parent's HRQOL and the family functioning as a whole, based on self-report, will also be described in Table 4.18.

4.11.1 ASSISTANCE TO PARTICIPATE SCALE

Table 4.19 demonstrates the mean, standard deviation (SD) and the ranges of the total scores of the two subscales (home alone activities and community and social activities) and the Assistance to Participate Scale (APS) total. The complete table, including the subscale components can be found in Appendix 15. The APS had a Cronbach Alpha of α=0.98, indicating excellent internal consistency or reliability on this population group.

Table 4.19: Assistance to Participate Scale at three months

	Mean (SD)	**Range**
Home alone activities Total	19.83 (1.42)	8-20
Community and Social Activities Total	19.82 (1.16)	11-20
APS Total	**39.65 (2.53)**	**19-40**

On the APS, the parents reported a mean total score of 39.65 (SD: ±2.53), indicating that the children were largely independent in the home setting (mean: 9.83, SD: ±1.42) and the community and social setting (mean: 19.82, SD: ±1.16) at three months.

4.11.2 PEDIATRIC QUALITY OF LIFE – FAMILY IMPACT MODULE

The total and subscale scores of the Pediatric Quality of Life – Family Impact Module (PedsQL-FIM) are demonstrated in Table 4.20 using mean, SD and range and is explained in percentage.

The Cronbach's alpha for the PedsQL FIM was α=0.93 indicating excellent internal consistency or reliability of this outcome measures on this population group.

Table 4.20: Pediatric Quality of Life-Family Impact Module at three months

	Mean (SD)	**Range**
Parents HRQOL Total (%)	**69.06 (20.44)**	**17.92-100**
Physical functioning (%)	63.56 (25.32)	0-100
Emotional functioning (%)	60.14 (26.98)	0-100
Social Functioning (%)	71.48 (27.62)	0-100
Cognitive functioning (%)	81.06 (19.36)	35-100
Communication (%)	71.36 (27.52)	0-100
Worry (%)	65.70 (25.33)	10-100
Family Functioning Total (%)	**64.75 (26.78)**	**4.17-100**
Daily activities (%)	69.72 (25.35)	8.33-100
Family relationships (%)	59.79 (35.43)	0-100
PedsQL-FIM Total (%)	**67.85 (19.09)**	**23.54-100**

*HRQOL – health related quality of life

On the PedsQL-FIM, the parents reported a mean total score of 67.85% (SD: ±19.09). A maximum score of 100% indicates that the parent's quality of life was not affected by the child's injury and/or disability. The results indicate that the parent's HRQOL had been affected to some degree. On the Parents HRQOL subscale and the Family Functioning subscale the parents reported mean totals of 69.06% (SD: ±20.44) and 64.75% (SD: ±26.28) respectively. Both parent and family function had been impacted by the child's injury and/or disability with the

family function being slightly more impacted. The parents scored the worst on the emotional functioning (mean: 60.14, SD: ±29.98) and the best on the cognitive functioning subscale of the HRQOL (mean: 81.06, SD: ±19.36). Family relationships were the most affected by the TBI (mean: 59.79, SD: ±35.43) on the Family Functioning subscale.

4.12 RELATIONSHIP BETWEEN OUTCOMES

The next set of statistics explores whether there are significant relationships between clinical and demographic data (independent variables) on functional outcome and type of injury (dependant variables). Table 4.21 will explore correlations between several variables.

Table 4.21: Factors affecting outcome.

	GMFCS	**GMFM-88**	**MABC-II**	**Sex**	**Type of TBI**	**Type of associated injuries**	**GCS**
GCS	**-0.60 (p<0.00) ****	**0.43 (p<0.00) ****	**0.55 (p<0.00) ****	4.95 (p<0.08) **	**29.92 (p<0.00) ***	**52.80 (p<0.00) ***	
Sex	-0.06 (p<0.58) **	-0.01 (p<0.91) **	-0.08 (p<0.51) **		7.18 (p<0.42) *	**12.15 (p<0.03) ***	4.76 (p<0.09) *
Age group	-0.13 (p<0.24) *	0.21 (p<0.08) **	0.11 (p<0.35) **	0.55 (p<0.74) *	**28.28 (p<0.01) ****	15.50 (p<0.22) *	4.98 (p<0.30) *

*comparison was significant at the 0.05 level.
**comparison was significant at the 0.01 level.

Table 4.21 depicts that the Pearson correlation coefficient revealed a strong correlation between the GCS score to the three primary motor outcome measures: the GMFCS, GMFM-88 and the MABC-II at three-month follow-up. The significant negative relationship between GCS scores and the GMFCS level (r (71) = -0.60, p<0.00, correlation is significant at the 0.01 level) at three months indicates that the lower the GCS score (the more severe the TBI), the higher the GMFCS level at three months, (the more motor disability the child had as a result of the injury). The significant positive relationships between the GCS score and the GMFM-88 (r (71) = 0.43, p<0.00, correlation is significant at the 0.01 level) and MABC-II (r (71) = 0.55, p<0.00, correlation is significant at the 0.01 level) at three-month follow-up indicates that the higher the GCS score, (the more mild the TBI), the higher the GMFM-88 and MABC-II scores at three months (the less motor disability present).

The Fishers Exact Test also revealed significant correlations between GCS score and the types of TBI as depicted in Table 4.22. The statistical significance (ρ=29.92, $p<0.00$, correlation is significant at the 0.05 level) indicates a relationship between the type of TBI and the severity of the TBI. The children that had mild head injuries generally had a diagnosis of unclassified head injury on admission (42.86%) followed by a diagnosis of nothing abnormal detected on computed tomography of the brain (CTB) (23.81%). Children that had a diagnosis of multiple types of TBI were more likely to sustain a lower GCS score and thus a more moderate (2.38%) or severe (3.57%) type of TBI. However, a diagnosis of 'multiple' did not necessarily indicate a more moderate or severe TBI and even children (5.95%) who sustained 'multiple' TBI's could have a high GCS level, or rather a mild injury. Thus, although there is a correlation between GCS level and type of TBI, it is not absolute.

There were no significant correlations between sex and motor outcome at three month follow-up as demonstrated by the Point Biserial Correlation test. There were also no significant correlations between sex and the type of TBI sustained or sex and the initial GCS score as demonstrated by the Pearson Chi Square test. However, the Fishers Exact Test revealed a statistically significant (ρ=12.15, $p<0.03$, correlation is significant at the 0.05 level) relationship between sex and the type of associate injuries with males demonstrating more associated injuries compared to females.

Table 4.22: Relationship between GCS score and type of TBI

	Mild (GCS 13-15) (n=71)	**Moderate (GCS 9-12) (n=6)**	**Severe (GCS 3-8) (n=7)**
Type of TBI			
Unclassified head injury (%)	42.86	0	0
Nothing abnormal detected on CTB (%)	23.81	2.38	2.38
Subarachnoid haemorrhage (%)	1.19	1.19	1.19
Intracranial haemorrhage (%)	0	0	1.19
Pneumocephalus (%)	3.57	0	0
Haematoma (%)	7.14	1.19	0
Multiple (%)	5.95	2.38	3.57

n=number of participants

CTB= Computed Tomography of the Brain

Table 4.23: Relationship between GCS score and type of TBI present in the multiple TBI diagnosis (n=10)

	Mild (GCS 13-15) (n=10)	**Moderate (GCS 9-12) (n=10)**	**Severe (GCS 3-8) (n=10)**
Multiple TBI			
Subarachnoid haemorrhage (n=6)	2	1	3
Pneumocephalus (n=4)	3	1	0
Haematoma (n=4)	2	1	1
Epidural haematoma (n=4)	3	1	0
Base of skull fracture (n=2)	1	0	1
Diffuse axonal injury (n=1)	0	0	1
Intracranial haemorrhage (n=3)	0	1	2

n=number of participants

Table 4.23 reveals the breakdown of the types of TBI present in the participants (n=10) that had a diagnosis of 'multiple' TBI to determine if there is a significance between the types of TBI present in a 'multiple' diagnosis and TBI severity. The presence of an ICH, diffuse axonal injury (DAI) and subarachnoid haemorrhage (SAH) appears to be indicative of more moderate and severe TBI whereas the presence of a pneumocephalus and EDH are indicative of a mild TBI.

Table 4.24: Relationship between GCS score and associated injuries

	Mild (GCS 13-15) (n=71)	**Moderate (GCS 9-12) (n=6)**	**Severe (GCS 3-8) (n=7)**
Associated injuries			
None (%)	14.23	0.0	0.0
Fractures (%)	2.38	0.0	0.0
Soft tissue injuries (%)	50.0	1.19	2.38
Fractures, soft tissue injuries and medical & surgical (%)	2.38	0.0	3.57
Fractures and soft tissue injuries (%)	15.48	4.76	0.0
Soft tissue injuries and medical & surgical (%)	0.0	0.0	1.19
Fractures and medical and surgical (%)	0.0	1.19	1.19

n=number of participants

The Pearson's Chi-Squared test revealed a statistically significant correlation between GCS score and associated injuries ($X^2_{\ 2} = 52.80$, $p<0.00$, correlation is set at the 0.05 level) as depicted in table 4.22. Participants with no associated injuries had more mild TBI compared to those that had associated injuries in combination with a traumatic brain injury. The more types of associated injuries present, the more severe the traumatic brain injury. Medical and surgical injuries were more likely to be associated with more severe TBI.

Table 4.25: Relationship between age group and type of TBI

	3-6 years (n=46)	7-9 years (n=31)	10-12 years (n=7)
Type of TBI			
Head injury on admission (%)	58.3	41.7	0.0
Nothing abnormal detected on CTB (%)	66.7	25.0	8.3
Multiple (%)	30.0	40.0	30.0
Subarachnoid haemorrhage (%)	33.3	66.7	0.0
Intracranial haemorrhage (%)	0.0	0.0	100.0
Pneumocephalus (%)	100.0	0.0	0.0
Haematoma (%)	28.6	57.1	14.3

n=number of participants

CTB= computed tomography of the brain

Table 4.25. reveals a statistically significant correlation between age group and type of TBI ($X^2_2 = 28.28$, $p<0.01$, correlation is set at the 0.01 level) as determined by the Pearson's Chi-Squared test. All of the participants in the 10-12 age group were admitted with head injuries that warranted a CT brain. The majority of the types of TBI in this age group were proportionally more severe (multiple types and ICH) compared to those sustained in the younger age groups.

Table 4.26: Relationship between sex and associated injuries

	Male (%)	**Female (%)**
Associated Injury		
None (n=12)	100.0	0.0
Fractures (n=2)	100.0	0.0
Soft tissue injuries (n=45)	60.0	40.0
Fractures, soft tissue injuries and medical & surgical (n=5)	60.0	40.0
Fractures and soft tissue injuries (n=17)	76.5	23.5
Soft tissue injuries and medical & surgical (n=1)	100.0	0.0
Fractures and medical and surgical (n=2)	50.0	50.0

n=number of participants

The Fishers Exact Test revealed a statistically significant correlation between the sex of the participants and the type of associated injuries ($\rho = 12.15$, $p<0.03$, correlation is set at the 0.05 level) as depicted in table 4.26. Every female participant (n=30) had a TBI and an associated injury. Males had a larger percentage of associated injuries compared to females.

4.12.1 CORRELATIONS BETWEEN GMFM-88 SCORES OF INDIVIDUALS WITH AND WITHOUT ASSOCIATED INJURIES AT DISCHARGE AND AT THREE MONTHS

A MANOVA test was used to determine if there is a statistically significant difference between both GMFM-88 scores of individuals at discharge and at a three-month follow-up as well as to compare those individuals with an isolated TBI and those with an associated injury and if there was a statistically significant difference between the scores of both groups at discharge and at three-month follow-up. The MANOVA test revealed a statistically significant relationship ($F_{5,1}$= 6.45, p<0.00) between the above variables, with individuals in both groups that have demonstrated improved GMFM-88 scores at the three-month follow-up compared to discharge. The individuals with an isolated TBI had higher scores at discharge and at three-month follow-up compared to individuals that had a TBI and an associated injury. Of the participants that had TBI and associated injuries, the participants with multiple injuries (fractures, STI and M&S) performed the worst at both discharge and at three months.

4.12.2 CORRELATIONS BETWEEN MABC-II SCORES OF INDIVIDUALS WITH AND WITHOUT ASSOCIATED INJURIES AT DISCHARGE AND AT THREE MONTHS

A MANOVA test was also used to determine if there is a statistically significant relationship between MABC-II scores of individuals with an isolated TBI and the MABC-II scores of individuals with a TBI and an associated injury and if there was a statistically significant difference between the scores of both groups at discharge and at three-month follow-up. The MANOVA test revealed a statistically significant relationship ($F_{5,1}$= 4.67, p<0.00) between the above variables, with individuals in both groups displaying improved MABC-II scores at the three-month follow-up compared to discharge. The individuals with an isolated TBI had higher scores at discharge and at the three-month follow-up compared to individuals that had a TBI and an associated injury.

4.13 SUMMARY OF RESULTS

- There was a statistically significant difference between the GMFCS levels, the GMFM-88, and the MABC-II scores of the participants at discharge and at three-month follow-up, with the majority of the sample demonstrating an improvement in motor function.

- The majority of the participants were independent at the three-month follow up in the home, community, and social setting. The primary caregiver's health related quality of life and family functioning had been impacted by the TBI.
- Lower GCS scores (i.e., more severe TBI) was associated with higher GMFCS levels and lower GMFM-88 and MABC-II scores at three months.
- Higher GCS scores (mild TBI) were associated with diagnosis of unclassified head injury on admission and NAD and lower GCS scores (moderate/severe TBI) were linked to a diagnosis of 'multiple' types of TBI.
- Males had a higher percentage of associated injuries compared to females.
- There were no significant correlations between age group on GCS score, type of associated injury, GMFCS level, GMFM-88, and MABC-II scores at three months.
- Participants that sustained a TBI in isolation had better GMFM-88 and MABC-II scores at discharge and at three-month follow up compared to those individuals that had a TBI and an associated injury.

4.14 CONCLUSION

In conclusion, more males sustained TBI's compared to females. The primary mechanism of injury was a type of RTA. The majority of participants were in the three to six age group and the majority of TBI's were classified as mild. Most TBI's had an accompanying associated injury. There was a statistically significant difference between the GMFCS levels, the GMFM-88, and the MABC-II scores of the participants at discharge and at three-month follow-up, with the majority of the sample demonstrating an improvement in motor function. The main factors that demonstrated statistically significant relationships were the GCS level and the primary motor outcome measures, the GCS level, and the type of TBI and the GCS level and the type of associated injuries. There was also a statistically significant relationship between the sex of the participants and the type of associated injuries as well as the age group and type of TBI. The majority of the participants were independent at three-month follow up in the home, community, and social setting. The primary caregiver's health related quality of life and family functioning had been impacted by the TBI. Interpretation and discussion of the findings will now follow in chapter five.

CHAPTER FIVE – DISCUSSION

5.1 INTRODUCTION

This research study set out to investigate the recovery of early motor function in children and adolescents aged three to twelve years old with a traumatic brain injury. The study included two assessment points, which were at discharge from hospital and at three months post discharge. This chapter serves to interpret and discuss the results of the present study. Clinical implications, limitations of the study and suggestions for future research will also be discussed.

5.2 GENERAL

The study included children and adolescents who were admitted to CHBAH with a diagnosis of a TBI, however, the inclusion was not limited to children with isolated TBI and included children with associated injuries. This TBI cohort was heterogeneous and included participants with mild, moderate, and severe head injuries. The heterogeneity of the sample is consistent with other research studies that also focused on motor outcomes post paediatric and adolescent TBI (Stephens et al., 2017, Buitendag et al., 2017).

5.3 DEMOGRAPHICS

This section will report and analyse the results that relate to the sex, age, and socio-economic status.

5.3.1 SEX

Males (64.3%) were the predominant sex compared to females (35.7%). The results are suggestive that males in the three to twelve age group, are at a higher risk for sustaining a TBI compared to females. The findings are consistent with the literature (Chaplin et al., 1993, O'Flaherty et al., 2000, Haley et al., 2003, Kuhtz-Buschbeck et al., 2003a, Willer et al., 2004, Kozlowski et al., 2007).

There are several potential reasons as to why males are more prone to sustaining a TBI compared to their female counterparts. Males generally engage in riskier behaviour, have higher activity levels and tend to behave with greater impulsivity compared to girls (Udry, 1998). Moreover, there is different socialization of sons and daughters. Parents are less likely to

restrain exploratory play and behaviour of boys compared to girls. Boys are often allowed to roam further away from home than the same-age girls and are often given more opportunities to play alone with less direct supervision. This further increases their risk of injury (Morrongiello and Rennie, 1998). The higher likelihood of males sustaining a TBI is not conducive to the fact that the male brain develops at a slower pace than females (Gogtay et al., 2004, Anderson et al., 2011).

5.3.2 AGE

The majority of the sample consisted of children in the three to six age group (54.8%), followed by the seven to nine age group consisting of 36.9% of the sample. The ten to twelve age group only comprised of 8.3% of the sample. It is important to note that the Paediatric Surgery Department at CHBAH did not consistently admit children older than 11 years into the Paediatric unit. They were often diverted to and managed by adult trauma and therefore many suitable participants of this particular age group were not identified by the researcher. This means that the percentage of participants identified in the 10-12 age group is likely not an accurate representation of this age group within this sample.

However, the fact that the majority of the sample were in the younger age group is consistent with the anatomical and physiological design of the younger child which predisposes them to sustaining a TBI (Kannan et al., 2014). The anatomy of the young child both heightens the chances of a head injury and is poorly designed to cushion the impact. The young child's head is disproportionally large compared to the body causing a higher centre of gravity. This high centre of gravity results in the child 'leading with his or her head' whether it be in a fall or in a motor vehicle accident. The thin scalp, increased skull pliability and decreased myelin content provide poor cushioning for the brain to absorb impact forces. Moreover, younger children have lower blood pressure (BP) and intracranial pressures (ICP) compared to older children and adults. This results in significant adverse effects with even the slightest increase in pressure predisposing the child to secondary brain injury such as oedema or ischaemia (Figaji, 2017).

Although the younger age groups may have a higher predisposition to sustaining a TBI and consequently a higher number of hospital admissions, a substantial portion of the head injuries sustained are minor (Langlois et al., 2006). Conversely, the older age groups tend to have fewer hospital admissions but they tend to be admitted with more moderate to severe TBI's (Huelke, 1998). The results of the study are supportive of the above as they demonstrate that only 13% of the children in the three to six age group and only 5.55% of children in the seven to nine age

group were admitted with moderate to severe TBI's, whereas 42.86% of the admissions in the 10-12 age group were classified as moderate or severe.

5.3.3 SOCIO-ECONOMIC DEMOGRAPHICS

The socio-economic profiles of the study's children and adolescents reveal a low socio-economic status (SES). The three dimensions that typically characterize socio-economic status are employment, money, and education. Most children and adolescents are growing up in single parent households (70.2%) with the majority of the primary caregivers being unemployed (57.1%) and receiving social grants (77.4%). Furthermore, only 32.1% of the primary caregivers have matric certification and only 8.4% have furthered their studies (either a diploma or tertiary education). The deficit in education reduces job opportunities which are already scarce in a population that is struggling with a 39.5% unemployment rate (StatsSA, 2019).

The home and environment plays a vital role in typical brain development (Anderson et al., 2011). The immature CNS has the intrinsic property of neural plasticity which is reliant on environment and experience to nurture its development (Anderson et al., 2011). Based on the physiology of normal brain development, a 'typically' developing child growing up in an underprivileged circumstance is often deprived of enriched environments needed to maximise and nurture brain maturity. Growing up in a household where there is poor education, unemployment and a scarcity of monetary resources (low SES), places a normal developing child at a disadvantage with respect to brain development which could impact a child with a traumatic brain injury.

A brain injury that occurs in an immature CNS allows for a 'window of opportunity' to maximise recovery depending on the developmental stage and age of the child (Kolb et al., 2000a). In order to maximise this 'window of opportunity' a child needs to be provided with sufficient prospects that will positively modulate the neural circuits. A child growing up in a poor socio-economic demographic may miss or underutilize this 'window of opportunity' owing to inaccessibility to appropriate healthcare and rehabilitation services. Research has demonstrated that children with severe TBI's growing up in disadvantaged backgrounds with limited access to appropriate resources have significantly greater impairment and slower recovery compared to those of better SES (Taylor et al., 2002).

With regards to the *recovery continuum model* proposed by Anderson et al., 2011, factors such as the environment, family function, socioeconomic status, and demographics are some of the key factors influencing a child's recovery post early cerebral insult. A child growing up in a

household of poor SES does not only have to contend with the adverse effects of the injury itself but the direct negative impact that the situation has on the recovery. A lack of funds affects the primary caregiver's ability to travel to and from the hospital to provide the necessary support to the child in the acute recovery stage and the ability to bring the child to the hospital for follow-up consultations and therapy in the sub-acute and chronic phases. I experienced these difficulties first-hand when the participants needed to return to CHBAH for the three-month follow-up appointment. The follow-up often had to be rescheduled owing to insufficient transport funds. The return for follow-up increased when I started taking an additional contact person's details (and not only that of the primary caregiver) for every participant prior to discharge from hospital. The second contact was often that of a family member or friend who assisted with financial support for transport which was reimbursed at follow-up as a component of the research study. However, a general follow-up consultation has no financial reimbursement. Therefore, the child may often miss the vital and scarce consultation or therapy service due to transport constraints.

Furthermore, the catchment area in which a child resides determines the allocation of rehabilitation services. Should the local clinic be understaffed and lack resources or equipment such as wheelchairs and standing frames, the child's recovery is further disadvantaged. In Gauteng, Tshwane Rehabilitation Centre is currently the only step-down State facility that caters for paediatric neurorehabilitation – of which TBI's are not the only condition requiring such services. Based on the low results of the SES component in the study, it would seem that the home environments of the majority of children are not conducive to receiving home based therapy services. Home based care is a scarcity within the South African medical care setting owing to a lack of resources. Therefore for individuals to receive such care often requires financial input from the families. The rate of unemployment of this sample is suggestive that such finances are not readily available. Thus, it is evident that there is limited availability and accessibility to rehabilitation care for the children in this study.

The level of education of the primary caregiver may also have a direct impact on the recovery of the child. A poorly educated caregiver may not fully understand or comprehend the child's injury and what is required to assist with optimizing recovery. Moreover, it has been reported that children growing up in poor socio-economic households with unemployed and uneducated mothers have a higher chance of sustaining a severe TBI. Thus, the poor SES of the child does not only provide a barrier to recovery, but it also predisposes a child to sustaining a TBI (O'Flaherty et al., 2000).

In the early recovery phases post TBI and for the small percentage of children that remain with permanent disabilities, the caregiver may need to provide full time care to aid the recovery process. This may mean surrendering a job and earning vital wages which deepens the poverty and unemployment trap of the population. It is unlikely, based on the SES statistics of the sample, for the primary caregivers to afford a full-time carer. The primary caregiver has to stay at home and care for the disabled child. This idea is complex as 88.1% of the primary caregivers in the study had multiple dependants (Table 4.2). Unemployment, poverty and taking care of a disabled child is likely to have a negative impact on the emotional, physical, and mental well-being of all the family members involved. Such a scenario is prone to place additional strain on family functioning and dynamics in families that are already facing tremendous challenges.

It was positive to discover that all eleven official languages of South Africa were represented in this demographic. This indicates the diversity of the population group studied. This information increases the relevance of this research and emphasises the strength of the sample size and the likelihood of it being a reliable representation for the greater Gauteng demographic relying on state services.

5.4 CLINICAL FINDINGS

This section will focus on the clinical findings of the study and will include an analysis of the mechanism of injury, TBI severity, the most common types of TBI, the presence of associated injuries and the medical management.

5.4.1 MECHANISM OF INJURY

Blunt force trauma accounted for 100% of the traumatic brain injuries. Road traffic accidents (RTA) accounted for the majority (67.1%) of TBI's, where the participants were either pedestrians (54.12%) or passengers (12.94%). These findings are consistent with data from Africa (Udoh and Adeyemo, 2013) and South Africa (Schrieff et al., 2013, Buitendag et al., 2017). Similarly, the findings are consistent with data from other countries where an RTA primarily results in a larger percentage of moderate and severe TBI's (Chaplin et al., 1993, Dumas et al., 2002, Haley et al., 2003, Kuhtz-Buschbeck et al., 2003b, Caeyenberghs et al., 2009).

The minibus taxi is the primary mode of transport for 86.9% of the participants. It is the most affordable and accessible means of transportation to the larger population yet travelling via a taxi vehicle (resulting in an MVA) or living in an area where there is a high saturation of taxi

vehicles (resulting in a PVA) may predispose the children of this particular demographic to sustaining a TBI via an RTA. Minibus taxis are not required to travel with car seats and there is poor enforcement of individuals to be restrained. Most children travel on the lap of an adult so as to maximize persons per seat. As mentioned above, it is critical that a child is appropriately restrained in a vehicle owing to the anatomical and physiological design of the young child as the head is the primary target for injury in the event of an RTA. The majority of TBI's in the three to six age group were caused by a type of RTA (60.87%), specifically a PVA (54.35%). This is likely due to the younger children of this demographic being poorly educated on road safety along with the high saturation of minibus taxis on the roads and pavements within the catchment area of the study.

The findings of this study contrast those from high income countries which report falls as the predominant mechanism of injury in the younger age groups (Andersson et al., 2012, Thurman, 2014, Olsen et al., 2019) and a decline in RTA's as a primary cause of TBI (Brazinova et al., 2016). The comparison highlights how different demographics effect the aetiology of injury. It also highlights that South Africa desperately requires the implementation of legislative changes and educational programmes to reduce the elevated risk of road related traumatic brain injuries. Improved road safety regulations will assist in decreasing the burden on our hospitals, considering that the majority of TBI's were caused by a type of road related incident. Furthermore, the statistics highlight the need for safer places for children in these areas to play, such as fenced parks, in order to prevent them from playing in the dangerous streets.

5.4.2 TBI SEVERITY

The Glasgow Coma Scale (GCS) was the primary tool to classify the TBI severity in this population. It is used by all emergency personnel and services within South Africa as a means of TBI classification. The GCS is prominent in the literature because it is the most widely used tool to classify TBI severity (Ghaffarpasand et al., 2013). In this sample, the majority (84.5%) of participants were classified as sustaining a mild traumatic brain injury (MTBI), 7.1% were classified as moderate and 8.3% were classified as severe. The mean GCS score of the sample was 13.49 (SD: ±2.4), indicating MTBI. The results are consistent with global findings with MTBI accounting for more than 80% of all worldwide head injuries in children and adolescents (Yeates, 2010). The participant's initial GCS score was reliant on either the EMS or medical professionals and not the researcher herself. There were some irregularities noted in the recording of the GCS scores. For example, it would be recorded that a child has a loss of consciousness at the scene of the accident, yet the child would have still been given a score of

15 on the GCS. Because there is a range of at least three points per TBI classification, the inaccuracies were unlikely to be of great enough variance to alter classifications. Hence, the irregularities noted were unlikely to have significantly affected the results and were deemed negligible.

5.4.3 MOST COMMON TYPES OF TRAUMATIC BRAIN INJURY

The type of TBI was determined either by the admission diagnosis or the CT brain (CTB) results (where available). Unclassified head injury (42.9%) was the most common and was diagnosed without a CT brain. A CTB was performed on 57.1% (n=48) of the sample. The following types of TBI were the most represented on CTB (in descending order): Nothing abnormal detected (50%), haematoma (25%), multiple (20.83%), subarachnoid haemorrhage (18.75%), pneumocephalus (6.25%) and an intracranial haemorrhage (2.08%). The patterns of TBI observed in this study are consistent with the literature for the following reasons:

Half the sample that had a CTB were diagnosed with nothing abnormal detected which is consistent with poor sensitivity of a CT brain to the microstructural changes that occur in a TBI, particularly those present in a MTBI (Cameron et al., 2006, Eierud et al., 2014). In the study sample, 76.92% of all fractures were skull fractures. This is consistent with the anatomical makeup of the pliable paediatric skull which predisposes it to fractures, making it a common injury type in this population group (Singh et al., 2016). An EDH was only present in 4.76% of the sample. The relatively small percentage is further consistent with the anatomical structure of the young brain in which an EDH is rarely seen owing to the strong adhesion of the dura mater to the inner surface of the skull (Araki et al., 2017). When an EDH is present, it is often in conjunction with a skull fracture (Araki et al., 2017) which was the case in this study sample in which every participant with an EDH also had an accompanying skull fracture. Four of the nine participants (44.44%) that had a SAH on CTB, had GCS scores of eight or below. These results are consistent with Hochstadter et al. (2014) who reported that a SAH was present in almost half of their study sample and its presence was indicative of TBI severity. A haematoma was fairly well represented in the sample and is supportive of the literature that suggests that this type of injury is relatively common in paediatric TBI (Figaji, 2017). Interesting to note, every child with an intracerebral haemorrhage on CTB (n=4), either had a severe TBI (n=3) or a moderate TBI (n=1). This is consistent with this type of injury involving damage to the white matter, basal ganglia and/or cerebellum and its presence often results in neurological deterioration (Araki et al., 2017). Moreover, when a pneumocephalus was present (n=6) it was

always accompanied by a skull fracture. This pattern of injury is consistent with the most common etiology of this type of TBI (Dabdoub et al., 2015).

5.4.4 ASSOCIATED INJURIES

Associated injuries were present in 86.9% of the sample. Soft tissue injuries were the most common and occurred in 61.6% of participants. Twenty-six participants (35.62%) sustained a fracture. Fractured body regions that were most likely to affect functional outcome (particularly at discharge) included: the upper limb, lower limb, and pelvis. Fractures in these areas would have contributed to limitations in motor function owing to weight bearing restrictions, limb immobilization and pain. Of the nine participants that sustained multiple fractures, three had fractures in either the upper limb (n=1), lower limb (n=1) or a combination of a pelvic and upper limb fracture (n=1). Therefore, 9.52% (n=8) of the entire sample (n=84) sustained fractures in primary 'areas of interest'. Soft tissue injuries in 'areas of interest' could have also contributed to limitations in motor function at hospital discharge. Soft tissue injuries in 'areas of interest' were represented as follows: 15.48% of the sample had soft tissue injuries of the lower limbs, 13.1% had soft tissue injuries of the upper limbs and 8.33% had soft tissue injuries of the pelvis. As with fractures these injuries may have contributed to the poor gross motor function of the participants, particularly at discharge.

5.4.5 MEDICAL MANAGEMENT

The average length of hospital admission was 6.51days (SD: ±10.64). The majority of participants (86.9%) were admitted primarily for neuro-observation with only four participants requiring ICU admission. This is consistent with other research studies and appears to support the notion that CHBAH has similar MTBI protocols to those in high-income countries such as those in the Montreal Children's Hospital, McGill University Health Centre, Montreal, QC (Gagnon et al., 2004). Many of the studies did not record the average length of hospital stay, but rather the average length of time that the child was in an inpatient rehabilitation centre making it is difficult to obtain comparative data (Dumas et al., 2002, Haley et al., 2003, Kuhtz-Buschbeck et al., 2003a).

The four children that were admitted to the paediatric ICU all sustained a severe TBI. Their medical management was consistent with those described in the literature. All four children were placed on neuroprotective ventilation with a SD of ±16.07 hours (range: 0-120) as a means of improving compliance with mechanical ventilation, reducing metabolic demand and eliminating shivering (Araki et al., 2017). An ICP monitor was inserted in two of the

participants (50%) that required ICU care as it is currently the only scientifically proven method of monitoring raised intracranial pressure in children with severe TBI (Alali et al., 2015). For the majority of the participants with moderate and severe TBI's mannitol and hypertonic saline were used to control intracranial pressure and hypovolemia (Kannan et al., 2014). Anti-epileptics were also given to a substantial portion of the TBI patients (21.4%) and was administered to every child in the sample with a GCS score of eight or less. This management is consistent with the paediatric physiology in which children have lower seizure thresholds and are at higher risk of early seizures compared to adults. The immediate administration of anticonvulsants particularly in children with severe TBI is therefore critical to prevent secondary brain damage (Kannan et al., 2014). Hypothermia has also proven to be effective in lowering ICP in paediatric patients but this therapeutic modality is not routinely used at CHBAH for paediatric TBI and none of the participants received this treatment (Araki et al., 2017).

Moreover, most of the fractures (80.77%) and soft tissue injuries (95.71%) were managed conservatively. None of the 23.81% of skull fractures needed surgical management which is consistent with the fact that the majority of paediatric skull fractures heal without intervention (Arrey et al., 2015), provided soft tissue does not disperse between the fractured edges interfering with bone healing and skull fusion (Singh et al., 2016). Paediatric fractures (provided they do not extend into the growth plate) generally heal rapidly owing to the paediatric skeletons unrivalled capacity for remodelling, hence the majority of fractures in this study sample did not require surgical intervention (Bryson et al., 2016).

5.5 MOTOR OUTCOMES

5.5.1 INTRODUCTION

The early motor function of children and adolescents with a TBI is the focal outcome of this study. This section analyses the results demonstrated in chapter 4 for the three primary motor outcome measures – the GMFCS, the GMFM-88 and the MABC-II. This section will briefly discuss the three primary outcome measures; the results obtained at hospital discharge for each measure and then compare them to the results identified three months later. The results will be critically explored and analysed, compared to prior relevant research and appropriate conclusions will be deduced.

5.5.2 THE GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM

The GMFCS is a standard classification scale that ranges from one to five in severity. The GMFCS has been standardized with a focus on the Cerebral Palsy (CP) population in which a child is likely to have varying degrees of overt gross motor deficits. Thus, every level on the GMFCS includes *some* difficulty in ambulation. In this study, the classification system was used primarily as an outcome measure for gross motor improvement. The degree of change amongst the five levels of the GMFCS at the three-month period was taken to provide an indication of gross motor recovery within this particular sample. Owing to the rapid recovery in the first few months post TBI (Kuhtz-Buschbeck et al., 2003a), it was unlikely for the participants to remain within one level throughout the acute and subacute recovery stage. The changes noted on the GMFCS between discharge and follow-up would thus provide an indication of gross motor function improvement. However, most participants within the study sustained a MTBI and the injury did not cause motor deficits severe enough to render them a classification on the GMFCS as per the GMFCS guidelines. Therefore, a level *nought* was introduced by the researcher and it indicated that the participants did not have obvious issues in ambulation post their cerebral insult.

5.5.2.1 GMFCS AT DISCHARGE

The data in this study suggests that the children were either discharged as independent in ambulation or the children required a fairly high degree of physical assistance, likely a wheelchair, for ambulation. The GMFCS, similar to some of the outcome measures used in other studies (GMFM, PEDI) does not look at the quality of the ambulation, but rather the child's ability to ambulate (Haley et al., 2003, Kuhtz-Buschbeck et al., 2003a). Owing to the fact that the majority of this sample sustained a mild TBI, it is understandable that overt motor issues such as ambulation were not present at hospital discharge. Thus, an outcome measure such as the MABC-II was implemented in order to detect the subtle motor impairments present in this population group. Nevertheless, the findings are similar to other studies in which the recovery of walking is on the high end, even in children and adolescents that sustain a severe TBI (Haley et al., 2003). In the study conducted by Haley et al, (2003), there was a high reported rate of ambulation recovery of 70% post severe TBI (although this was at discharge from a rehabilitation centre and should be taken into account). The definition of walking in this study is similar to that of the GMFCS, in that it is on a basic level and it focuses on the child's ability to ambulate with or without assistance of any kind. Moreover, in a study conducted by Kuhtz-

Buschbeck et al., 2003a, which consisted of children with moderate to severe TBI's, most of the gait changes took place within the first two months post injury. The results of this particularly study are suggestive that the child's ability to ambulate recovers fairly quickly post TBI and after five months of in-patient rehabilitation, most gait variables were within the range of the control values by Kuhtz-Buschbeck et al., 2003a).

5.5.2.2 GMFCS AT THREE-MONTH FOLLOW-UP

There was a statistically significant improvement ($p<0.00$) in the GMFCS levels of the participants. The GMFCS levels ranged from nought to two (median:0.00; SD: 0.41), with only three participants (4.23%) scoring a level two and the remaining 68 participants (95.77%) scoring a level nought. The results indicate that during the three-month follow-up period, only 4.23% of the sample did not return to independent ambulation. Of the three participants that did not regain independent ambulation, two of them had a severe TBI with initial GCS scores of three and five respectively and the third had a moderate TBI with an initial GCS score of 11. Furthermore, the participant with a moderate TBI had also sustained a femur fracture which could have contributed to their ambulatory difficulties at the three-month mark. The presence of lower limb injuries contributing to slower ambulatory recovery in children and adolescents with TBI is consistent with the literature (Haley et al., 2003). The high proportion of participants improving in ambulatory function is consistent with prior research even in the studies that focused solely on moderate and severe TBI's (Di Scala et al., 1992, Emanuelson et al., 1996, Rossi and Sullivan, 1996, O'Flaherty et al., 2000, Haley et al., 2003, Kuhtz-Buschbeck et al., 2003b, Caeyenberghs et al., 2011). None of the studies reviewed used the GMFCS as an outcome measure therefore no direct comparisons can be deduced. However, this study revealed that the GMFCS showed statistically significant improvements with time and was sensitive to detecting changes. It could possibly be considered as a quick easy screening system for gross motor function in future research.

5.5.3 GROSS MOTOR FUNCTION MEASURE

The GMFM-88 was administered to all participants at discharge and at three-month follow up. It was used to determine the effects of TBI on gross motor function in the paediatric and adolescent population. This measure was useful for detecting gross motor function in the moderate and severe TBI population group and those children with associated injuries which were hindering their physical function such as an upper or lower limb fracture. The GMFM-88 does not focus on the quality of the function but rather on the ability of a child to perform a specific function (Linder-Lucht et al., 2007). The inclusion of this measure was beneficial as it

was sensitive to change in physical function on a more basic motor skill level such as lying and sitting (Russell et al., 2000).The dimensions of the measure also span to incorporate complex gross motor skills like running and jumping (Russell et al., 2000). The inclusion of this measure was necessary because it allowed for the inclusion of participants with more complex injuries, and it was sensitive to their improvements over time. Outcome measures similar to the GMFM-88, such as gait analysis, that focused on more natural motor behaviour as opposed to probing maximum speed and precision have been used in previous studies and have proven to be effective in tolerating greater variations in motor performance (Dumas and Carey, 2002, Haley et al., 2003, Kuhtz-Buschbeck et al., 2003a, Kuhtz-Buschbeck et al., 2003b).

5.5.3.1 GMFM-88 AT DISCHARGE

At discharge from hospital the mean total score on the GMFM-88 was 93.2% (SD: ±18.04), with a range of 23-100 (%). The participants scored the lowest in Dimension E (87.5%) which consists of walking, running, and jumping and scored the highest in Dimension A (99.07%) which consists of lying and rolling. Therefore, the participants performed the worst in the tasks that required more complex gross motor function. The findings are consistent with prior research where participants with a TBI struggled to perform more complex motor tasks in the acute phase of a TBI (O'Flaherty et al., 2000, Gagnon et al., 2004, Howell et al., 2014, Stephens et al., 2017).

5.5.3.2 GMFM-88 AT THREE-MONTH FOLLOW-UP

There was a statistically significant difference ($p<0.00$) between the GMFM-88 scores of the participants at discharge and at three-month follow up. The mean total GMFM-88 score had improved to 99.38% (SD: ±2.62) with a range of 84-100 (%). There was a 6.18% improvement over the three -month recovery period. All of the participants (n=71) scored 100% on two of the dimensions (Dimension A and B) at the three-month follow-up. These dimensions measure an individual's function in lying and rolling (Dimension A) and sitting (Dimension B). This highlights that none of the participants had difficulty in these motor skills. The greatest progress occurred in Dimension E (walking, running, and jumping) which improved by 10.61% to a mean total score of 98.15% at three-month follow-up. The results are consistent with a study conducted by Kuhtz-Buschbeck et al. (2003a) where most of the advances were made in Dimensions D and E respectively. It is interesting to note that the children in the aforementioned study made advances after a five -month interval of in-patient rehabilitation, compared to the children in this research study. Fifteen percent of the sample in the Kuhtz-Buschbeck et al. (2003a) study attained maximum GMFM-88 scores at the first assessment. The first assessment

was on admission to a rehabilitation unit and equated to roughly three months after the initial injury. Conversely, in this study, 77.5% of the participants attained perfect scores on the GMFM-88 at three months (i.e., at the same time point). The Kuhtz-Buschbeck et al. (2003a) study only included children that had moderate to severe TBI, whereas the present study also included mild TBI which could account for the comparably larger percentage of children attaining perfect GMFM-88 scores after three months. The results are thus suggestive of children and adolescents with MTBI having fewer gross motor problems compared to children with moderate and severe TBI at three months' post TBI. Nonetheless, without separating the participants of this study into their appropriate type of TBI classification, the mean scores indicate that on a whole the participants of this study had minimal loss of gross motor function three months after a TBI. Dahl and Emanuelson (2013) reported similar findings in which the participants did not differ in motor proficiency compared to controls at three to six months post TBI. The fact that so many achieved 100% also points to the fact that the GMFM-88 has a low ceiling, and a more challenging test is needed to determine whether there were less overt gross motor problems. Using the GMFM-88 alone might result in under diagnosis of problems.

5.5.4 THE MOVEMENT ASSESSMENT BATTERY FOR CHILDREN – SECOND EDITION

The MABC-II assessed the participants in three areas: manual dexterity (MD), throwing and catching and balance. The inclusion of this outcome measure was beneficial because it included more complex motor tasks compared to the GMFM-88. The MABC-II was sensitive to milder forms of gross motor disability and was particularly useful for the participants in the MTBI category who did not present with overt gross motor issues and for whom the GMFM-88 had reached a ceiling. Although the direct aim of this study was to assess change in gross motor function, the MD component provided results on fine motor (FM) control. This allowed the research results to be compared to studies that included gross and fine motor measures and provided additional and relevant information (Chaplin et al., 1993, O'Flaherty et al., 2000, Dumas et al., 2002, Kuhtz-Buschbeck et al., 2003a, Dahl and Emanuelson, 2013, Stephens et al., 2017).

5.5.4.1 MABC-II AT DISCHARGE

The mean total score of the participants on the MABC-II was 7.75 (SD: ±3.75) at hospital discharge. The performance on the three subscales were as follows: throwing and catching

(mean: 7.75, SD: ±3.59); manual dexterity (mean: 7.81, SD: ±3.11) and balance (mean: 9.15, SD: ±4.39).

According to the MABC-II, a score within one standard deviation (one SD is a score of three) away from the mean (10) is acceptable. When one analyses the above scores, a mean total score of 7.75 falls within one SD of ten, the maximum score is 19 and indicates that as a group the participants did not present with motor impairment. However, on closer investigation, the SD of the sample is greater than three, indicating that there were participants that were classified either 'at risk' for or had a high likelihood of motor impairment. Moreover, the SD scores for all the subscales were greater than three with the balance subscale having the greatest standard deviation.

The MABC-II also uses the *traffic light* system to interpret the scores and it classifies the individuals into three colours (green, amber, and red). Green indicates no motor impairment, amber indicates 'at risk' for motor impairment and red indicates a high likelihood of motor impairment. At hospital discharge, 46 children (54.76%) were in the green category, 20 children (23.81%) were in the amber category and 18 children (21.43%) were in the red category. The *traffic light* system therefore provides a better indication and understanding of motor function of the study sample. Even though the mean standard scores fell within one SD of the mean, there was a significant percentage of the participants (45.24%) that were either 'at risk' for or had a high likelihood of motor impairment at discharge. These children would warrant further assessment and intervention from a physiotherapist.

5.5.4.2 MABC-II AT THREE-MONTH FOLLOW-UP

There was a statistically significant difference ($p<0.00$) between the MABC-II mean total scores at discharge (mean: 7.75, SD: ±3.75) and at three-months (mean: 9.44, SD: ±2.86), indicating an improvement in motor function. There were also improvements in all three subscale scores (in descending order): balance (mean:11.80, SD: ±3.84); throwing and catching (mean: 8.93, SD: ±2.48) and manual dexterity (mean: 8.66, SD: ±2.83). All the subscale standard deviation scores fell below three except for balance. The results highlight that the participants were unlikely to have motor impairments after three months, yet some participants still presented with balance problems.

The *traffic light* system showed, 54 children (76.06%) as green, nine children as amber (12.68%) and eight children as red (11.27%). The *traffic light* system therefore provided us with a more precise picture of the motor function of the participants at three-month follow-up.

Whilst the vast majority of children had no motor impairment, 23.95% of the study were still either classified as *at risk* or had a high likelihood of motor impairment after three months. The unresolved motor deficits, extending post 12 weeks, are consistent with previous research studies (Chaplin et al., 1993, O'Flaherty et al., 2000, Dumas et al., 2002, Haley et al., 2003, Kuhtz-Buschbeck et al., 2003a, Kuhtz-Buschbeck et al., 2003b, Gagnon et al., 2004, Caeyenberghs et al., 2009, Caeyenberghs et al., 20011, Dahl and Emanuelson, 2013, Howell et al., 2014, Rhine et al, 2017, Stephens et al., 2017).

5.5.5 THE SUBTESTS OF THE MABC-II

The results of the three subtests of the MABC-II: 1) manual dexterity, 2) throwing and catching and 3) balance will now be explored further.

5.5.5.1 MANUAL DEXTERITY

The MD subtest demonstrated an improvement over the three-month period, but it yielded the least progress. The mean standard score for MD at discharge was 7.81(SD: ±3.11) which improved to 8.66 (SD: ±2.83) after three months. It is known that the establishment of hand dominance only happens at three years old (Dahl and Emanuelson, 2013) and fine motor control develops and matures later than gross motor skills (Lemon, 1993, Patra, 1996, Kuhtz-Buschbeck et al., 2003a). Therefore, the early age at injury may be a contributing factor to the above results as the three to six age group was the highest represented in the study. These results may provide supportive evidence that the degree of functional recovery is largely reliant on the skills acquisition mastered at the time of the cerebral injury (Dennis, 1988, Chaplin et al., 1993, Barnes et al., 1999, Ewing-Cobbs et al., 2004, Anderson et al., 2011). Moreover, the relatively slower progress in fine motor skills, speed, and coordination after a TBI is consistent with previous studies and should be expected (O'Flaherty et al., 2000, Kuhtz-Buschbeck et al., 2003a, Dahl and Emanuelson, 2013).

The MD component of the MABC-II (for all three age ranges) consists of two fine motor tasks that are timed and one task requiring accuracy and precision (child is required to follow and stay within a narrow line using a pen). These results are consistent with prior research which suggests that tasks that require precision and accuracy are the most affected in children and adolescents post TBI (Chadwick et al., 1981a, Chadwick et al., 1981b, Chadwick et al., 1981c, Bawden et al., 1985, Chaplin et al., 1993, Kuhtz-Buschbeck et al., 2003a). Furthermore, the findings are similar to studies which demonstrate fine motor tasks that require upper limb speed and dexterity to be most affected post TBI (O'Flaherty et al., 2000). Thus, the MABC-II was

sensitive to detecting problems with fine motor control, similar to those identified in previous research.

Associated injuries may account for some of the slower progress in manual dexterity scores. Fractures of the upper limb (5.95%) were the most common in the 'areas of interest' (as depicted in 5.4.4) and soft tissue injuries of the upper limbs (13.1%) were also well represented amongst the study sample. Fractures, particularly of the upper limb heal relatively quickly in children with healing times being inversely proportional to the age of the child, provided there are no complications (Bryson et al., 2016). As the youngest age group constituted the largest portion of the study, fractures of the upper limbs should have healed by the three-month follow-up point unless there was weakness and/or loss of joint range of motion at the joint region. However, owing to the pathophysiology of fracture healing and the small portion of the sample that were affected, the associated upper limb injuries may be deemed almost negligible. Therefore, it is highly likely that the results represented are indicative of early motor recovery in manual dexterity function as a result of the TBI itself and this test was not overtly influenced by associated injuries. Moreover, if the upper limb injuries were to have had a significant impact on the outcome, there would have been a greater improvement noted as the associated injury would have resulted in low scores at discharge which would have improved drastically at the three-month point when the injuries healed. However, this did not occur, and the MD subtest progressed the slowest.

5.5.5.2 THROWING AND CATCHING

At three-months the throwing and catching subtest had greater improvement than the MD subtest but less improvement than the balance subtest. The mean standard score for throwing and catching at discharge was 7.75(SD: ±3.59) and 8.93(SD: ±2.48) at three months. Although the majority of the sample scored within one SD of the mean at hospital discharge, the SD was closer to four, indicating that there were participants who had difficulty performing this task. The results are suggestive that the participants did not have difficulty with this motor skill after three-months. For this particular subtest, the possible reasons for the lowest scores observed at discharge (i.e., in the acute recovery stage) will be explored.

The complexity of this task may provide an explanation as to why the participants performed the worst on this subtest at hospital discharge. Throwing and catching is a complex motor skill that incorporates a prominent level of somatosensory processing in order for the child to execute the task successfully. It combines upper and lower limb function, hand eye coordination, bilateral limb coordination, and dynamic balance in a 'functional manner'. Prior research has

revealed that children and adolescents post TBI, demonstrate poorer performance when the complexity of the task increases (Howell et al., 2014)

The child's ability to integrate visual information about the speed, flight and size of the object and make the appropriate postural adjustments is an example of such processing required. It also examines a child's proprioceptive abilities as the child requires spatial awareness in order to make the appropriate body movements and adjustments. These results are consistent with previous findings where children and adolescents have difficulty with somatosensory integration post TBI (Shumway-Cook and Olmscheid, 1990, Ingersoll and Armstrong, 1992, Wober et al., 1993, Guskiewicz, 2001).

Associated injuries affecting 'areas of interest' (upper limb, lower limb, and pelvis) were present in a substantial portion of the sample at hospital discharge. Unlike the manual dexterity tasks which included only the upper limbs or the balance tasks which included the pelvis and lower limbs, this task involved all the relevant limbs. Fractures in these areas were present in 9.52% and soft tissue injuries of these areas were present in 36.91% of the sample. Such injuries would have affected lower limb weight bearing and upper limb mobility needed to perform this task. However, like with the MD subtest above, the fractures should have healed by the three-month follow up and would no longer have interfered with the execution of this task. The level that the associated injuries could have directly impacted the initial results of this subtest pose a challenge to interpreting the results at three months as it is difficult to quantify what degree of functional improvement is as a result of recovery from TBI. It is important to deduce from these findings that there was a significant improvement in this subtest over three months regardless of the extent of the associated injuries. The results reveal that over three months, not only does a TBI recover to a certain extent, but a child is often able to make a remarkable recovery in all other aspects caused by the traumatic event, allowing the child to return to play and activities of daily living.

Furthermore, in order for the child to execute the task successfully, the child is required to have good hand-eye coordination. The task requires the child to use the visual system and coordinate the information received through the eyes to control, guide and direct the hands to execute the task. Thus, the findings are supportive of previous research suggesting the speed of hand-eye coordination to be particularly sensitive to the effects of TBI (Chadwick et al., 1981a, Bawden et al., 1985, Chaplin et al., 1993, Kuhtz-Buschbeck et al., 2003b, Caeyenberghs et al., 2011, Stephens et al., 2017). Moreover, these findings are consistent with research that reports compromised vision, problems with bilateral coordination and delayed reaction times in

children and adolescents post TBI, which would further have contributed to poorer results at hospital discharge (Guskiewicz, 2001, Kuhtz-Buschbeck et al., 2003b, Gagnon et al., 2004, Caeyenberghs et al., 2009, Caeyenberghs et al., 2011).

There are elements of postural control that are essential in performing a throwing and catching task. Postural control is a vital feature of this motor task because it involves anticipatory (feedforward) and reactive elements (feedback). The task requires a child to successfully adjust their position and transfer body weight (feedforward) whilst intercepting and catching a moving object (feedback). These results are consistent with prior research which has consistently identified postural instability post paediatric and adolescent TBI (Gagnon et al., 2004, Dahl and Emanuelson, 2013, Rhine et al., 2017). Results by Gagnon et al. (2004) pays particular attention to postural instability in the first three months post TBI. These findings provide support for the research and demonstrate that children perform worse when refined postural control and higher levels of anticipatory control are required, particularly in the acute recovery stage.

5.5.5.3 BALANCE

The balance results obtained in this research study are somewhat contradictory. On the one hand the highest scores were obtained in the balance subscale at both discharge and follow-up with the balance subscale also demonstrating the greatest improvement at follow-up. Yet on the other hand the balance subscale had the greatest variance in standard deviation at both discharge and at three-month follow-up which suggests that there were participants who scored poorly on this subtest.

In previous studies, balance deficits have been identified in children and adolescents post TBI, particularly in those that sustained MTBI and did not present with overt motor impairments (Gagnon et al., 2004, Dahl and Emanuelson, 2013, Howell et al., 2014, Rhine et al., 2017, Stephens et al., 2017). In this study, the large variance in standard deviation, indicating the presence of balance deficits are consistent with the results of the aforementioned studies. However, this study yielded unexpected results compared to previous studies. The participants of this study not only obtained the highest scores on the balance subscale at hospital discharge and at three-month follow-up, but the subtest also demonstrated the greatest improvement over the recovery period.

On closer inspection and examination of the results of this study there were several differences that could account for the higher balance scores. None of the balance components of the MABC-II required the individual to balance with vision eliminated. The MABC-II only

assesses the function of the proprioceptive and vestibular systems at varying difficulties such as standing on one leg, standing on an unstable surface and tandem walking on a narrow line. Studies that reported balance deficits post TBI utilized outcome measures such as the BOTMP (eyes closed on a balance beam) and the Pediatric Clinical Test of Sensory Interaction for Balance (P-CTSIB) which includes the three sensory systems required for balance: the proprioceptive, vestibular and the visual systems (Gagnon et al., 2004, Stephens et al., 2017, Rhine et al., 2017). Hence, the studies where balance issues were reported included tasks where vision was eliminated. The results of this study provide further support for the hypothesis discussed by Gagnon et al. (2004) which theorizes that the balance issues caused by TBI includes the integration of available sensory information required for balance control. The results indicate that the injured individual's capacity to efficiently use the proprioceptive and vestibular information received in the absence of visual input is affected. These results could also challenge the findings that the visual system is commonly affected post TBI, and the visual deficits are the primary contributors to balance problems noted in this population. Further research investigating and focusing on vision would be required to make definitive conclusions regarding this hypothesis.

The mechanism of injury could also potentially shed light on the balance results presented in this research. Children do not routinely undergo balance testing prior to sustaining a TBI and thus, there are no baseline results with regards to a child's premorbid balance ability. It is possible that balance issues reported in prior studies may have preceded the injury. The children that had pre-existing balance deficits were potentially more susceptible to sustaining a concussive brain injury through falls – the most common mechanism of injury in most other studies. In some of the aforementioned studies that underscore balance deficits in participants that otherwise did not have overt motor deficits post TBI, only Gagnon et al. (2004), reported the mechanism of injury. Gagnon et al. (2004) reported that the vast majority (42%) of TBI's resulted from falls, whereas in this study only 15% of TBI's were as a result of falls and the majority (67.1%) were as a result of road traffic accidents (RTA). The mechanism that results in an RTA versus a fall is generally vastly different. The cause of an RTA has a higher likelihood of being independent of the injured individual and is often resultant of errors produced by another individual. This is particularly the case of a paediatric TBI in which the subject is unable to be the driver of the vehicle. In other words, the TBI's sustained by the majority of participants in this study were caused by external factors that involved another individual and were not as a direct result of the child's independent actions. This makes it difficult to assume that the TBI was a result of prior balance deficits. Conversely, the children

that sustain a TBI as a result of a fall have a higher likelihood that balance deficits existed prior to the injury because the mechanism of injury is largely dependent on the individual's action. Therefore, the poor balance scores obtained in such research cases may not be as a *result* of the injury but rather a contributing factor to the *cause* of the injury. However, a larger number of research studies would need to be analysed further in order to support this hypothesis.

Furthermore, the age range of the assorted studies could also account for the comparably different balance results. This study included participants extending from three to 12 years old, whereas other studies included children of ages extending further into adolescence (Chaplin et al., 1993, Kuhtz-Buschbeck et al., 2003a., Gagnon et al., 2004, Caeyenberghs et al., 2009, Dahl and Emanuelson, 2013, Howell et al., 2014, Stephens et al., 2017). These results could potentially reveal that balance post TBI is affected to a greater extent in the older adolescent population compared to the younger age groups. This may be further supported by the fact that the majority of participants in this study were pre-adolescence with the oldest age group (10-12 years old) only comprising 8.3% of the sample size.

Time since injury could also account for the differences in balance results. Two studies conducted by Caeyenberghs et al. (2009) and Caeyenberghs et al. (2011) that used the MABC as an outcome measure included participants that were three and four years post insult respectively. The lower balance sub-scores in the aforementioned studies were associated with lower FA in the cerebellum and the corticospinal tracts (CST) which are responsible for coordination, balance, and postural control. Previous studies have identified deterioration in these specific brain regions with time and have reported microstructural changes during the chronic stages of TBI (specifically moderate and severe TBI) as well as reduced cerebellar grey matter in children with TBI (Spanos et al., 2007). Research has revealed the vulnerability of the cerebellum to TBI and the negative long-term effects of TBI on the cerebellum, contributing to cerebellar atrophy and consequent balance and coordination impairments. Therefore, microstructural changes that occur with time may contribute to a delay in balance and coordination problems which could support the notion of emerging deficits that have been identified in children post TBI (Anderson et al., 2011, Koskiniemi et al., 1995). This hypothesis may be strengthened by several other long term follow-up studies that have also identified balance deficits in this population (Chaplin et al., 1993, Kuhtz-Buschbeck et al., 2003a).

5.5.6 FACTORS AFFECTING MOTOR OUTCOME

The relationship between motor function and a number of demographic and clinical factors was investigated. Age at injury did not appear to affect motor function. This is consistent with findings reported in previous studies (Klonoff et al., 1993, Dumas et al., 2002, Kuhtz-Buschbeck et al., 2003b, Dahl and Emanuelson, 2013). The sex of the participants also did not have any direct correlation to motor function which is consistent with results by Dahl and Emanuelson (2013). Lower GCS scores were associated with poorer motor function on the GMFCS, GMFM-88 and the MABC-II at the three-month follow-up. The results suggest that the more severe the TBI, the greater the motor disability and similar findings have been reported in the literature (O'Flaherty et al., 2000, Stephens et al., 2017). The type of TBI and the severity of the TBI were also correlated. The more types of TBI present, the greater the severity (the lower the GCS score) of the TBI and consequently the poorer functional outcomes.

The results of this study also bring into question the 'cerebral plasticity' versus the 'cerebral vulnerability' concepts as the age at injury did not appear to have correlations to functional outcomes. The results rather provide supportive evidence for the *recovery continuum model* proposed by Anderson et al. (2011) in which recovery post paediatric TBI is reliant on various factors such as severity and type of the insult.

5.5.7 SUMMARY OF MOTOR OUTCOMES

The participants demonstrated significant improvements in motor function over the three-month recovery period. Although there were still a substantial portion of participants that were either at risk of motor impairment or were likely to have motor impairment, the sample as a whole regained motor function after three months. The participants in the study did not only have an isolated TBI and many of them had associated injuries, yet they still demonstrated functional motor recovery. The findings provide supportive evidence that recovery of motor function occurs faster than other functional domains such as cognition which demonstrates persistent negative sequela post TBI (Caeyenberghs et al., 2011). This study provides further information that motor function can be regained as early as three months for the majority of TBI patients of all classifications and varied age ranges. The improvement or resolution of motor deficits observed from discharge to three months could be in part attributed to developmental maturation or familiarity with the measure, although this is unlikely as the scoring for the MABC-II incorporates age-based norms. Therefore, the children with TBI did not only improve numerically between tests but also caught up to their uninjured peers over the

three-month recovery period. Only severity of injury as determined by the GCS was associated with functional motor outcome.

5.6 ASSISTANCE TO PARTICIPATE SCALE

The ICF takes a holistic approach in determining the major factors that impact on recovery and return to function of a TBI. This classification predominantly focuses on the impacted individual. This study saw the need to extend the focus to the caregiver as a fundamental participant in recovery. Therefore, the Assistance to Participate Scale (APS) was applied which further determines the extent of involvement required by the caregiver in daily activities and in facilitating participation. The relationship between the disabled child and the family carer who enables the child's participation is inextricably linked (Bourke-Taylor et al., 2009). Therefore, measuring the child's capabilities must extend to measuring the extent of the caregiver's assistance required.

The results of the APS demonstrated that the children of this sample did not require assistance from the primary caregiver to participate in play and leisure activities in the home, community, and social setting (mean: 39.65, SD: ±2.53) at three months post discharge. The results are consistent with the motor function recovery demonstrated in 5.5 in which the majority of children and adolescents had no motor impairment at three months. Children with greater physical dysfunction generally require more assistance to participate in play and leisure activities compared to children with psychosocial issues (Bourke-Taylor et al., 2009). The findings are also supportive of research studies that report self-care-levels to be the highest in a group of TBI patients (Dumas et al., 2002).

In future research it is warranted to extend this study to the affected child as the child's perception is often underestimated. The child may not successfully communicate the extent of assistance required to perform optimally throughout their return to more subtle preinjury function. Certain aspects of daily life may require more assistance to enable participation compared to that which is perceived by the caregiver. Further research also needs to be conducted to investigate the relationship between socio-economic status and APS. Factors such as access to services and well as caregiver education and understanding of the condition could be investigated.

5.7 PEDIATRIC QUALITY OF LIFE – FAMILY IMPACT MODULE

Similar to the APS, the utilization of the Pediatric Quality of Life – Family Impact Module (PedsQL-FIM) allowed for the impact of the child's injury on the primary caregiver and family function to be quantified. While the extent of environmental supports such as wheelchairs and communication devices can be easily measured, human support in the form of a family's capacity to provide the assistance required (be it physical, emotional, or financial) is both complex and difficult to measure. The family play an integral role in the recovery of a disabled individual; however, this often impacts the quality of life of these family members. Quantifying this impact is vital because a family that is not coping with the burden of living with a disabled child can have tremendous knock-on effects on recovery. Research has demonstrated that the restrictive or facilitative nature of a child's home life, including the attitudinal environment, affect the caregiver's capacity to support the child's participation and recovery (Bourke-Taylor et al., 2009, Medrano et al., 2013a).

A study conducted in Brazil, which is considered to be of similar SES to that of South Africa, used the PedsQL-FIM to monitor the HRQOL of parents/guardians of children and adolescents with cancer in active therapy. The Brazilian version of the PedsQL-FIM was considered reliable and valid for assessing the impact of a chronic paediatric health condition on the HRQOL of parents and family functioning. This is an important finding as it suggests that the instrument can be cross-culturally adapted to suit the specific context in which it is used, such as in the case of this study (Scarpelli et al., 2008).

The PedsQL-FIM revealed that in this study there were primary caregivers whose health-related quality of life (mean: 69.06%, SD: ±20.44) and family functioning (mean: 64.75%, SD: ±26.78) had been affected as a result of the child's TBI. The parents scored the lowest on the emotional functioning component (mean: 60.14%) and family relationships (mean: 59.79%) had taken noticeable strain over the three-month period. The results are consistent with studies demonstrating that medically fragile children living at home have more of a negative impact on family functioning compared to those that are receiving 'in-hospital' care. This is imperative to note as none of the children in this study were placed in an in-hospital rehabilitation centre post-acute care and were all discharged home, indicating that the strain placed on the families caring for them was significantly higher than those in a rehabilitation facility (Houtzager et al., 2005).

The disabled child relies on dedicated support structures in order to overcome the burden of disability and optimize recovery. Yet a family that is struggling to cope, such as the ones in this study, hinders the environment needed for recovery and participation enablement which negatively impacts on recovery according to the *recovery continuum model* (Anderson et al., 2011). Government bodies and service providers rely on the availability of such data to track and predict needed financial and human service support, such as respite care, for primary caregivers and family members. Those caring for paediatric and adolescent TBI are a vital cog in the wheel and their functioning and emotional well-being is imperative to assist with the injured individual's functional recovery. Implementation of support services and coping mechanisms for primary caregivers and family members (particularly of this study) should not be overlooked. Currently there is limited data available on the usage of the PedsQL-FIM, making it difficult to quantify the impact a childhood disability or chronic illness has on family functioning and quality of life. This study has revealed that the outcome measure is user-friendly and inexpensive making it an easy tool to capture such necessary data and could be used in future studies.

5.8 STRENGTHS OF THE STUDY

The strengths of the study are as follows:

- The study included a fairly large sample size when compared to other studies that also researched motor function in this population group (Chaplin et al., 1993, O'Flaherty et al., 2000, Dumas and Carey, 2002, Haley et al., 2003).
- The study had 84.5% of the sample return to follow-up. This is exceptionally high, particularly in a population with low socio-economic status. The high follow-up rate in this study is contrasted by a study conducted by Dahl and Emanuelson (2013) which took place in Sweden – a high income country – in which only 21% of the sample returned for follow-up.
- It appears to be the first known study on paediatric and adolescent TBI in Gauteng and took place at CHBAH, which services a significant percentage of the Gauteng population. Thus, the results demonstrated in this research are likely transferable to rest of the Province and South Africa as a whole.
- The study included a 12 week follow-up by which time the post-concussion symptoms should have resolved (Gagnon et al., 2004) and therefore it is unlikely that lingering neurological symptoms could have altered the outcome.

- The heterogeneity of the inclusion criteria (i.e., included all TBI classifications, all mechanism of injuries, all neuropathology's, and a wide age range) are in conjunction with TBI being a heterogeneous condition and the findings can be extrapolated to motor recovery of TBI as a whole.
- The MABC-II demonstrated a sensitivity to subtle changes in motor function, particularly in fine motor control, where other studies have reported the outcome measures used to be less sensitive to fine motor control problems, particularly in MTBI (Chaplin et al., 1993, O'Flaherty et al., 2000, Dahl and Emanuelson, 2013, Stephens et al., 2017).

5.9 LIMITATIONS OF THE STUDY

The limitations of the study are as follows:

- On the whole the outcome measures were appropriate to use on this population, however the GMFCS had to be modified to incorporate a level nought which may have altered the reliability as it is a standardized outcome measure.
- The parent questionnaires were in English but only 4.76% of the sample used English as their first language. A translator (in the form of the Matron in PSAW) was often required, but because the questionnaire is self-report, the translation may have affected the understanding and resulted in inappropriate answers.
- The study included the quality of life of the primary caregiver; however, it did not include that of the participant and based on ICF, the quality of life of the individual is of vital importance.
- At the three-month follow-up, several parents reported that the children were presenting with headaches, ill-disciplined behaviour, and poor attention, yet there was no formal recording of this information. Although PCS are transient in 90% of MTBI, there was no documentation for the remaining 10% that may have presented with lingering symptoms, such as those mentioned above (Bodnar et al., 2019).
- Many of the research studies focus on gait post TBI, this study only looked at the participant's ability to ambulate and not at the quality of ambulation. Gait problems have been identified in children and adolescents post TBI.
- The MANOVA was used to determine correlations, yet it is only verified to be used on parametric data and the data of this study was non-parametric. Future studies, including more evenly distributed data for each TBI classification would be needed in order to verify the results obtained.

- Although vision has been identified as a problem after TBI, none of the outcome measures included visual motor control.
- Not all of the children aged 10-12, admitted to CHBAH with TBI were included in the study.
- The location of the brain injury was not recorded, and research has demonstrated that the site of the lesion may also be a prognostic factor for outcome as well as a predictor of potential problems based on structure versus function.
- The results are only based on CT findings as MRI scans are not routinely done at CHBAH. Therefore, DAI as a diagnosis and the complete extent of the brain damage is possibly underreported in some of the participants. This underreporting and misdiagnosis may have affected correlations such as the type of TBI and functional outcome.
- The parents HRQOL was only assessed at three-month follow-up and not at discharge. Baseline data would have assisted in more accurately ascertaining the direct impact of the child's injury on the primary caregiver.

5.10 CLINICAL IMPLICATIONS OF THE STUDY

South Africa is a low- middle income country with limited access to healthcare and particularly in-patient paediatric rehabilitation services. (Hyder et al., 2007). It is of interest to note that the results of this study highlight that most children and adolescents regained motor function after three months post traumatic brain injury without receiving a structured inpatient rehabilitation programme. The study showed that mild traumatic brain injury is the most common type of paediatric TBI admitted to CHBAH. The majority of children did not require extensive medical and/or surgical management, however, it is crucial to note that 23.95% of the sample still presented with motor impairments or were at risk of developing motor problems after three months. These results should not be undermined by the 76.05% of the sample that regained motor function after three months. Structured rehabilitation programmes need to be implemented in order to maximise the recovery of this sizeable portion of participants. The outcome measures used in the study were sensitive to change over time and this provides further support for their usage in this population group.

In spite of the positive results above, an initiative-taking management strategy should be implemented across the board as part of the discharge protocol for children and adolescents seeking care for TBI at a South African healthcare facility. South Africa should take heed from the successful implementations of discharge programmes such as those at the Montreal

Children's Hospital in which children and adolescents who are hospitalised or seen in the emergency department after a TBI, are provided with activity restrictions and required to gradually return to school (Swaine and Friedman, 2001). The restrictions are particularly important for the first four weeks post insult when PCS have not yet resolved (Bodnar et al., 2019). Such restrictions provide the necessary time for the vulnerable brain to heal and prevent further damage which is crucial considering the fact that children with a TBI have a higher likelihood of sustaining a subsequent TBI compared to the uninjured population (Gagnon et al., 2004). Recurrent head injuries can have dire consequences (such as brain atrophy and impaired neuropsychological performance), particularly if such an event occurs during the healing period (Torres et al., 2019). Currently, there is no formal discharge documentation provided to the primary caregivers and children at CHBAH explaining TBI, post -concussion syndrome, signs of raised ICP as well as how to gradually return to daily activities. Formalized pamphlets explaining the above could be implemented, not only at CHBAH but in all primary, secondary, and tertiary facilities nationwide as an attempt to create awareness of the condition and prevent subsequent injury.

The research results obtained, as they pertain specifically to physiotherapy, provide insight into the type of rehabilitation required post TBI in children. Owing to the lack of resources available in the State setting and the fact that the majority of the participants demonstrated positive motor outcomes after three months, there is now evidence that most children admitted to the hospital for general neuro-observation do not require routine physiotherapy intervention. For those children that had lower GCS scores, associated injuries, and sustained multiple types of TBI, a thorough assessment and rehabilitation intervention should be provided. The intervention should target sensorimotor integration, hand-eye coordination, manual dexterity, and balance training. Physiotherapists should also advocate and assist with the admission to inpatient rehabilitation for those children that meet the criteria, owing to the positive outcomes demonstrated in children that receive such services.

Furthermore, a lack of State paediatric inpatient rehabilitation centres has been identified, yet this research study has acknowledged children that would benefit from long term inpatient rehabilitation in order to optimise function. This is of particular importance for this demographic where poor socio-economic status is a barrier to rehabilitation and recovery. Such research is crucial to provide the evidence required to assist with advocating appropriate care for this vulnerable population group who are at a critical juncture in their development and enriched environments can assist with optimizing functional recovery in all domains.

MVA and PVA were statistically the highest mechanism of injury in the research. Education strategies regarding road safety could be taught in schools from an early age in an attempt to limit the number of pedestrian vehicle accidents. Car seat and seat belt campaigns could be set up and promoted throughout the country to enforce their correct and effective usage. Interventions regarding formal car seat donations and allocations should be implemented. Taxi drivers should be incentivised to have car seats available and to prevent overloading of vehicles. If the country can work towards limiting the number of road related TBI's, the burden on the healthcare system will be greatly reduced.

South Africa should follow in the footsteps of many high-income countries that have national trauma registries. Such data is crucial for the improved tracking and surveillance of the TBI epidemic as a means of improving the morbidity and mortality in the paediatric and adolescent population of South Africa.

The necessary support structures, such as psychological assessments and referrals, for primary caregivers and family members of children with disabilities should not be overlooked. The people caring for the disabled children play a crucial role in the participation enablement of the injured child and optimization of their functional recovery. Therefore, their health-related quality of life should be a focal element throughout the recovery process.

5.11 RESEARCH IMPLICATIONS OF THE STUDY

This is a purely paediatric centred research study. The results have thus contributed to the paucity of data present in the paediatric and adolescent population post TBI. One of the indirect aims of this particular research study included contributing to the lack of epidemiological surveillance of PTBI in a low-middle income country such as South Africa, with a particular focus on the Gauteng Province. By including a heterogeneous sample, the results extrapolated are relevant to PTBI has a whole. This is in contrast to other studies conducted in South Africa which had more stringent inclusion criteria (Schrieff et al., 2013). Although the Government is trying to regulate the taxi industry and improve road safety, the results of this study reveal that the high number of paediatric TBI in South Africa is still as a result of high incidence of road traffic accidents (Levin, 2004, Schrieff et al., 2013, Patel et al., 2017). Such research can be used to provide substantial evidence for improvements in road safety regulations.

Vulnerability of the immature CNS to undergo a TBI appears to continue through the first five or six years of life with infants and preschool children demonstrating poorer outcomes than school aged children (Koskiniemi et al., 1995, Müller et al., 1998, Kolb et al., 2000a). Owing

to the fact that the majority of this sample were between three and six, a long-term follow-up for all participants is warranted. Such long term follow up may provide further information regarding recovery progression, emerging deficits and provide necessary insight into rehabilitation services required. Furthermore, future research including a bigger sample with regards to mechanism of injury – falls versus a road traffic accident – may assist in determining whether balance is a cause of or as a result of a traumatic brain injury. If future research is able to support this hypothesis it could lead to the implementation of preventative intervention strategies such as balance screenings in schools. Future research is warranted to compare the recovery (both short and long term) of children and adolescents from differing socio-economic circumstances. The results of such studies may provide insight into the factors which promote or inhibit paediatric functional recovery. Such information can assist in identifying appropriate allocation of resources to optimize recovery, particularly during the 'window of opportunity'. Further research comparing children with severe functional disability at discharge who receive a home exercise programme containing specific training of the motor areas identified as being affected post TBI (as mentioned in 5.10.) to children that receive in-patient rehabilitation services would provide further insight into the necessity of inpatient rehabilitation as it pertains to motor function specifically. Future research could also include a child centred questionnaire to ascertain the child's health related quality of life after a brain injury to determine if there are specific areas that can be targeted with rehabilitation therapy services to improve participation and activities of daily living.

Many high income countries have national trauma registries (Buitendag et al., 2017). Considering that TBI in Africa is expected to be at 10 million cases by 2050, improved intervention and surveillance is required (Wong et al., 2016). CHBAH has recently set up a paediatric electronic database and research utilizing this data should be performed to improve injury surveillance and tracking leading to improved outcomes and prevention strategies.

CHAPTER SIX – CONCLUSION

This study set out to investigate the early functional outcomes in children and adolescents with a traumatic brain injury at hospital discharge and after three months. The study utilized three primary motor outcome measures which included the GMFCS, GMFM-88 and the MABC-II.

The study included children and adolescents aged three to twelve years old admitted with a traumatic brain injury but not limited to an isolated TBI. The three to six age group comprised the majority of the sample. More males sustained a TBI compared to females and road traffic accidents accounted for the majority of injuries. Mild traumatic brain injuries were the most common amongst the sample.

The findings revealed statistically significant improvements in the motor function of the participants at three-month follow-up. The majority of the participants were independent in ambulation and had no gross or fine motor deficits. However, there was a considerable percentage of participants that were still classified as 'at risk' of motor impairment or had a high likelihood of motor impairment three months post brain insult.

Factors that influenced the outcome included the GCS score, the type of TBI sustained, and the presence of associated injuries. Lower GCS scores at the time of the injury were associated with poorer functional outcomes at three months. The type of TBI and GCS scores were also related, with participants who sustained multiple types of TBI and intracerebral haemorrhages and have more severe head injuries. Although age was not a direct correlation to functional outcome at three months, the children in the three to six and seven to nine age groups were admitted with more mild types of TBI compared to those in the ten to twelve age group. Males sustained more associated injuries compared to the female participants. Children and adolescents that were admitted with isolated head injuries and higher GCS scores performed better than those that had lower GCS scores and associated injuries at three months.

Moreover, the participants were largely independent in the home, community and social setting and they did not require assistance from a primary caregiver. The primary caregivers reported that their health-related quality of life and family functioning had been affected as a result of the TBI.

To our knowledge, this is the first study of its kind conducted in South Africa that includes a large heterogeneous sample size of children and adolescents with TBI with a primary focus on functional outcomes. The results of this study are unique as they are a representation of the TBI

epidemic as it pertains to Gauteng and to a considerable extent South Africa as a whole. It demonstrates vital information that can assist with the stratification of resources in the State setting to enhance appropriate care for children with TBI to optimize recovery and functional outcomes. It was positive to note that the majority of the sample regained motor function at three months and physiotherapy services for this particular group would not necessarily be warranted. However, the fairly substantial portion of participants that remained with functional problems at three months should not be ignored. These children require extensive follow-up and appropriate rehabilitation services, many of which are lacking in South Africa. Future research is warranted to include long term follow-up of these children to determine residual impairments and emerging deficits in all functional domains.

TBI in children remains a significant public health issue in South Africa, yet childhood injuries continue to receive little attention (van As and Millar, 2012). The study highlights that morbidity and mortality caused by a paediatric traumatic brain injury is largely preventable. Higher income countries around the world have implemented effective trauma systems and have put interventions in place. Their preventative measures and appropriate interventions have seen a drastic reduction in preventable TBI's such as those caused by RTA's (Ademuyiwa et al., 2012). Unlike the field of infectious diseases where vaccinations and prevention strategies are the norm, paediatric trauma is largely overlooked and prevention strategies are scarce (van As and Millar, 2012). Children are disproportionately affected by trauma and the findings of this study support the need for a close follow-up of these vulnerable children by a resolute interprofessional team.

'There can be no keener revelation of a society's soul than the way in which it treats its children.' Nelson Mandela, former President of South Africa

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APPENDICES

APPENDIX 1: ADMINISTERING, SCORING, AND INTERPRETING THE GMFM-88

The GMFM-88 is the original criterion-referenced measure consisting of 88 items, which are divided into five domains of motor function that are ordered to resemble the typical acquisition of gross motor milestones (Alotaibi et al., 2014):

A. lying and rolling (17 items)
B. sitting (20 items)
C. crawling and kneeling (14 items)
D. standing (13 items)
E. walking, running, and jumping (24 items)

Each Item is scored on a four-point ordinal scale:

0 = does not initiate
1 = initiates (performs < 10% of the described activity)
2 = partially completes (>10% but <100% of task completion)
3 = completes (100% task completion as described for that activity)

All four levels of activity are specifically described for each item in Chapter 6 of the User's Manual. Individual item scores are recorded on the GMFM score sheet. A score of "0" is recorded if the child is either unable to initiate the item; unable to assume the starting position or refuses to attempt the item. Percent scores for each dimension are calculated and the GMFM total score is the average of the five dimensions. The percentage difference from initial assessment and reassessment provides an indication of the change in dimension. For example: if a child scored 80% on Dimension C (crawling and kneeling) at the initial assessment and three months later at the re-assessment, the child scored 89% on the same dimension, the child has demonstrated a 9% change in Dimension C. However, it is recommended to report change on the total score as opposed to individual dimensions as this has proven to be more dependable (Russell et al., 2000).

APPENDIX 2: ADMINISTERING, SCORING, AND INTERPRETING THE MABC-II

The MABC-II consists of eight test items across each age band. The three age bands are divided as follows: Age Band 1 (3-6 years); Age Band 2 (7-10 years); Age Band 3 (11-16). The exact chronological age of the child is calculated prior to commencing the test to ensure the correct age band is used. The test involves completing a series of gross, fine motor and balance tasks grouped into three subsections:

1. Manual Dexterity (MD, 1,2 and 3)
2. Aiming and Catching 1 and 2 (A&C, 1 and 2)
3. Balance (Bal 1; Bal 2 and Bal 3)

Converting the raw scores to a standard score

The raw scores are then converted to standard scores. The standard scores for each item for every age group are presented in APPENDIX B, Table 1 of the manual. The standard scores are based on a child's age. The child's age in years and months (as recorded on the cover page) determines which table is used. For ages 3 and 4 the age span is 6 months as opposed to 1 year for all other age groups. It is important to note that there is no rounding up or down for age in the MABC-II. The requisite norm for a child aged 5 years 11 months and 26 days, is the one labelled 5:0-5:11. The standard scores are then entered into each item in the box to the right of the raw scores. If the child has failed on both attempts in the MD task, then a standard score of one is recorded. When the task has been completed by both sides of the body (hands, legs), the standard scores for both sides are first recorded, then summed and divided by two. If the resultant value is above 10 then the score is rounded upwards; if it is below then the score is rounded downwards (this is essential to maintain the standard deviation of the combined score at 3).

The standard scores are then converted to percentile ranks and then interpreted in terms of percentile equivalent. The MABC-II consists of an innovative score interpretation method that uses a three-colour 'traffic light' scoring system based on the percentile achieved:

Red zone – significant movement difficulty (at or below the fifth percentile)

Amber zone – at risk for movement difficulties (between the 6^{th} and 15^{th} percentile)

Green zone – unlikely to have a movement difficulty (above the 15^{th} percentile)

APPENDIX 3: ADMINISTERING, SCORING, AND INTERPRETING THE APS

The APS consists of eight items. For each of the eight items a 5-point Likert scale is used:

1 = Unable to participate

2 = Participates with my assistance at all stages of the activity

3 = Participates after I have set them up and help at times during the activity

4 = Participates with my supervision only

5 = Participates independently

Three separate scores are calculated for the APS: APS – Home alone (summing responses of items 1 to 4); APS – Community social (summing the responses of items 5 to 8) and APS-Total (summing the subscale scores of APS-Home alone and APS – Community Social). A table is provided to assist with the conversion of the raw scores to Rasch-converted scores (0-100) in order to convert the scores to an interval scale. A higher score on an item; subscale or total score indicates less assistance is required for a child to participate in the activity described by the item(s), whereas a lower score indicates the opposite and consequently more severe disability (Bourke-Taylor et al., 2009).

APPENDIX 4: ADMINISTERING, SCORING, AND INTERPRETING THE PEDSQL-FIM

The FIM is a standardized questionnaire consisting of 36 items that is aimed at assessing parents' self-reported HRQOL and family functioning as a result of their child's health. The FIM consists of eight dimensions:

1. Physical functioning (6 items)
2. Emotional functioning (5 items)
3. Social functioning (4 items)
4. Cognitive functioning (5 items)
5. Communication (3 items)
6. Worry (5 items)
7. Daily activities (3 items)
8. Family relationships (5 items)

The items are scored on a 5-point Likert scale from 0-4:

0 = never

1 = almost never

2 = sometimes

3 = often

4 = almost always

The items are then reversed scored and linearly transformed to a 0-100 scale as follows:
0 = 100, 1 = 75,2 = 50,3 = 25,4 = 0
The scores are then calculated by dimension and the mean score is the sum of the items divided by the number of items answered. The overall total score is the sum of the 36 items divided by the number of items answered. The parent HRQOL summary score which consists of 20 items is computed by averaging the 20 items comprising the Physical, Emotional, Social and Cognitive Functioning scales. The family functioning summary score which consists of eight items is computed as the sum of the items divided by the number of items answered in the Daily Activities and Family Relationship scales. The higher scores indicate a better HRQOL, or less negative impact for the parent and/or family of the child with the disability.

APPENDIX 5: ETHICS APPROVAL

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Ms D Rosen
School of Therapeutic Sciences
Department of Physiotherapy
Medical School
University

E-mail: dalyarosen@gmail.com

CC: Supervisor: Professor J Potterton <Joanne.Potterton@wits.ac.za>
and <HREC-Medical.ResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 24/11/2017

REF: *R14/49*

PROTOCOL NO: **M1711107** *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *Early functional outcomes in children with traumatic brain injury*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

R14/49 Ms D Rosen

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M1711107

NAME: (Principal Investigator)	Ms D Rosen
DEPARTMENT:	School of Therapeutic Sciences Department of Physiotherapy Medical School University
PROJECT TITLE:	Early functional outcomes in children with traumatic brain injury
DATE CONSIDERED:	24/11/2017
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Professor J Potterton
APPROVED BY:	Professor CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	24/11/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially reviewed in **November** and will therefore be due in the month of **November** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature _____ Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX 6: PERMISSION

PERMISSION TO CONDUCT RESEARCH – CHRIS HANI BARAGWANATH HOSPITAL

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE
CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 8 Feb 2018

TITLE OF PROJECT: Early functional outcomes in children with traumatic brain injury (TBI)

UNIVERSITY: Witwatersrand

Principal Investigator: D Rosen

Department: Physiotherapy

Supervisor (If relevant): J Petterton

Permission Head Department (where research conducted): Yes

Date of start of proposed study: Feb 2018
Date of completion of data collection: Dec 2019

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Hospital. The CEO /management of Chris Hani Baragwanath Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Human Research Ethics Committee of the University of the Witwatersrand.
- the Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- the MAC will be informed of any serious adverse events as soon as they occur
- permission is granted for the duration of the Ethics Committee approval.

.....
Recommended
(On behalf of the MAC)
Date: 08 February 2018

.....
Approved/Not Approved
Hospital Management
Date: 13/02/18

PERMISSION TO CONDUCT RESEARCH – PROFESSOR LOVELAND

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL
Directorate: Paediatric Surgery
Enquiries: Prof. J.A. Loveland
Tel. number: (011)933 8138; Email: Loveland@wol.co.za

17th January 2018

Dalya Rosen
Chris Hani Baragwanath Academic Hospital

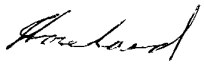
Dear Dalya,

RE: PERMISSION TO CONDUCT A STUDY

Your request to conduct a study titled "**Early Functional Outcomes in Children with Traumatic Brain Injuries**", intended for your Ethics application, on Paediatric Surgery Patients at Chris Hani Baragwanath Academic Hospital is granted.

You therefore can obtain relevant information from patient files, as well as access the Paediatric Surgery database.

Regards,



2018/01/17

Professor JA Loveland
Academic Head
Department of Paediatric Surgery
School of Clinical Medicine
University of the Witwatersrand

Date

APPENDIX 7: INFORMATION SHEET

PARENT INFORMATION SHEET

Dear Parent,

Thank you for taking the time to read this letter.

With your permission I would like to invite you and your child to take part in a research study at Chris Hani Baragwanath Academic Hospital (CHBAH) which is being conducted by Dalya Rosen, a physiotherapist at the hospital.

I would like to find out the functional outcomes in children with a brain injury. The information obtained from this research study will help to develop better services for future parents and children in the management of children with traumatic brain injuries, as well as benefit other physiotherapists in the management of children with head injuries.

The study will include information such as the cause of the brain injury, the type of the injury and the management of the injury. This information will help us identify the things that affect your child's recovery.

I would like to do two activities with your child before their discharge from the hospital. These two activities will evaluate your child's ability to do things like running, jumping, and climbing stairs. Depending on the injury either one or both of the tests will be conducted. They are called the GMFM-88 (Gross Motor Function Measure) and the MABC (Movement Battery Assessment for children). They are fun and will not cause any harm to your child.

Before your child gets discharged from hospital, a follow up appointment date will be made. The follow up date will be in three months after your child is discharged from hospital and will take place at the Physiotherapy Outpatient department in the *New Building* at CHBAH. At this appointment, the same activities that were done in hospital will be done again. You will be asked to complete a few questions about life after the injury for both the child and the family.

The tests and questionnaire should not take more than one hour to administer.

If you agree to help me, I will ask you to sign a consent form before any questions or tests will begin. If your child is older than seven, I will ask them to sign an assent form where they will write their name if your child is healthy enough to do so. I will explain what I will be doing and why to your child verbally in a language that they understand.

If you have any questions or concerns regarding this study, please do not hesitate to ask me. Whether or not your child takes part in this study, they will still receive Physiotherapy and all other types of therapy (Occupational Therapy, Speech Therapy, Dietician etc.,) during their stay in hospital and once your child has been discharged from hospital. Your transport to and from the Hospital for your three-month appointment will be provided for if you are coming back specifically for the research study appointment.

Your name and your child's name will not be used in the data collection sheet. This means that your child's privacy will be respected at all times and no one will have access to the information except me and my supervisor, Professor Potterton. Participation in this study in voluntary and you may withdraw your child from the study at any time. Even if you withdraw, your child will still receive physiotherapy as indicated.

Please feel free to contact me if you have any questions. My contact details are telephone numbers 011 933 8309 or 073.792 0861 and e-mail dalyarosen@gmail.com ; alternatively, you may e-mail my supervisor on Joanne.Potterton@wits.ac.za

This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg. If you have any concern over the way the study is being conducted, the Chairperson of this Committee is Professor Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Thank you for reading this Information Sheet. Your time and input is highly valued.

CHILD INFORMATION SHEET

Dear Child

Hello, Sawubona, Dumela. You have been specially chosen to take part in a project which Dalya Rosen, a Physiotherapist working at Chris Hani Baragwanath Academic Hospital will be doing.

I have carefully chosen you because you are between three and 12 and have recently suffered a head injury.

I want to see how children your age with this type of brain injury recovers and how life is for you and your family after the injury. All the information that I get from the study will help me and Physiotherapists all over the world to treat children with brain injuries in the best way that we know we can.

What will I be doing? I will collect valuable information about you and your injury. Before you get discharged from hospital, I will ask you to do a few fun activities like climbing stairs, walking, running, and hopping. I will then make a special time with your mom or dad to bring you back 3 months after you get discharged from hospital to redo the same fun activities. This time you may even be able to do more than you could when you were in hospital!

If you do not want to take part in this project, you must tell the physiotherapist and she will ask you to write your name on a piece of paper and you will no longer be included in the study. Your mom or dad will also have to sign a piece of paper saying that they do not want you to be included in the project. Even if you do not want to be included in the study you can still come to physiotherapy for all your therapy and the physiotherapist will not be angry or upset with you.

Just to make sure that the information stays a secret, I will not put your name on the piece of paper with all the results.

Thank you for helping me and being a part of my project.

APPENDIX 8: CONSENT FORMS

PARENT CONSENT FORM

I _____ understand the purpose of this project and give consent for my child _____ to participate in the Traumatic Brain Injury research study. I have read and understand the information provided to me and all my questions have been answered. I am fully aware of the procedures and the fact that the research study will not harm my child in any way. I am aware that I may withdraw my child from the research without prejudice towards myself or my child.

_____	_____
Parent/Caregiver	Researcher
_____	_____
Date	Date

CHILD ASSENT FORM

I _____ give permission to test me in this project. I understand what this project is about and understand what I have to do to be part of the study. I understand what has been explained to me. Any questions that I had have been answered. I know that taking part in this project will not harm me in any way. I understand that I am allowed to say if I do not want to be evaluated in the project at any time.

_____ _____

Patient Researcher

_____ _____

Date Date

APPENDIX 9: DATA CAPTURING SHEET

DATA SHEET

PATIENT INFORMATION				
Patient study number			**Age**	
Date of admission	__/__/20__		**Date of discharge**	__/___/20__
Sex	Male	Female	**Length of stay (LOS- days)**	

CLINICAL INFORMATION						
Mechanism of injury (MOI)	**Penetrating 1**	Gunshot 1	Stab 2	Other 3		
	Blunt 2	MVA 1	PVA 2	NAI 3	Fall on head 4 Object fall on head 5	
	MVA	Restrained 1	Unrestrained 2			
	Initial GCS	____/15				
	LOC	Y 1	N 0 unsure 2 **vomiting** Y 1 N 0 unsure 2 **seizures** Y 1 N 0 unsure 2			
	Incident witnessed	Y 1	N0			
	Transport	Private	1		EMS 2	
	If EMS	Intubation	Y 1		N 0	
Type of TBI	**CT brain**	Y 1	N 0	NAD 1	SAH 2	SDH 3
	ICB 4	DAI 5	BOS 6	Pneumo-cephalus 7	Haematoma 8	IVH 9 EDH 10
Secondary complications **Y 1 /N 0**	Cerebral oedema 1	Seizures 2	Hypotension/ hypertension 3		Hypoxia 4	Raised ICP 5
Associated injuries (orthopaedic) **Y 1 /N 0**	**Fractures/dislocations [1]**	Upper limb 1	LL 2	Pelvic 3	Rib 4	Facial skull 5 6
	Other/specify 7					
Fractures=1 **STI=2** **M&S= 3**	**Mx [ORIF (1)/EX-FIX (2)/conservative (3)]**					
ORIF= 1 **EX-FIX= 2**	**Soft tissue injuries [2]**	Upper limb 1	LL 2	Pelvic 3	Chest 4 facial 5	skull/scalp 6 orbital/eye 7

Conservative=3 **Debridement= 1** **SSG= 2**	**Mx [debridement (1)/SSG (2)] and number of each surgery**					
	Other/specify					
Associated injuries (medical and surgical) [3]	Pneumothorax 1	Haemothorax 2	Lung contusion 3		Internal organ damage (specify) 4	
	Laparotomy 5	Trachy 6	PEG 7		Dialysis other 8	9
Pharmacological management						

RESUS					
Intubated on arrival	Y 1		N 0		
ICU admission	Y 1		N 0		
Length of stay in ICU (days)					
Mode of ventilation	SIMV 1	Pressure control (PC) 2	pressure support (PS) 3	Volume control (VC) 4	CPAP 5
Length of ventilation (days)			**CPR**	Y (when) 1	N 0
Neuroprotective ventilation	Y 1		N 0	Number of days not documented 2	
Hypothermia	Y 1		N 0	Number of days not documented 2	
ICP monitoring	Y 1		N 0		
Neurosurgery consult	Y 1		N 0		

SOCIAL CIRCUMSTANCES AND FAMILY SUPPORT					
Primary caregiver		**Marital status**	Single 1	Married 2	Divorced 3
Number of people living in the house		**Living conditions** House 1	Hostel 2	Shack 3	Flat 4 Room 5
Number of dependants		**Work** employed 1	Unemployed 2	Social grant	Y 1 N 0
Highest level of education		**Mode of transport**	Taxi 1	Private car 2	Other 3
Home language		**Cost of transport return (pp)**		**No of taxis to hospital (return)**	

APPENDIX 10 GROSS MOTOR FUNCTION MEASURE-88

GROSS MOTOR FUNCTION MEASURE (GMFM)
SCORE SHEET (GMFM-88 and GMFM-66 scoring)

Child's Name: _____ ID#: _____

Assessment Date: _____
year / month / day

GMFCS Level[1]:
☐ I ☐ II ☐ III ☐ IV ☐ V

Date of Birth: _____
year / month / day

Chronological Age: _____
year / month / day

Evaluator's Name: _____

Testing Condition (e.g., room, clothing, time, others present):

_____

The GMFM is a standardized observational instrument designed and validated to measure change in gross motor function over time in children with cerebral palsy. The scoring key is meant to be a general guideline. However, most of the items have specific descriptors for each score. It is imperative that the guidelines contained in the manual be used for scoring each item.

SCORING KEY

0 = does not initiate
1 = initiates
2 = partially completes
3 = completes
9 (or leave blank) = not tested (NT) [used for the GMAE-2 scoring*]

It is important to differentiate a true score of "0" (child does not initiate) from an item which is Not Tested (NT) if you are interested in using the GMFM-66 Ability Estimator (GMAE) Software.

*The GMAE-2 software is available for downloading from www.canchild.ca for those who have purchased the GMFM manual. The GMFM-66 is only valid for use with children who have cerebral palsy.

Contact for Research Group:
CanChild Centre for Childhood Disability Research,
Institute for Applied Health Sciences, McMaster University,
1400 Main St. W., Room 408,
Hamilton, ON Canada L8S 1C7
Email: canchild@mcmaster.ca Website: www.canchild.ca

[1]GMFCS level is a rating of severity of motor function. Definitions for the GMFCS-E&R (expanded & revised) are found in Palisano et al. (2008). Developmental Medicine & Child Neurology. 50:744-750 and in the GMAE-2 scoring software. http://motorgrowth.canchild.ca/en/GMFCS/resources/GMFCS-ER.pdf

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Check (3) **the appropriate score:** if an item is not tested (NT), circle the item number on the right column

	Item	A: LYING & ROLLING	SCORE				NT
	1.	SUP, HEAD IN MIDLINE: TURNS HEAD WITH EXTREMITIES SYMMETRICAL	0☐	1☐	2☐	3☐	1.
*	2.	SUP: BRINGS HANDS TO MIDLINE, FINGERS ONE WITH THE OTHER	0☐	1☐	2☐	3☐	2.
	3.	SUP: LIFTS HEAD 45°	0☐	1☐	2☐	3☐	3.
	4.	SUP: FLEXES R HIP & KNEE THROUGH FULL RANGE	0☐	1☐	2☐	3☐	4.
	5.	SUP: FLEXES L HIP & KNEE THROUGH FULL RANGE	0☐	1☐	2☐	3☐	5.
*	6.	SUP: REACHES OUT WITH R ARM, HAND CROSSES MIDLINE TOWARD TOY	0☐	1☐	2☐	3☐	6.
*	7.	SUP: REACHES OUT WITH L ARM, HAND CROSSES MIDLINE TOWARD TOY	0☐	1☐	2☐	3☐	7.
	8.	SUP: ROLLS TO PR OVER R SIDE	0☐	1☐	2☐	3☐	8.
	9.	SUP: ROLLS TO PR OVER L SIDE	0☐	1☐	2☐	3☐	9.
*	10.	PR: LIFTS HEAD UPRIGHT	0☐	1☐	2☐	3☐	10.
	11.	PR ON FOREARMS: LIFTS HEAD UPRIGHT, ELBOWS EXT., CHEST RAISED	0☐	1☐	2☐	3☐	11.
	12.	PR ON FOREARMS: WEIGHT ON R FOREARM, FULLY EXTENDS OPPOSITE ARM FORWARD	0☐	1☐	2☐	3☐	12.
	13.	PR ON FOREARMS: WEIGHT ON L FOREARM, FULLY EXTENDS OPPOSITE ARM FORWARD	0☐	1☐	2☐	3☐	13.
	14.	PR: ROLLS TO SUP OVER R SIDE	0☐	1☐	2☐	3☐	14.
	15.	PR: ROLLS TO SUP OVER L SIDE	0☐	1☐	2☐	3☐	15.
	16.	PR: PIVOTS TO R 90° USING EXTREMITIES	0☐	1☐	2☐	3☐	16.
	17.	PR: PIVOTS TO L 90° USING EXTREMITIES	0☐	1☐	2☐	3☐	17.
		TOTAL DIMENSION A					

	Item	B: SITTING	SCORE				NT
*	18.	SUP, HANDS GRASPED BY EXAMINER: PULLS SELF TO SITTING WITH HEAD CONTROL	0☐	1☐	2☐	3☐	18.
	19.	SUP: ROLLS TO R SIDE, ATTAINS SITTING	0☐	1☐	2☐	3☐	19.
	20.	SUP: ROLLS TO L SIDE, ATTAINS SITTING	0☐	1☐	2☐	3☐	20.
*	21.	SIT ON MAT, SUPPORTED AT THORAX BY THERAPIST: LIFTS HEAD UPRIGHT, MAINTAINS 3 SECONDS	0☐	1☐	2☐	3☐	21.
*	22.	SIT ON MAT, SUPPORTED AT THORAX BY THERAPIST: LIFTS HEAD MIDLINE, MAINTAINS 10 SECONDS	0☐	1☐	2☐	3☐	22.
*	23.	SIT ON MAT, ARM(S) PROPPING: MAINTAINS, 5 SECONDS	0☐	1☐	2☐	3☐	23.
*	24.	SIT ON MAT: MAINTAIN, ARMS FREE, 3 SECONDS	0☐	1☐	2☐	3☐	24.
*	25.	SIT ON MAT WITH SMALL TOY IN FRONT: LEANS FORWARD, TOUCHESTOY, RE-ERECTS WITHOUT ARM PROPPING	0☐	1☐	2☐	3☐	25.
*	26.	SIT ON MAT: TOUCHES TOY PLACED 45° BEHIND CHILD'S R SIDE, RETURNS TO START	0☐	1☐	2☐	3☐	26.
*	27.	SIT ON MAT: TOUCHES TOY PLACED 45° BEHIND CHILD'S L SIDE, RETURNS TO START	0☐	1☐	2☐	3☐	27.
	28.	R SIDE SIT: MAINTAINS, ARMS FREE, 5 SECONDS	0☐	1☐	2☐	3☐	28.
	29.	L SIDE SIT: MAINTAINS, ARMS FREE, 5 SECONDS	0☐	1☐	2☐	3☐	29.
*	30.	SIT ON MAT: LOWERS TO PR WITH CONTROL	0☐	1☐	2☐	3☐	30.
*	31.	SIT ON MAT WITH FEET IN FRONT: ATTAINS 4 POINT OVER R SIDE	0☐	1☐	2☐	3☐	31.
*	32.	SIT ON MAT WITH FEET IN FRONT: ATTAINS 4 POINT OVER L SIDE	0☐	1☐	2☐	3☐	32.
	33.	SIT ON MAT: PIVOTS 90°, WITHOUT ARMS ASSISTING	0☐	1☐	2☐	3☐	33.
*	34.	SIT ON BENCH: MAINTAINS, ARMS AND FEET FREE, 10 SECONDS	0☐	1☐	2☐	3☐	34.
*	35.	STD: ATTAINS SIT ON SMALL BENCH	0☐	1☐	2☐	3☐	35.
*	36.	ON THE FLOOR: ATTAINS SIT ON SMALL BENCH	0☐	1☐	2☐	3☐	36.
*	37.	ON THE FLOOR: ATTAINS SIT ON LARGE BENCH	0☐	1☐	2☐	3☐	37.
		TOTAL DIMENSION B					

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Item	C: CRAWLING & KNEELING	SCORE				NT
38.	PR: CREEPS FORWARD 1.8m (6')	0☐	1☐	2☐	3☐	38.
* 39.	4 POINT: MAINTAINS, WEIGHT ON HANDS AND KNEES, 10 SECONDS	0☐	1☐	2☐	3☐	39.
* 40.	4 POINT: ATTAINS SIT ARMS FREE	0☐	1☐	2☐	3☐	40.
* 41.	PR: ATTAINS 4 POINT, WEIGHT ON HANDS AND KNEES	0☐	1☐	2☐	3☐	41.
* 42.	4 POINT: REACHES FORWARD WITH R ARM, HAND ABOVE SHOULDER LEVEL	0☐	1☐	2☐	3☐	42.
* 43.	4 POINT: REACHES FORWARD WITH L ARM, HAND ABOVE SHOULDER LEVEL	0☐	1☐	2☐	3☐	43.
* 44.	4 POINT: CRAWLS OR HITCHES FORWARD 1.8m(6')	0☐	1☐	2☐	3☐	44.
* 45.	4 POINT: CRAWLS RECIPROCALLY FORWARD1.8m (6')	0☐	1☐	2☐	3☐	45.
* 46.	4 POINT: CRAWLS UP 4 STEPS ON HANDS AND KNEES/FEET	0☐	1☐	2☐	3☐	46.
47.	4 POINT: CRAWLS BACKWARDS DOWN 4 STEPS ON HANDS AND KNEES/FEET	0☐	1☐	2☐	3☐	47.
* 48.	SIT ON MAT: ATTAINS HIGH KN USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	48.
49.	HIGH KN: ATTAINS HALF KN ON R KNEE USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	49.
50.	HIGH KN: ATTAINS HALF KN ON L KNEE USING ARMS, MAINTAINS, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	50.
* 51.	HIGH KN: KN WALKS FORWARD 10 STEPS, ARMS FREE	0☐	1☐	2☐	3☐	51.

TOTAL DIMENSION C ☐

Item	D: STANDING	SCORE				NT
* 52.	ON THE FLOOR: PULLS TO STD AT LARGE BENCH	0☐	1☐	2☐	3☐	52.
* 53.	STD: MAINTAINS, ARMS FREE, 3 SECONDS	0☐	1☐	2☐	3☐	53.
* 54.	STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS R FOOT, 3 SECONDS	0☐	1☐	2☐	3☐	54.
* 55.	STD: HOLDING ON TO LARGE BENCH WITH ONE HAND, LIFTS L FOOT, 3 SECONDS	0☐	1☐	2☐	3☐	55.
* 56.	STD: MAINTAINS, ARMS FREE, 20 SECONDS	0☐	1☐	2☐	3☐	56.
* 57.	STD: LIFTS L FOOT, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	57.
* 58.	STD: LIFTS R FOOT, ARMS FREE, 10 SECONDS	0☐	1☐	2☐	3☐	58.
* 59.	SIT ON SMALL BENCH: ATTAINS STD WITHOUT USING ARMS	0☐	1☐	2☐	3☐	59.
* 60.	HIGH KN: ATTAINS STD THROUGH HALF KN ON R KNEE, WITHOUT USING ARMS	0☐	1☐	2☐	3☐	60.
* 61.	HIGH KN: ATTAINS STD THROUGH HALF KN ON L KNEE, WITHOUT USING ARMS	0☐	1☐	2☐	3☐	61.
* 62.	STD: LOWERS TO SIT ON FLOOR WITH CONTROL, ARMS FREE	0☐	1☐	2☐	3☐	62.
* 63.	STD: ATTAINS SQUAT, ARMS FREE	0☐	1☐	2☐	3☐	63.
* 64.	STD: PICKS UP OBJECT FROM FLOOR, ARMS FREE, RETURNS TO STAND	0☐	1☐	2☐	3☐	64.

TOTAL DIMENSION D ☐

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Item		E: WALKING, RUNNING & JUMPING	SCORE				NT
*	65.	STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO R	0☐	1☐	2☐	3☐	65.
*	66.	STD, 2 HANDS ON LARGE BENCH: CRUISES 5 STEPS TO L	0☐	1☐	2☐	3☐	66.
*	67.	STD, 2 HANDS HELD: WALKS FORWARD 10 STEPS	0☐	1☐	2☐	3☐	67.
*	68.	STD, 1 HAND HELD: WALKS FORWARD 10 STEPS	0☐	1☐	2☐	3☐	68.
*	69.	STD: WALKS FORWARD 10 STEPS	0☐	1☐	2☐	3☐	69.
*	70.	STD: WALKS FORWARD 10 STEPS, STOPS, TURNS 180°, RETURNS	0☐	1☐	2☐	3☐	70.
*	71.	STD: WALKS BACKWARD 10 STEPS	0☐	1☐	2☐	3☐	71.
*	72.	STD: WALKS FORWARD 10 STEPS, CARRYING A LARGE OBJECT WITH 2 HANDS	0☐	1☐	2☐	3☐	72.
*	73.	STD: WALKS FORWARD 10 CONSECUTIVE STEPS BETWEEN PARALLEL LINES 20cm (8") APART	0☐	1☐	2☐	3☐	73.
*	74.	STD: WALKS FORWARD 10 CONSECUTIVE STEPS ON A STRAIGHT LINE 2cm (3/4") WIDE	0☐	1☐	2☐	3☐	74.
*	75.	STD: STEPS OVER STICK AT KNEE LEVEL, R FOOT LEADING	0☐	1☐	2☐	3☐	75.
*	76.	STD: STEPS OVER STICK AT KNEE LEVEL, L FOOT LEADING	0☐	1☐	2☐	3☐	76.
*	77.	STD: RUNS 4.5m (15'), STOPS & RETURNS	0☐	1☐	2☐	3☐	77.
*	78.	STD: KICKS BALL WITH R FOOT	0☐	1☐	2☐	3☐	78.
*	79.	STD: KICKS BALL WITH L FOOT	0☐	1☐	2☐	3☐	79.
*	80.	STD: JUMPS 30cm (12") HIGH, BOTH FEET SIMULTANEOUSLY	0☐	1☐	2☐	3☐	80.
*	81.	STD: JUMPS FORWARD 30 cm (12"), BOTH FEET SIMULTANEOUSLY	0☐	1☐	2☐	3☐	81.
*	82.	STD ON R FOOT: HOPS ON R FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE	0☐	1☐	2☐	3☐	82.
*	83.	STD ON L FOOT: HOPS ON L FOOT 10 TIMES WITHIN A 60cm (24") CIRCLE	0☐	1☐	2☐	3☐	83.
*	84.	STD, HOLDING 1 RAIL: WALKS UP 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET	0☐	1☐	2☐	3☐	84.
*	85.	STD, HOLDING 1 RAIL: WALKS DOWN 4 STEPS, HOLDING 1 RAIL, ALTERNATING FEET	0☐	1☐	2☐	3☐	85.
*	86.	STD: WALKS UP 4 STEPS, ALTERNATING FEET	0☐	1☐	2☐	3☐	86.
*	87.	STD: WALKS DOWN 4 STEPS, ALTERNATING FEET	0☐	1☐	2☐	3☐	87.
*	88.	STD ON 15cm (6") STEP: JUMPS OFF, BOTH FEET SIMULTANEOUSLY	0☐	1☐	2☐	3☐	88.

TOTAL DIMENSION E ☐

Was this assessment indicative of this child's "regular" performance? YES ☐ NO ☐
COMMENTS:

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GMFM-88 SUMMARY SCORE

DIMENSION	CALCULATION OF DIMENSION % SCORES	GOAL AREA (indicated with ✓ check)
A. Lying & Rolling	$\frac{\text{Total Dimension A}}{51} = \frac{\quad}{51} \times 100 = \quad\%$	A. ☐
B. Sitting	$\frac{\text{Total Dimension B}}{60} = \frac{\quad}{60} \times 100 = \quad\%$	B. ☐
C. Crawling & Kneeling	$\frac{\text{Total Dimension C}}{42} = \frac{\quad}{42} \times 100 = \quad\%$	C. ☐
D. Standing	$\frac{\text{Total Dimension D}}{39} = \frac{\quad}{39} \times 100 = \quad\%$	D. ☐
E. Walking, Running & Jumping	$\frac{\text{Total Dimension E}}{72} = \frac{\quad}{72} \times 100 = \quad\%$	E. ☐

TOTAL SCORE = $\frac{\%A + \%B + \%C + \%D + \%E}{\text{Total \# of Dimensions}}$

$= \frac{\quad}{5} = \quad = \quad\%$

GOAL TOTAL SCORE = $\frac{\text{Sum of \%scores for each dimension identified as a goal area}}{\text{\# of Goal areas}}$

$= \quad = \quad\%$

GMFM-66 Gross Motor Ability Estimator Score [1]

GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

previous GMFM-66 Score = _____ _____ to _____ 95% Confidence Intervals

change in GMFM-66 = _____

[1] from the Gross Motor Ability Estimator (GMAE-2) Software

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TESTING WITH AIDS/ORTHOSES USING THE GMFM-88

Indicate below with a check (4) which aid/orthosis was used and what dimension it was first applied. (There may be more than one).

AID	Dimension	Orthosis	Dimension
Rollator/pusher	☐ _____	Hip Control	☐ _____
Walker	☐ _____	Knee Control	☐ _____
H Frame crutches	☐ _____	Ankle-foot Control	☐ _____
Crutches	☐ _____	Foot Control	☐ _____
Quad Cane	☐ _____	Shoes	☐ _____
Cane	☐ _____	None	☐ _____
None	☐ _____	Other _____ (please specify)	☐ _____
Other _____ (please specify)	☐ _____		

GMFM-88 SUMMARY SCORE USING AIDS/ORTHOSES

DIMENSION	CALCULATION OF DIMENSION % SCORES	GOAL AREA (indicated with ✓ check)
F. Lying & Rolling	$\frac{\text{Total Dimension A}}{51} = \frac{\quad}{51} \times 100 = \quad\%$	A. ☐
G. Sitting	$\frac{\text{Total Dimension B}}{60} = \frac{\quad}{60} \times 100 = \quad\%$	B. ☐
H. Crawling & Kneeling	$\frac{\text{Total Dimension C}}{42} = \frac{\quad}{42} \times 100 = \quad\%$	C. ☐
I. Standing	$\frac{\text{Total Dimension D}}{39} = \frac{\quad}{39} \times 100 = \quad\%$	D. ☐
J. Walking, Running & Jumping	$\frac{\text{Total Dimension E}}{72} = \frac{\quad}{72} \times 100 = \quad\%$	E. ☐

TOTAL SCORE = $\frac{\%A + \%B + \%C + \%D + \%E}{\text{Total \# of Dimensions}}$

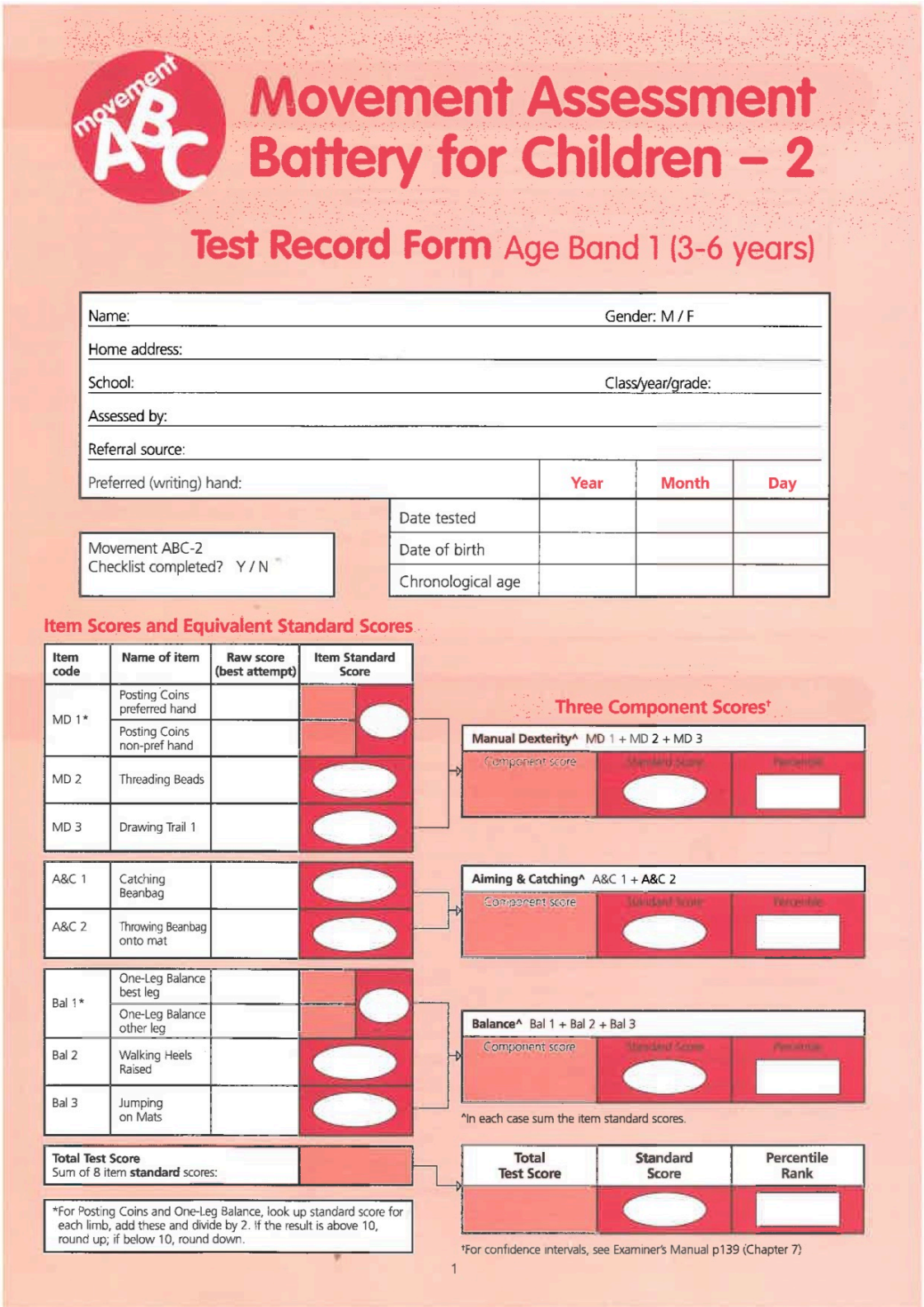
$= \frac{\quad}{5} = \quad = \quad\%$

GOAL TOTAL SCORE = $\frac{\text{Sum of \%scores for each dimension identified as a goal area}}{\text{\# of Goal areas}}$

$= \quad = \quad\%$

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APPENDIX 11: MABC-II



Movement Assessment Battery for Children – 2

Test Record Form Age Band 1 (3-6 years)

Name: Gender: M / F

Home address:

School: Class/year/grade:

Assessed by:

Referral source:

Preferred (writing) hand:

Movement ABC-2 Checklist completed? Y / N

	Year	Month	Day
Date tested			
Date of birth			
Chronological age			

Item Scores and Equivalent Standard Scores

Item code	Name of item	Raw score (best attempt)	Item Standard Score
MD 1*	Posting Coins preferred hand		
	Posting Coins non-pref hand		
MD 2	Threading Beads		
MD 3	Drawing Trail 1		
A&C 1	Catching Beanbag		
A&C 2	Throwing Beanbag onto mat		
Bal 1*	One-Leg Balance best leg		
	One-Leg Balance other leg		
Bal 2	Walking Heels Raised		
Bal 3	Jumping on Mats		
Total Test Score Sum of 8 item **standard** scores:			

*For Posting Coins and One-Leg Balance, look up standard score for each limb, add these and divide by 2. If the result is above 10, round up; if below 10, round down.

Three Component Scores†

Manual Dexterity^ MD 1 + MD 2 + MD 3		
Component score	Standard score	Percentile

Aiming & Catching^ A&C 1 + A&C 2		
Component score	Standard score	Percentile

Balance^ Bal 1 + Bal 2 + Bal 3		
Component score	Standard score	Percentile

^In each case sum the item standard scores.

Total Test Score	Standard Score	Percentile Rank

†For confidence intervals, see Examiner's Manual p139 (Chapter 7)

1

Manual Dexterity 1: POSTING COINS

Note: 6 coins for 3-4 years, 12 for 5-6 years

Record: Preferred hand: R / L (should be same as for Drawing Trail); Time taken (secs); **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)

Preferred hand		Only administer a second trial if the first trial takes longer than the time stated below:							Non-preferred hand		Only administer a second trial if the first trial takes longer than the time stated below:						
Trial 1			3:0-3:5	3:6-3:11	4:0-4:5	4:6-4:11	5:0-5:11	6:0-6:11	Trial 1			3:0-3:5	3:6-3:11	4:0-4:5	4:6-4:11	5:0-5:11	6:0-6:11
Trial 2			16 secs	15 secs	13 secs	12 secs	22 secs	21 secs	Trial 2			21 secs	18 secs	15 secs	14 secs	25 secs	22 secs

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds head too close to task ☐
- Holds head at an odd angle ☐
- Does not look at slot while inserting coins ☐
- Does not use pincer grip to pick up coins ☐
- Exaggerates finger movements in releasing coins ☐
- Does not use the supporting hand to hold box steady ☐
- Does extremely poorly with one hand (asymmetry striking) ☐
- Changes hands or uses both hands during a trial ☐
- Hand movements are jerky ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Misaligns coins with respect to slot ☐
- Uses excessive force when inserting coins ☐
- Is exceptionally slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐
- **Other** _____

Comments: _____

Manual Dexterity 2: THREADING BEADS

Note: 6 beads for 3-4 years, 12 for 5-6 years

Record: Time taken (secs); **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)

No. of seconds		Only administer a second trial if the first trial takes longer than the time stated below:					
Trial 1		3:0-3:5	3:6-3:11	4:0-4:5	4:6-4:11	5:0-5:11	6:0-6:11
Trial 2		78 secs	73 secs	53 secs	41 secs	60 secs	55 secs

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds materials too close to face ☐
- Holds head at an odd angle ☐
- Does not look at bead while inserting tip of lace ☐
- Does not use pincer grip to pick up beads ☐
- Holds lace too far from tip ☐
- Holds lace too near tip ☐
- Finds it difficult to push tip with one hand and pull it through with the other ☐
- Changes threading hands during a trial ☐
- Hand movements are jerky ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Sometimes misses hole with tip of lace ☐
- Picks up beads the wrong way round ☐
- Is exceptionally slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐
- **Other** _____

Comments: _____

Manual Dexterity 3: DRAWING TRAIL 1

Note: Berol pen to be used

Record: Hand used: R/L/Both; No. of errors; **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)
Number of errors should be counted after testing using scoring criteria provided in Appendix A of the Manual.

	No. of errors
Trial 1	
Trial 2	



Do not administer a second trial if the child completes the first trial perfectly (i.e. no errors).

Qualitative observations

Posture/body control

- ☐ Sitting posture is poor
- ☐ Holds head too near paper
- ☐ Holds head at an odd angle
- ☐ Does not look at trail
- ☐ Holds pen with an odd/immature grip
- ☐ Holds pen too far from point
- ☐ Holds pen too close to point
- ☐ Does not hold paper still
- ☐ Changes hands during a trial
- ☐ Moves constantly/fidgets

Adjustment to task requirements

- ☐ Progresses in short jerky movements
- ☐ Uses excessive force, presses very hard on paper
- ☐ Is exceptionally slow
- ☐ Goes too fast for accuracy
- **Other** _____

Comments: _____

Aiming & Catching 1: CATCHING BEANBAG

Note: Trapping allowed for 3-4 year olds, not for 5-6

Record: Number of correctly executed catches out of 10; **R** for refusal; **I** if inappropriate (note reasons below)

Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total: _____

Qualitative observations

Posture/body control

- ☐ Standing posture is poor
- ☐ Does not follow trajectory of beanbag with eyes
- ☐ Turns away or closes eyes as beanbag approaches
- ☐ Arms are not raised symmetrically for catching
- ☐ Holds hands out flat with fingers stiff as the beanbag approaches
- ☐ Hands and arms held wide apart, fingers extended
- ☐ Fingers close too early or too late
- ☐ Does not move until beanbag strikes body
- ☐ Movements lack fluency

Adjustment to task requirements

- ☐ Does not adjust body position for catching
- ☐ Does not adjust position of feet as necessary
- ☐ Does not adjust to height of throw
- ☐ Does not adjust to direction of throw
- ☐ Does not adjust to force of throw
- **Other** _____

Comments: _____

Aiming & Catching 2: THROWING BEANBAG ONTO MAT

Note: Target is the whole mat, not just the orange circle

Record: Hand used: R / L / Both; Number of successful hits; **R** for refusal; **I** if inappropriate (note reasons below)

Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total:_____

Qualitative observations

Posture/body control

- Balance while throwing is poor ☐
- Does not keep eyes on target ☐
- Does not use a pendular swing of the arm ☐
- Does not follow through with the throwing arm ☐
- Releases beanbag too early or too late ☐
- Changes hands from trial to trial ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Errors are consistently to one side of target (asymmetry striking) ☐
- Control of direction variable ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- **Other** _____

Comments: _____

Balance 1: ONE-LEG BALANCE



Record: Time balanced (secs); **R** for refusal; **I** if inappropriate (note reasons below)

		No. of seconds			No. of seconds
Right Leg	Trial 1		Left Leg	Trial 1	
	Trial 2			Trial 2	



Do not administer a second trial if the child maintains balance for 30 seconds

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Sways wildly to try to maintain balance ☐
- Does not hold head and eyes steady ☐
- Makes no or few compensatory arm movements to help maintain balance ☐

- Exaggerated movements of arms and trunk disrupt balance ☐
- Does extremely poorly on one leg (asymmetry striking) ☐
- **Other** _____

Comments: _____

Balance 2: WALKING HEELS RAISED

Record: Number of correct consecutive steps from the beginning of the line; Whether entire line was walked successfully; **R** for refusal; **I** if inappropriate (note reasons below)

	No. of steps	Entire line?
Trial 1		YES / NO
Trial 2		YES / NO



Do not administer a second trial if the child completes 15 steps OR completes the whole line in fewer than 15 correctly executed steps.

Qualitative observations

Posture/body control

- ☐ Body appears rigid/tense
- ☐ Body appears limp/floppy
- ☐ Sways wildly to try to maintain balance
- ☐ Does not keep head steady
- ☐ Does not compensate with arms to maintain balance
- ☐ Exaggerated arm movements disrupt balance
- ☐ Is very wobbly when placing feet on line

Adjustment to task requirements

- ☐ Goes too fast for accuracy
- ☐ Individual movements lack smoothness and fluency
- ☐ Sequencing of steps is not smooth/pauses frequently
- **Other** _____

Comments: _____

Balance 3: JUMPING ON MATS

Note: Need only be continuous at 5-6 years

Record: Number of correct consecutive jumps (maximum of 5); **R** for refusal; **I** if inappropriate (note reasons below)

	No. of jumps
Trial 1	
Trial 2	



Do not administer a second trial if the child completes 5 perfect jumps on the first trial

Qualitative observations

Posture/body control

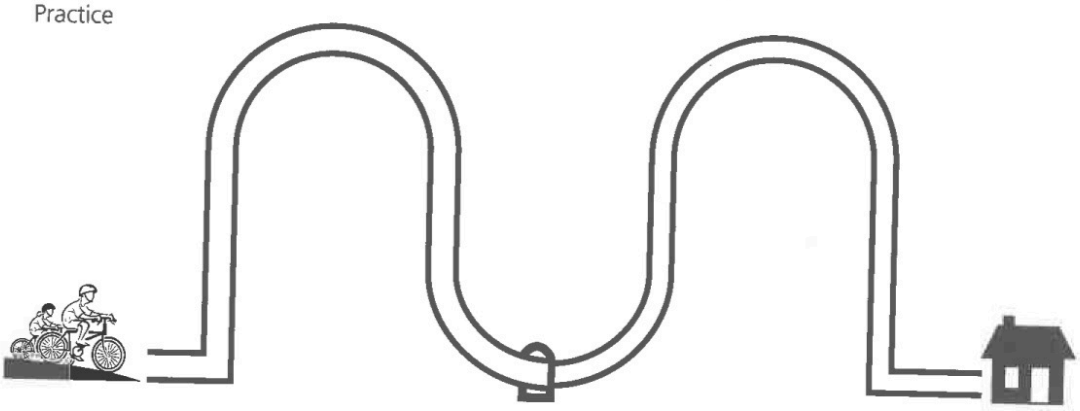
- ☐ Body appears rigid/tense
- ☐ Body appears limp/floppy
- ☐ Makes no preparatory crouch
- ☐ Jumps with stiff legs/on flat feet
- ☐ Arms swing out of phase with legs
- ☐ Arm movements are exaggerated
- ☐ Does not use arms to assist jump
- ☐ Lacks springiness/no push-off from feet
- ☐ Uneven take off and loss of symmetry in flight and landing
- ☐ Stumbles on landing

Adjustments to task requirements

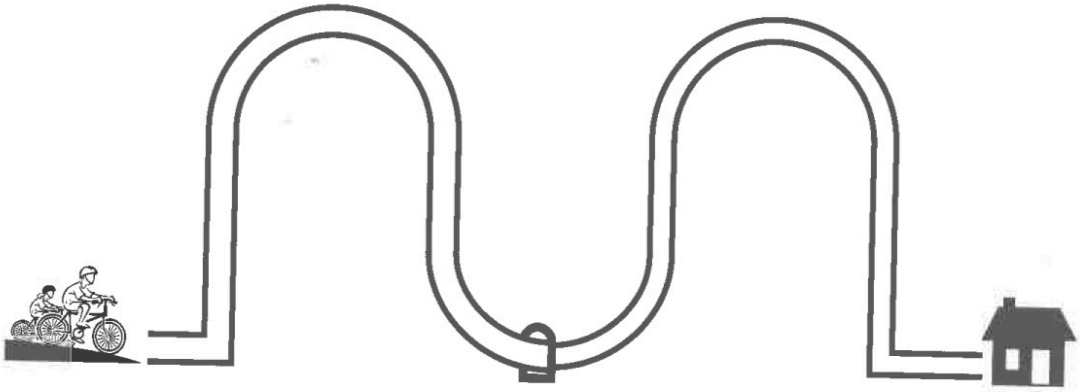
- ☐ Goes too fast for accuracy
- ☐ Does not combine upward and forward movements effectively
- ☐ Uses too much effort
- ☐ Movements are jerky
- **Other** _____

Comments: _____

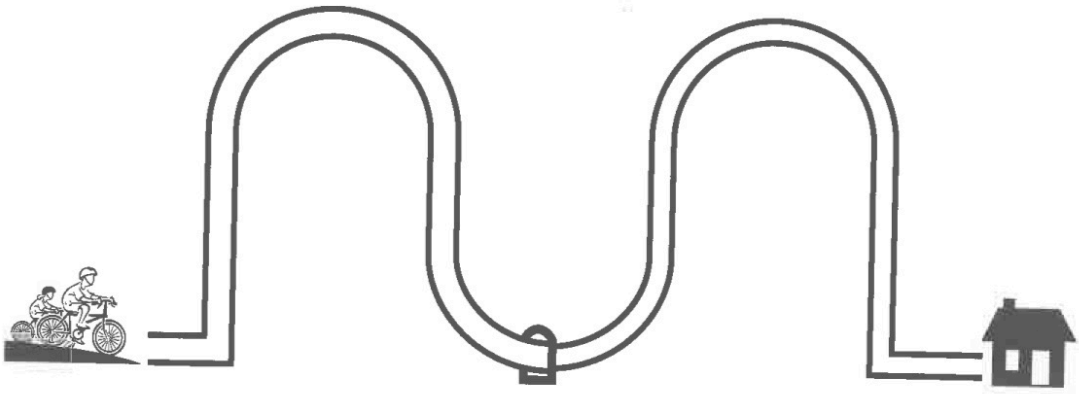
AB1
Practice



Trial 1



Trial 2



Movement Assessment Battery for Children – 2

Test Record Form Age Band 2 (7-10 years)

Name: Gender: M / F

Home address:

School: Class/year/grade:

Assessed by:

Referral source:

Preferred (writing) hand:	Year	Month	Day
Date tested			
Date of birth			
Chronological age			

Movement ABC-2 Checklist completed? Y / N

Item Scores and Equivalent Standard Scores

Item code	Name of item	Raw score (best attempt)	Item Standard Score
MD 1*	Placing Pegs preferred hand		
	Placing Pegs non-pref hand		
MD 2	Threading Lace		
MD 3	Drawing Trail 2		
A&C 1	Catching with Two Hands		
A&C 2	Throwing Beanbag onto Mat		
Bal 1*	One-Board Balance best leg		
	One-Board Balance other leg		
Bal 2	Walking Heel-to-Toe Forwards		
Bal 3*	Hopping on Mats best leg		
	Hopping on Mats other leg		
Total Test Score Sum of 8 item **standard** scores:			

*For Placing Pegs, One-Board Balance and Hopping on Mats, look up standard score for each limb, add these and divide by 2. If the result is above 10, round up; if below 10, round down.

Three Component Scores†

Manual Dexterity^ MD 1 + MD 2 + MD 3

Component score	Standard Score	Percentile

Aiming & Catching^ A&C 1 + A&C 2

Component score	Standard Score	Percentile

Balance^ Bal 1 + Bal 2 + Bal 3

Component score	Standard Score	Percentile

^In each case sum the item standard scores

Total Test Score	Standard Score	Percentile Rank

†For confidence intervals, see Examiner's Manual p139 (Chapter 7)

1

Manual Dexterity 1: PLACING PEGS



Record: Preferred hand: R / L (should be same as for Drawing Trail); Time taken (secs); F for failure; R for refusal; I if inappropriate (note reasons below)

Preferred hand	
Trial 1	
Trial 2	

Non-preferred hand	
Trial 1	
Trial 2	

Qualitative observations

Posture/body control

Sitting posture is poor ☐
Holds head too close to task ☐
Holds head at an odd angle ☐
Does not look at board while inserting pegs ☐
Does not use pincer grip to pick up pegs ☐
Exaggerates finger movements in releasing pegs ☐
Does not use the supporting hand to hold board steady ☐
Does extremely poorly with one hand (asymmetry striking) ☐
Changes hands or uses both hands during a trial ☐

Hand movements are jerky ☐
Moves constantly/fidgets ☐

Adjustment to task requirements

Misaligns pegs with respect to holes ☐
Uses excessive force when inserting pegs ☐
Is exceptionally slow/does not change speed from trial to trial ☐
Goes too fast for accuracy ☐
Other _____

Comments: _____

Manual Dexterity 2: THREADING LACE



Record: Time taken (secs); F for failure; R for refusal; I if inappropriate (note reasons below)

No. of seconds	
Trial 1	
Trial 2	

Qualitative observations

Posture/body control

Sitting posture is poor ☐
Holds materials too close to face ☐
Holds head at an odd angle ☐
Does not look at board while inserting tip of lace ☐
Does not use pincer grip to hold lace ☐
Holds lace too far from tip ☐
Holds lace too near tip ☐
Finds it difficult to push tip with one hand and pull it through with the other ☐

Changes threading hands during a trial ☐
Hand movements are jerky ☐
Moves constantly/fidgets ☐

Adjustment to task requirements

Sometimes misses hole with tip of lace ☐
Gets muddled in the threading sequence ☐
Is exceptionally slow/does not change speed from trial to trial ☐
Goes too fast for accuracy ☐
Other _____

Comments: _____

Manual Dexterity 3: DRAWING TRAIL 2

Note: BIC Atlantis pen to be used

Record: Hand used: R/L/Both; No. of errors; **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)
Number of errors should be counted after testing using scoring criteria provided in Appendix A of the Manual.

	No. of errors
Trial 1	
Trial 2	



Do not administer a second trial if the child completes the first trial perfectly (i.e. no errors).

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds head too near paper ☐
- Holds head at an odd angle ☐
- Does not look at trail ☐
- Holds pen with an odd/immature grip ☐
- Holds pen too far from point ☐
- Holds pen too close to point ☐
- Does not hold paper still ☐
- Changes hands during a trial ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Progresses in short jerky movements ☐
- Uses excessive force, presses very hard on paper ☐
- Is exceptionally slow ☐
- Goes too fast for accuracy ☐
- **Other** _____

Comments: _____

Aiming & Catching 1: CATCHING WITH TWO HANDS

Note: With a bounce at 7 and 8; without a bounce at 9 and 10

Record: Number of correctly executed catches; **R** for refusal; **I** if inappropriate (note reasons below)

Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total: _____

Qualitative observations

Posture/body control

- Standing posture is poor ☐
- Does not follow trajectory of ball with eyes ☐
- Turns away or closes eyes as ball approaches ☐
- Arms are not raised symmetrically for catching ☐
- Holds hands out flat with fingers stiff as the ball approaches ☐
- Hands and arms held wide apart, fingers extended ☐
- Arms and hands do not 'give' to meet impact of ball ☐
- Fingers close too early or too late ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Does not adjust body position for catching ☐
- Does not adjust position of feet as necessary ☐
- Judges force of throw poorly (too much or too little) ☐
- Does not adjust to height of rebound ☐
- Does not adjust to direction of rebound ☐
- Does not adjust to force of rebound ☐
- **Other** _____

Comments: _____

Aiming & Catching 2: THROWING BEANBAG ONTO MAT

Note: Target is the orange circle, not the whole mat

Record: Hand used: R / L / Both; Number of successful hits; **R** for refusal; **I** if inappropriate (note reasons below)

Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total:_____

Qualitative observations

Posture/body control

- Balance while throwing is poor ☐
- Does not keep eyes on target ☐
- Does not use a pendular swing of the arm ☐
- Does not follow through with the throwing arm ☐
- Releases beanbag too early or too late ☐
- Changes hands from trial to trial ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Errors are consistently to one side of target (asymmetry striking) ☐
- Control of direction variable ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- **Other** _____

Comments: _____

Balance 1: ONE-BOARD BALANCE



Record: Time balanced (secs); **R** for refusal; **I** if inappropriate (note reasons below)

		No. of seconds			No. of seconds
Right Leg	Trial 1		Left Leg	Trial 1	
	Trial 2			Trial 2	



Do not administer a second trial if the child maintains balance for 30 seconds

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Sways wildly to try to maintain balance ☐
- Does not hold head and eyes steady ☐
- Makes no or few compensatory arm movements to help maintain balance ☐

- Exaggerated movements of arms and trunk disrupt balance ☐
- Does extremely poorly on one leg (asymmetry striking) ☐
- **Other** _____

Comments: _____

Balance 2: WALKING HEEL-TO-TOE FORWARDS

Record: Number of correct consecutive steps from the beginning of the line; Whether entire line was walked successfully; **R** for refusal; **I** if inappropriate (note reasons below)

	No. of steps	Entire line?
Trial 1		YES / NO
Trial 2		YES / NO



Do not administer a second trial if the child completes 15 steps OR completes the whole line in fewer than 15 correctly executed steps.

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Sways wildly to try to maintain balance ☐
- Does not keep head steady ☐
- Does not compensate with arms to maintain balance ☐
- Exaggerated arm movements disrupt balance ☐
- Is very wobbly when placing feet on line ☐

Adjustment to task requirements

- Goes too fast for accuracy ☐
- Individual movements lack smoothness and fluency ☐
- Sequencing of steps is not smooth/pauses frequently ☐
- **Other** _____

Comments: _____

Balance 3: HOPPING ON MATS

Record: Number of correct consecutive hops (maximum of 5); **R** for refusal; **I** if inappropriate (note reasons below)

		No. of hops			No. of hops
Right Leg	Trial 1		Left Leg	Trial 1	
	Trial 2			Trial 2	



Do not administer a second trial if the child completes 5 perfect hops on the first trial

Qualitative observations

Posture/body control

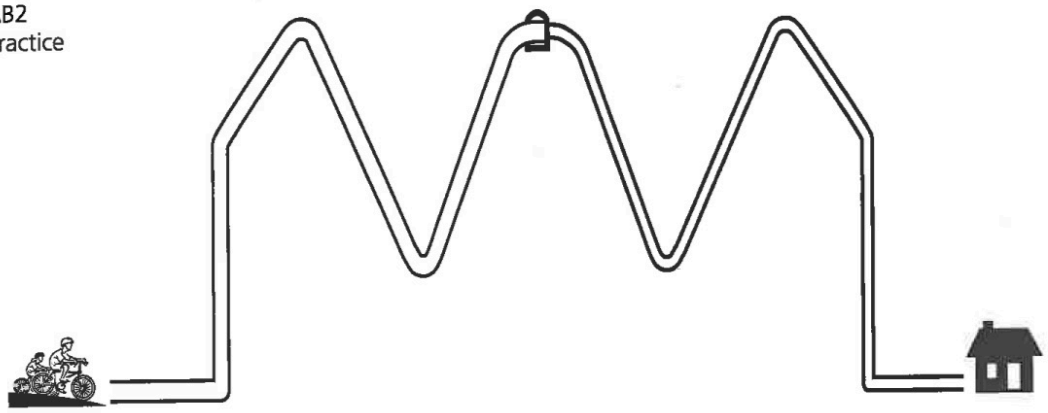
- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Non-supporting leg held up in front of body ☐
- Hops with stiff legs/on flat feet ☐
- Lacks springiness/no push-off from feet ☐
- Arm movements are exaggerated ☐
- Arms swing out of phase with legs ☐
- Does not use arms to assist hop ☐
- Stumbles on landing ☐
- Does extremely poorly with one leg (asymmetry striking) ☐

Adjustments to task requirements

- Goes too fast for accuracy ☐
- Does not combine upward and forward movements effectively ☐
- Uses too much effort ☐
- Movements are jerky ☐
- **Other** _____

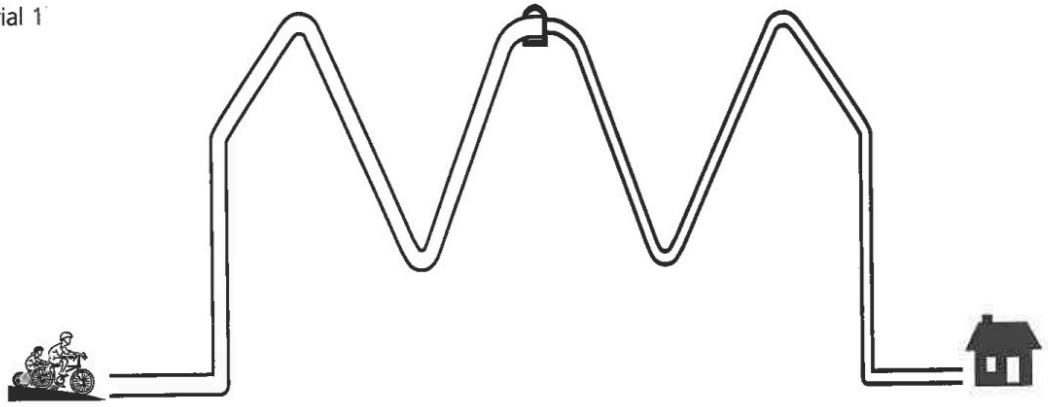
Comments: _____

AB2
Practice



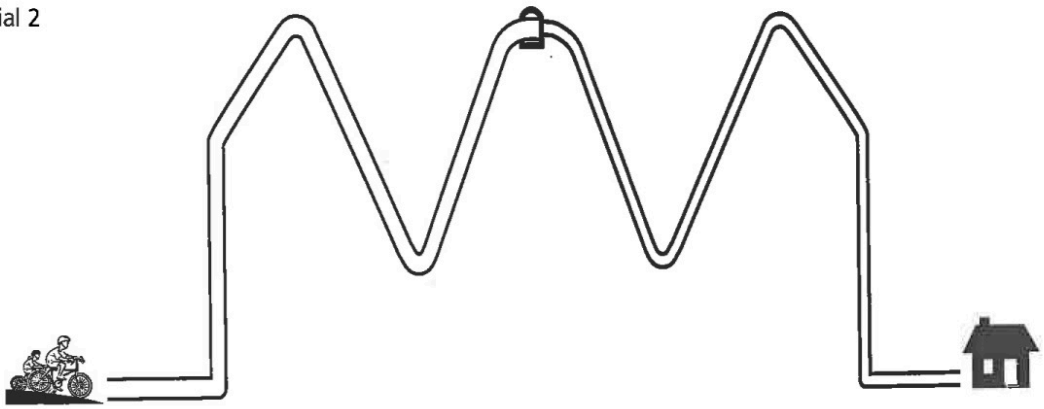
Name _____

Trial 1



Name _____

Trial 2



Name _____

Movement Assessment Battery for Children – 2

Test Record Form Age Band 3 (11-16 years)

Name: Gender: M / F

Home address:

School: Class/year/grade:

Assessed by:

Referral source:

Preferred (writing) hand:

Movement ABC-2 Checklist completed? Y / N

	Year	Month	Day
Date tested			
Date of birth			
Chronological age			

Item Scores and Equivalent Standard Scores

Item code	Name of item	Raw score (best attempt)	Item Standard Score
MD 1*	Turning Pegs preferred hand		
	Turning Pegs non-pref hand		
MD 2	Triangle with Nuts and Bolts		
MD 3	Drawing Trail 3		
A&C 1*	Catching with one Hand – best hand		
	Catching with one Hand – other hand		
A&C 2	Throwing at Wall Target		
Bal 1	Two-Board Balance		
Bal 2	Walking Toe-to-Heel Backwards		
Bal 3*	Zig-Zag Hopping best Leg		
	Zig-Zag Hopping other Leg		
Total Test Score Sum of 8 item **standard** scores:			

*For Turning Pegs, Catching with One Hand and Zig Zag Hopping, look up standard score for each limb, add these and divide by 2. If the result is above 10, round up; if below 10, round down.

Three Component Scores'

Manual Dexterity^ MD 1 + MD 2 + MD 3

Standard Score | Percentile

Aiming & Catching^ A&C 1 + A&C 2

Standard Score | Percentile

Balance^ Bal 1 + Bal 2 + Bal 3

Standard Score | Percentile

^In each case sum the item standard scores.

Total Test Score	Standard Score	Percentile Rank

^For confidence intervals, see Examiner's Manual p159 (Chapter 7)

Manual Dexterity 1: TURNING PEGS

Record: Preferred hand: R / L (should be same as for Drawing Trail); Time taken (secs); **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)

Preferred hand		Only administer a second trial if the first trial takes longer than the time stated below:							Non-preferred hand		Only administer a second trial if the first trial takes longer than the time stated below:						
Trial 1			11:0-11:11	12:0-12:11	13:0-13:11	14:0-14:11	15:0-15:11	16:0-16:11	Trial 1			11:0-11:11	12:0-12:11	13:0-13:11	14:0-14:11	15:0-15:11	16:0-16:11
Trial 2			25 secs	22 secs	22 secs	22 secs	22 secs	22 secs	Trial 2			31 secs	26 secs	26 secs	26 secs	26 secs	26 secs

Qualitative observations

Posture/body control

Sitting posture is poor ☐
Holds head too close to task ☐
Holds head at an odd angle ☐
Does not look while manipulating pegs ☐
Does not use pincer grip to pick up pegs ☐
Exaggerates finger movements in releasing pegs ☐
Does not use the supporting hand to hold board steady ☐
Does extremely poorly with one hand (asymmetry striking) ☐
Changes hands or uses both hands during a trial ☐

Hand movements are jerky ☐
Moves constantly/fidgets ☐

Adjustment to task requirements

Misaligns pegs with respect to holes ☐
Uses excessive force when inserting pegs ☐
Is exceptionally slow/does not change speed from trial to trial ☐
Goes too fast for accuracy ☐
Other _____

Comments: _____

Manual Dexterity 2: TRIANGLE WITH NUTS AND BOLTS

Record: Time taken (secs); **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)

No. of seconds		Only administer a second trial if the first trial takes longer than the time stated below:						
Trial 1			11:0-11:11	12:0-12:11	13:0-13:11	14:0-14:11	15:0-15:11	16:0-16:11
Trial 2			55 secs	48 secs	48 secs	48 secs	48 secs	48 secs

Qualitative observations

Posture/body control

Sitting posture is poor ☐
Holds materials too close to face ☐
Holds head at an odd angle ☐
Does not look at hole while inserting bolt ☐
Does not use pincer grip to hold nuts and bolts ☐
Finds it difficult to hold bolt with one hand and screw nut on with the other ☐
Changes hands during a trial ☐

Hand movements are jerky ☐
Moves constantly/fidgets ☐

Adjustment to task requirements

Sometimes misses hole with tip of bolt ☐
Gets muddled in the construction sequence ☐
Is exceptionally slow/does not change speed from trial to trial ☐
Goes too fast for accuracy ☐
Other _____

Comments: _____

Manual Dexterity 3: DRAWING TRAIL 3

Note: Bic Atlantis pen to be used

Record: Hand used: R/L/Both; No. of errors; **F** for failure; **R** for refusal; **I** if inappropriate (note reasons below)
Number of errors should be counted after testing using scoring criteria provided in Appendix A of the Manual.

	No. of errors
Trial 1	
Trial 2	



Do not administer a second trial if the child completes the first trial perfectly (i.e. no errors).

Qualitative observations

Posture/body control

- Sitting posture is poor ☐
- Holds head too near paper ☐
- Holds head at an odd angle ☐
- Does not look at trail ☐
- Holds pen with an odd/immature grip ☐
- Holds pen too far from point ☐
- Holds pen too close to point ☐
- Does not hold paper still ☐
- Changes hands during a trial ☐
- Moves constantly/fidgets ☐

Adjustment to task requirements

- Progresses in short jerky movements ☐
- Uses excessive force, presses very hard on paper ☐
- Is exceptionally slow ☐
- Goes too fast for accuracy ☐
- **Other** _____

Comments: _____

Aiming & Catching 1: CATCHING WITH ONE HAND

Record: Number of correctly executed catches; **R** for refusal; **I** if inappropriate (note reasons below)

Right Hand Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total: _____

Left Hand Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total: _____

Qualitative observations

Posture/body control

- Standing posture is poor ☐
- Does not follow trajectory of ball with eyes ☐
- Turns away or closes eyes as ball approaches ☐
- Holds hand out flat with fingers stiff as the ball rebounds ☐
- Hands and arms held wide apart, fingers extended ☐
- Arm and hand do not 'give' to meet impact of ball ☐
- Fingers close too early or too late ☐
- Does extremely poorly with one hand (asymmetry striking) ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Does not adjust body position for catching ☐
- Does not adjust position of feet as necessary ☐
- Judges force of throw poorly (too much or too little) ☐
- Does not adjust to height of rebound ☐
- Does not adjust to direction of rebound ☐
- Does not adjust to force of rebound ☐
- **Other** _____

Comments: _____

Aiming & Catching 2: THROWING AT WALL TARGET

Record: Hand used: R / L / Both; Number of successful hits; **R** for refusal; **I** if inappropriate (note reasons below)

Practice: ☐☐☐☐☐ 10 Trials: ☐☐☐☐☐☐☐☐☐☐ Total:_____

Qualitative observations

Posture/body control

- Balance while throwing is poor ☐
- Does not keep eyes on target ☐
- Does not follow through with the throwing arm ☐
- Releases ball too early or too late ☐
- Changes hands from trial to trial ☐
- Movements lack fluency ☐

Adjustment to task requirements

- Errors are consistently to one side of the target (asymmetry striking) ☐
- Control of direction is variable ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- **Other** _____

Comments: _____

Balance 1: TWO-BOARD BALANCE



Record: Time balanced (secs); **R** for refusal; **I** if inappropriate (note reasons below)

	No. of seconds
Trial 1	
Trial 2	



Do not administer a second trial if the child maintains balance for 30 seconds

Qualitative observations

Posture/body control

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Sways wildly to try to maintain balance ☐
- Does not hold head and eyes steady ☐
- Makes no or few compensatory arm movements to help maintain balance ☐
- Exaggerated movements of arms and trunk disrupt balance ☐
- Cannot hold feet in a straight line ☐
- **Other** _____

Comments: _____

Balance 2: WALKING TOE-TO-HEEL BACKWARDS

Record: Number of correct consecutive steps from the beginning of the line; Whether entire line was walked successfully; **R** for refusal; **I** if inappropriate (note reasons below)

	No. of steps	Entire line?
Trial 1		YES / NO
Trial 2		YES / NO

Do not administer a second trial if the child completes 15 steps OR completes the whole line in fewer than 15 correctly executed steps

Qualitative observations

Posture/body control

Body appears rigid/tense ☐
Body appears limp/floppy ☐
Sways wildly to try to maintain balance ☐
Does not look behind to check position on track ☐
Does not compensate with arms to maintain balance ☐
Exaggerated arm movements disrupt balance ☐
Is very wobbly when placing feet on line ☐

Adjustments to task requirements

Goes too fast for accuracy ☐
Individual movements lack smoothness and fluency ☐
Sequencing of steps is not smooth/pauses frequently ☐
Other _____

Comments: _____

Balance 3: ZIG-ZAG HOPPING

Record: Number of correct consecutive hops (maximum of 5); **R** for refusal; **I** if inappropriate (note reasons below)

		No. of hops			No. of hops
Right Leg	Trial 1		Left Leg	Trial 1	
	Trial 2			Trial 2	

Do not administer a second trial if the child completes 5 perfect hops on the first trial

Qualitative observations

Posture/body control

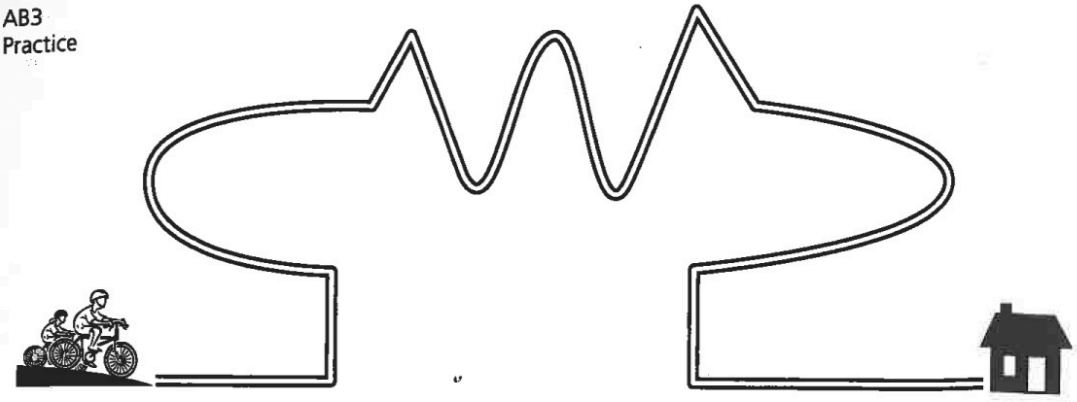
Body appears rigid/tense ☐
Body appears limp/floppy ☐
Non-supporting leg held up in front of body ☐
Hops with stiff legs/on flat feet ☐
Lacks springiness/no push-off from feet ☐
Arm movements are exaggerated ☐
Does not use arms to assist hop ☐
Stumbles on landing ☐
Does extremely poorly with one leg (asymmetry striking) ☐

Adjustments to task requirements

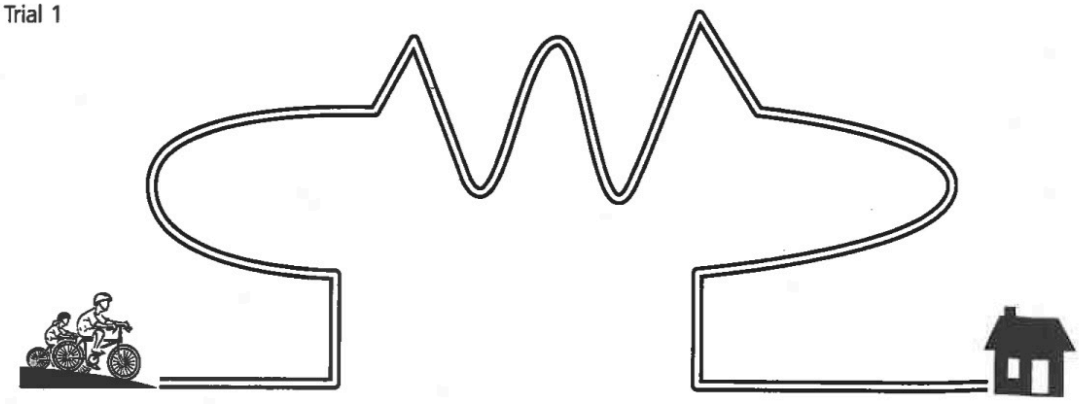
Goes too fast for accuracy ☐
Does not combine upward and forward movements effectively ☐
Uses too much effort ☐
Movements are jerky ☐
Other _____

Comments: _____

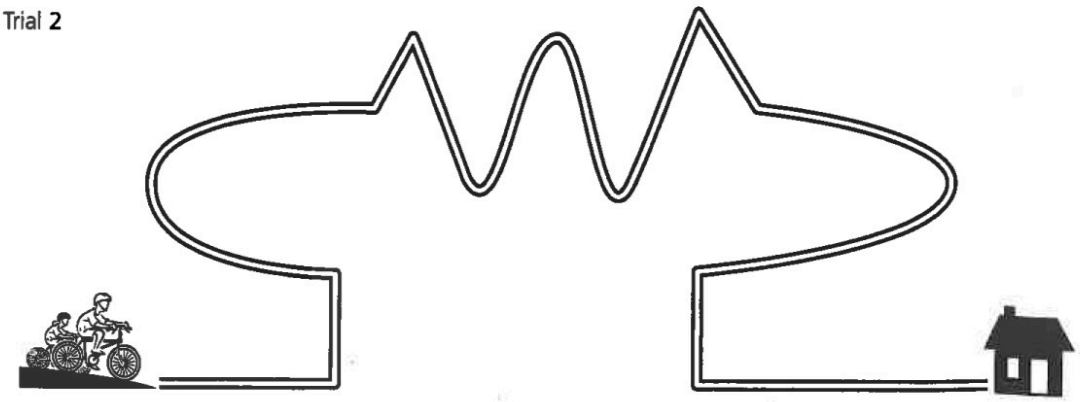
AB3
Practice



Trial 1



Trial 2



APPENDIX 12 ASSISTANCE TO PARTICIPATE SCALE

Assistance to Participate Scale (APS) for children with disabilities: participation in play and leisure information booklet.

Appendix: Scale items and response schedule

Please note, any reproduction of this scale must occur verbatim, including the instructions.

ASSISTANCE TO PARTICIPATE SCALE

The following questions are about activities that many children and teenagers participate in at some time. What is of interest is how much assistance you provide in order for your child to participate in the task at hand. Lots of different parents have described the types of assistance that their child needs. For the following activities, consider which category of assistance your child usually requires. Select that option by ticking the box.

Activity	***Unable to participate***	***Participates with my assistance at all stages of the activity***	***Participates after I have set him/her up and help at times during the activity***	***Participates with my supervision only***	***Participates independently***
1. Watching television	☐1	☐2	☐3	☐4	☐5
2. Listening to music	☐1	☐2	☐3	☐4	☐5
3. Playing with a toy/activity alone inside the house	☐1	☐2	☐3	☐4	☐5
4. Playing alone around the outside of your house (parent home)	☐1	☐2	☐3	☐4	☐5
5. Sharing time with a friend within your home	☐1	☐2	☐3	☐4	☐5
6. Sharing time with a friend at the friends home	☐1	☐2	☐3	☐4	☐5
7. Spending time at a playground or outdoor recreation area	☐1	☐2	☐3	☐4	☐5
8. Attending an organized recreational club (Ballet, soccer, scouts etc.)	☐1	☐2	☐3	☐4	☐5

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APPENDIX 13: PEDSQL-FIM

ID#_____

Date:_____

PedsQL™

Family Impact Module

Version 2.0

PARENT REPORT

DIRECTIONS

Families of children sometimes have special concerns or difficulties because of the child's health. On the following page is a list of things that might be a problem for **you**. Please tell us **how much of a problem** each one has been for **you** during the **past ONE month** by circling:

0 if it is **never** a problem
1 if it is **almost never** a problem
2 if it is **sometimes** a problem
3 if it is **often** a problem
4 if it is **almost always** a problem

There are no right or wrong answers.
If you do not understand a question, please ask for help.

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*In the past **ONE month**, as a result of your child's health, how much of a problem have **you** had with…*

PHYSICAL FUNCTIONING *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. I feel tired during the day	0	1	2	3	4
2. I feel tired when I wake up in the morning	0	1	2	3	4
3. I feel too tired to do the things I like to do	0	1	2	3	4
4. I get headaches	0	1	2	3	4
5. I feel physically weak	0	1	2	3	4
6. I feel sick to my stomach	0	1	2	3	4

EMOTIONAL FUNCTIONING *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. I feel anxious	0	1	2	3	4
2. I feel sad	0	1	2	3	4
3. I feel angry	0	1	2	3	4
4. I feel frustrated	0	1	2	3	4
5. I feel helpless or hopeless	0	1	2	3	4

SOCIAL FUNCTIONING *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. I feel isolated from others	0	1	2	3	4
2. I have trouble getting support from others	0	1	2	3	4
3. It is hard to find time for social activities	0	1	2	3	4
4. I do not have enough energy for social activities	0	1	2	3	4

COGNITIVE FUNCTIONING *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. It is hard for me to keep my attention on things	0	1	2	3	4
2. It is hard for me to remember what people tell me	0	1	2	3	4
3. It is hard for me to remember what I just heard	0	1	2	3	4
4. It is hard for me to think quickly	0	1	2	3	4
5. I have trouble remembering what I was just thinking	0	1	2	3	4

COMMUNICATION *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. I feel that others do not understand my family's situation	0	1	2	3	4
2. It is hard for me to talk about my child's health with others	0	1	2	3	4
3. It is hard for me to tell doctors and nurses how I feel	0	1	2	3	4

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*In the past **ONE month**, as a result of your child's health, how much of a problem have **you** had with…*

WORRY *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. I worry about whether or not my child's medical treatments are working	0	1	2	3	4
2. I worry about the side effects of my child's medications/medical treatments	0	1	2	3	4
3. I worry about how others will react to my child's condition	0	1	2	3	4
4. I worry about how my child's illness is affecting other family members	0	1	2	3	4
5. I worry about my child's future	0	1	2	3	4

DIRECTIONS

Below is a list of things that might be a problem for **your family**. Please tell us **how much of a problem** each one has been for **your family** during the **past ONE month.**

*In the past **ONE month**, as a result of your child's health, how much of a problem has **your family** had with…*

DAILY ACTIVITIES *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. Family activities taking more time and effort	0	1	2	3	4
2. Difficulty finding time to finish household tasks	0	1	2	3	4
3. Feeling too tired to finish household tasks	0	1	2	3	4

FAMILY RELATIONSHIPS *(problems with…)*	Never	Almost Never	Some-times	Often	Almost Always
1. Lack of communication between family members	0	1	2	3	4
2. Conflicts between family members	0	1	2	3	4
3. Difficulty making decisions together as a family	0	1	2	3	4
4. Difficulty solving family problems together	0	1	2	3	4
5. Stress or tension between family members	0	1	2	3	4

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APPENDIX 14: COMPLETE LIST OF MEDICAL AND PHARMACOLOGICAL MANAGEMENT

	Frequency (n=84)	Percent (%)
Medical and pharmacological management		
Neuro-observation	73	86.9
Anti-biotics	13	15.5
Wound dressing (chloromax, jelonet)	13	15.5
Anti-epileptic drugs (epilim, keppra, phenytoin)	18	21.4
Analgesia (panado, perfalgen, valeron drops, morphine)	62	73.8
HAART	1	1.2
Cortisone	2	2.4
Anticoagulants	4	4.8
Inotropes	2	2.4
Sedation (ketamine, dormicum)	3	3.6
Head up at 30 degrees	11	13.1
Blood transfusion	6	7.1
Oxygen	3	3.6
Mannitol	1	1.2
Eye surgery	1	1.2

APPENDIX 15: DESCRIPTIVE STATISTICS OF APS AT THREE MONTHS

	Minimum	Maximum	Mean	SD
Assistance to Participate Scale (APS)				
Home alone activities Total	8	20	19.83	1.42
Watching television	3	5	4.97	0.24
Listening to music	2	5	4.96	0.36
Playing with a toy/activity alone	1	5	4.95	0.48
Playing alone around the outside of your house (parent home)	2	5	4.96	0.36
Community Social Activities Total	11	20	19.82	1.16
Sharing time with a friend within your home	3	5	4.97	0.23
Sharing time with a friend at the friend's home	3	5	4.96	0.26
Spending time at a playground or outdoor recreation area	2	5	4.94	0.37
Attending an organized recreational club (ballet, soccer etc.)	3	5	4.94	0.33
APS Total	19	40	39.65	2.53

APPENDIX 16: TURNITIN REPORT

Turnitin Originality Report

Processed on: 16-Apr-2021 11:46 AM SAST
ID: 1560792148
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Early Functional outcomes in children with traumatic brain injuries By Dalya Rosen

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