

https://dspace.org/

Factors that affect gait patterns in children with spastic diplegia in a South African school setting

Hanley, Rosemary

2022
https://hdl.handle.net/10539/34871

Downloaded from a DSpace repository. https://dspace.org/

Factors that affect gait patterns in children with spastic diplegia in a South African school setting

Student: Rosemary Hanley

Student number: 1894928

Supervisors: Prof Joanne Potterton & Dr Natalie Benjamin-Damons

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 2022

ABSTRACT

Background: Spastic diplegia is the most common form of cerebral palsy (CP) globally. Little is known about the gait patterns of South African children with spastic diplegia and the factors which may influence it.

Aim: The aim of this study is to describe the gait patterns of children with spastic diplegia and identify what factors affect the gait pattern by assessing their muscle strength, muscle tone, lower limb sensation.

Methods: Participants with spastic diplegia (Gross Motor Function Classification Scale [GMFCS] I to III) between the ages of five and 17 were selected at two special schools in Johannesburg. Thirty participants were assessed using the Edinburgh Visual Gait Score (EVGS) for gait, the Modified Ashworth Scale (MAS) for muscle tone, handheld dynamometer (HHD) for muscle strength, and Brief Peripheral Neuropathy Screen (BPNS) and pin-prick sensation test for lower limb sensation.

Results: There were no statistically significant relationships between EVGS, MAS, muscle strength, BPNS and the pin-prick test. Thirty percent of participants tested positive in the BPNS and pin-prick test and almost 90% of those participants had HIV (P=0.034). There was an age trend for gait pattern amongst participants: older children presented with crouch gait and younger children presented with jump gait. There was a relationship between muscle strength and gait quality (p=0.021) but no relationship between muscle tone and gait quality (P=0.234; P=0.703).

Conclusion: In conclusion, there were relationships between age, muscle strength and gait, however, due to the small sample, these relationships were statistically insignificant. The prevalence of HIV-related peripheral neuropathies was high amongst participants; however, no relationship was found between gait and lower limb sensation. Future studies should focus on sensation and gait as HIV sensory deficits are prevalent in this country. A small sample size was a limitation in this study.

DECLARATION

I, Rosemary Hanley, student number 1894928, 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 Witwatersrand. It has not been submitted before for any other degree or examination at any university.

Signed on this day in Johannesburg

Student's Signature**Date:** 21 September 2022

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the support and guidance of others. I would like to thank the following individuals and organisations for their assistance with this dissertation:

Joanne Potterton – for your advice, support, and guidance throughout this dissertation

Natalie Benjamin-Damons – for your advice throughout this dissertation

Jeanine Blumenau – for assistance with the statistical work in this study

Lilané Putter Joubert – for assistance with editing this study

The children and the caregivers of Forest Town and West Rand CP School – for your willingness and patience to participate in this research study

Principal and Physiotherapy Department at Forest Town School – for allowing me to collect data and recruiting participants

Principal and Physiotherapy Department at West Rand CP School – for allowing me to collect data and recruiting participants

Barry Edwards – for your encouragement and support throughout this dissertation

Mandy Hanley – for your kindness and support throughout this dissertation

TABLE OF CONTENTS

Contents

ABSTRACT 2
DECLARATION 3
ACKNOWLEDGEMENTS 4
TABLE OF CONTENTS 5
LIST OF ABBREVIATIONS 9
LIST OF FIGURES 11
LIST OF TABLES 12
CHAPTER 1 – INTRODUCTION TO THE STUDY 13
1.1 Introduction 13
1.2 Justification for this Study 15
1.3 Problem Statement 15
1.4 Research Question 15
1.5 Aim 15
1.6 Objectives 16
1.7 Conclusion 16
CHAPTER 2 – LITERATURE REVIEW 17
2.1 Introduction 17
2.2 Cerebral Palsy 17
2.2.1 Definition 17
2.2.2 Prevalence 17
2.2.3 Aetiology and Risk Factors 18
2.2.4 Diagnosis of CP 19
2.2.5 Clinical Features of CP 19
2.2.6 Classification of CP 19
2.2.7 Gross Motor Function Classification Scale (GMFCS) 20
2.3 Spastic Diplegia 22
2.3.1 Gait Pattern in Spastic Diplegia 22
2.3.2 Muscle Strength and Muscle Tone in Spastic Diplegia 25
2.3.3 Lower Limb Sensation in Children with Spastic Diplegia 26
2.3.4 Co-morbidities in Children with Spastic Diplegia 28
2.4 Outcome Measures and Measuring Devices 30

2.4.1 Edinburgh Visual Gait Score (EVGS) 30
2.4.2 Modified Ashworth Scale (MAS) 32
2.4.3 Muscle Strength using a Handheld Dynamometer (HHD) 33
2.4.4 Brief Peripheral Neuropathy Screening (BPNS) and Pin-prick Test 35
2.5 Conclusion 37
CHAPTER 3 – Methodology 39
3.1 Study Design 39
3.2 Ethical Clearance 39
3.2.1 Permission to Conduct Research 39
3.2.2 Ethical Considerations 39
3.3 Location 40
3.4 Study Population 40
3.4.1 Sample Size 40
3.4.2 Inclusion Criteria 40
3.4.3 Exclusion Criteria 40
3.5 Outcome Measures and Measurement Devices 41
3.5.1 The Edinburgh Visual Gait Score 41
3.5.2 The Modified Ashworth Scale 41
3.5.3 Handheld Dynamometer 42
3.5.4 Brief Peripheral Neuropathy Screening Tool and Pin-prick Test 42
3.5.5 Anthropometric Data 42
3.6 Procedure 42
3.6.1 Recruitment 42
3.6.2 Medical History 43
3.6.3 Measurements 43
CHAPTER 4 – Research Results 46
4.1 Introduction 46
4.2 Demographic, Anthropometric and Clinical Data 46
4.2.1 Gender 46
4.2.2 Participants, Age, Height, Weight and BMI 46
4.2.3 Birth History and Mode of Delivery 49
4.2.4 Medical, Surgical and Co-morbidities History 50
4.2.5 Assistive Device and Ankle Foot Orthosis 51
4.2.6 Clinical Presentation 51
4.2.7 Muscle Tone 52

4.2.8 Muscle Strength 54
4.2.9 Brief Peripheral Neuropathy Screening and Pin-prick Test 56
4.2.10 EVGS Scores 57
4.2.11 Rodda Classification 57
4.3 Correlation Between Factors 58
4.3.1 Correlation Between Anthropometric Information and EVGS 58
4.3.2 Correlation Between BMI and Rodda Classification 59
4.3.3 Correlation Between Age and EVGS Score 60
4.3.4 Correlation Between Age and Rodda Classification 60
4.3.5 Correlation Between Co-morbidities and Rodda Classification 62
4.3.6 Correlation Between BPNS and EVGS Scores 63
4.3.7 Correlation Between BPNS and HIV 64
4.3.8 Correlation Between Muscle Strength and Gait 65
4.3.9 Correlation Between Muscle Tone and Gait 66
4.4 Summary of Results 68
4.5 Conclusion 69
CHAPTER 5 – Discussion 70
5.1 Introduction 70
5.2 General 70
5.2.1 Gender 70
5.2.2 Anthropometric Information 70
5.2.3 Co-morbidity History 71
5.2.4 Clinical Presentation 71
5.3 Lower Limb Sensation 72
5.4 Rodda Classification and EVGS 72
5.5 Correlation Between Gait Pattern, Anthropometric Information and Clinical Presentation 72
5.6 Correlation Between Gait Pattern, Muscle Tone and Muscle Strength 73
5.7 Correlation Between Lower Limb Sensation and HIV 74
5.8 Limitations of this Study 74
5.9 Recommendations for Future Research 75
5.10 Clinical Implications 76
CHAPTER 6 – Conclusion 77
Reference List 78
Appendices 89

Appendix 1 Ethics Clearance Certification 89
Appendix 2 Forest Town School Approval Letter 90
Appendix 3 West Rand CP School Approval Letter 92
Appendix 4 Department of Education Approval Letter 93
Appendix 5 Child Information Sheet 95
Appendix 6 Information Sheet for Parent/Caregiver/Guardian 97
Appendix 7 Consent Form 99
Appendix 8 Assent Form (Children over the age of 6) 100
Appendix 9 The Patients' Rights Charter 101
Appendix 10 Parent Questionnaire 102
Appendix 11 Data Collection Sheet 104
Appendix 12 Muscle Tone Testing Procedure 105
Appendix 13 Normal Joint Range of Movement 106
Appendix 14 Muscle Strength Testing Procedure with HHD 107
Appendix 15 Edinburgh Visual Gait Score 108
Appendix 16 Brief Peripheral Neuropathy Screening Tool 109

LIST OF ABBREVIATIONS

3DGA	Three-dimensional gait analysis
AFO	Ankle foot orthoses
ARV	Anti-retroviral therapy
AS	Ashworth Scale
BAZ	BMI for age z-score
BMI	Body Mass Index
BPNS	Brief Peripheral Neuropathy Screen
CNS	Central nervous system
CP	Cerebral palsy
CV	Coefficient of variation
EVGS	Edinburgh Visual Gait Score
GMFCS E&R	Gross Motor Function Classification System Expanded & Revised
GMFCS	Gross Motor Function Classification System
GMFM	Gross Motor Function Measure
HAZ	Height for age z-score
HHD	Handheld dynamometer
HIV	Human Immunodeficiency Virus
HIVE	HIV Encephalopathy
ICC	Intraclass correlation co-efficient
MAS	Modified Ashworth Scale
MRI	Magnetic Resonance Imaging
NDS	Neuropathy disability score

NSS	Neuropathy symptom score
PEDI	Paediatric Evaluation of Disability Inventory
PVHI	Periventricular Haemorrhagic Infarction
PVL	Periventricular Leukomalacia
SEM	Standard error of measurement
SEMLS	Single event multilevel surgery
WAZ	Weight for age z-score
WHO	World Health Organisation

LIST OF FIGURES

Chapter 2

Figure 2.1 Topographical description of cerebral palsy: unilateral and bilateral cerebral palsy 20
Figure 2.2 Sagittal gait patterns in spastic diplegia 25
Figure 2.3 Dermatomal areas assessed when performing the pin-prick test 37

Chapter 4

Figure 4.1 Gender 46
Figure 4.2 Figure 4.2 BMI distribution for all participants 48
Figure 4.3 BMI by age to WHO data/anthropometric data (n=30) 48
Figure 4.4 BMI by age and gender on WHO data (n=30) 49
Figure 4.5 BPNS distribution amongst participants 56
Figure 4.6 Rodda classification distribution 58
Figure 4.7 Distal Muscle Tone Distribution 66
Figure 4.8 Proximal Muscle Tone Distribution 67

LIST OF TABLES

Chapter 2

Table 2.1 GMFCS (E&R) 21

Chapter 3

Table 3.1 The Modified Ashworth Scale 41

Chapter 4

Table 4.1 Demographic and anthropometric findings 47
Table 4.2 Anthropometric z-scores 47
Table 4.3 Term and mode of delivery (n=30) 49
Table 4.4 Surgical and Medical History 50
Table 4.5 Assistive Device and AFO use 51
Table 4.6 Lower Limb Contractures 52
Table 4.7 Distribution of participants in GMFCS level II and level III 52
Table 4.8 Average frequencies expressed as percentages for tone in muscle groups (n=30). 53
Table 4.9 Average frequencies expressed as percentages comparing proximal and distal muscle tone groups 53
Table 4.10 Average muscle strength values in newtons (N). 55
Table 4.11 Dermatomal areas affected 56
Table 4.12 EVGS Scores 57
Table 4.13 Correlation between age, WAZ, HAZ, BAZ and EVGS average 58
Table 4.14 Rodda Classification and BMI 59
Table 4.15 Relationship between weight and Rodda Classification 60
Table 4.16 Correlation between age and EVGS average score 60
Table 4.17 Relationship between age and Rodda Classification 61
Table 4.18 Rodda Classification and age group crosstabulation 61
Table 4.19 Relationship between age and gait pattern 62
Table 4.20 Directional measures between age and gait pattern 62
Table 4.21 Rodda Classification and Co-morbidity 63
Table 4.22 Directional Measures Between BPNS and EVGS 63
Table 4.23 Symmetric Measure BPNS and EVGS 64
Table 4.24 Comorbidity and BPNS crosstabulation 64
Table 4.25 Pearson Chi-Square test between comorbidity and BPNS 65
Table 4.26 Correlation between muscle strength and EVGS average scores 65
Table 4.27 Proximal tone and gait pattern crosstabulation 67
Table 4.28 Distal tone and gait pattern crosstabulation 68

CHAPTER 1 – INTRODUCTION TO THE STUDY

1.1 Introduction

Cerebral palsy (CP) is a neurological condition caused by non-progressive injury or malformation of the developing brain. This neurological condition can manifest with physical, cognitive, sensory or growth disturbances (Krigger, 2006; Donald et al., 2014a). Globally 2–2.5 of 1 000 babies are born with CP and a systematic review has shown that South Africa's prevalence of CP could be four times higher than this global statistic (Donald et al., 2014b). The most common risk factors for CP in Southern Africa are low birth weight and central nervous system infections (Donald et al., 2014b).

Spastic diplegia is a form of CP where both the lower limbs are impaired. It is the most common form of CP globally and a subgroup that is frequently seen in children that are born prematurely with a low birth weight (Pauk et al., 2016). Analysing the gait pattern of children with CP can assist physiotherapists to identify impairments and subsequently plan their treatment (Stanger & Oresic, 2003). There are various factors that influence gait pattern that need to be examined closely.

Rodda et al. (2004) looked at the sagittal gait patterns in 187 ambulant children with spastic diplegia. This study was fundamental in gait analysis research as it assisted in categorising five distinct patterns in children with spastic diplegia, namely: true equinus, jump gait, apparent equinus, crouch gait, and asymmetrical gait. Findings showed that younger children walked with a true equinus and jump gait and older children walked with an apparent equinus and crouch gait. This suggests that age is a factor that influences gait pattern and that there is possibly a natural progression of gait amongst children with spastic diplegia. The study found that over time there are changes in muscles distally to proximally and the flexors of the hip, knee and plantarflexors of the ankle are key muscle groups where spasticity and contractures are found. These muscular changes are significant factors that influence gait pattern in each individual (Rodda et al., 2004).

Co-morbidities or diseases are relevant factors to consider when assessing children from South Africa. According to the South African Statistical Release (2019), the Human Immunodeficiency Virus (HIV) has a prevalence rate of approximately 13.5% in South Africa. Diseases such as HIV, meningitis and Tuberculosis can infiltrate the central nervous system in utero and infancy and cause neurological fallout and CP (Be et al., 2009; Mann et

al., 2017). South African babies are therefore at higher risk due to the infection rate. Banks et al. (2015) also highlighted the strong link between infection and disability in sub-Saharan Africa where the burden of HIV is the highest. It emphasised the need for further research into the appropriate strategies needed for those that are infected, including children with CP.

Langerak et al. (2014) looked at gait pattern and physical status of children with spastic diplegic children secondary to human immunodeficiency virus encephalopathy (HIVE). This study assessed 14 children using a three-dimensional gait analysis (3DGA) system and a physical examination. Findings of this study showed that these children had increased impairments from proximal to distal (excluding hip extension). These are conflicting findings when compared to the study done by Rodda et al. (2004) where children with spastic diplegia were found to have increasing impairments distally to proximally. The children with spastic diplegia secondary to HIVE have a unique presentation and were not able to fit the descriptions outlined by Rodda et al. (2004).

Naik et al. (2018) looked at these unique differences between HIV spastic diplegic children and non-infected spastic diplegic children. The findings of this study showed that HIV spastic diplegic children were weaker and had less severe muscle tone than those that are uninfected. Tone, weakness and co-morbidities are factors that affect the clinical presentation and ultimately the gait pattern of children as outlined in Langerak et al. (2014). Co-morbidities such as HIV are factors to consider when assessing and comparing gait, especially when the prevalence rate in South Africa is high (Donald et al., 2014; Banks et al., 2015).

Environmental or external factors may affect the gait pattern. A study by Pauk et al. (2014) assessed and compared the gait pattern of children with spastic diplegia with normal developing children and found that various external factors influence gait pattern. The study found that ankle foot orthosis (AFOs) affect the manner and position in which the foot strikes the ground as well as the position of the body over the foot which affects the centre of gravity. The type of AFO prescribed to each child was a factor that affected their gait pattern. According to Pauk et al. (2016) and Bennett et al. (2005), children with spastic diplegia have a wider step and shorter stride length to compensate for poor motor control and weakness when compared to a normally developed child. AFOs have potential to improve and alter the gait pattern amongst children with spastic diplegia and are therefore a factor to consider when assessing and treating.

McLaughlin et al. (2005) noted lower limb sensory differences between children with CP and normal developing children. The study found that there was a decrease in sensory accuracy and

direction of stimulus to the lower limb in children with CP. It also highlighted the feasibility of assessing sensation in children with CP. Benjamin et al. (2015) found that there is a high prevalence of peripheral neuropathies in the HIV-infected paediatric population in South Africa. Peripheral neuropathies or damage to the peripheral nervous system can cause discomfort or even loss of function to the extremities. These sensory deficits of the lower limbs could be a direct factor that affects gait pattern and further research is required to explore this area.

1.2 Justification for this Study

Assessing gait and identifying factors that affect gait pattern will give therapists a clearer picture of where the child's impairments lie and assist with the direction of treatment. This study will investigate the various factors affecting gait pattern in children with spastic diplegia and contribute to the lack of research in this field.

In this study factors that influence gait will be determined and compared. Gait analysis, muscle tone, muscle strength, lower limb sensation, and co-morbidities of each child will be identified. There is a lack of research in this field, especially in Southern Africa where the CP and co-morbidity prevalence is high.

1.3 Problem Statement

Little is known about the gait patterns of South African children with spastic diplegia and the factors which may influence it.

1.4 Research Question

What factors affect gait pattern in children with spastic diplegia in a South African school setting?

1.5 Aim

The aim of this study is to describe the gait patterns of children with spastic diplegia and identify what factors affect the gait pattern by assessing their muscle strength, muscle tone, lower limb sensation.

1.6 Objectives

1. To determine and describe the height and weight and the co-morbidities of each child.
2. To determine and describe the gait pattern of each child using the Edinburgh Visual Gait Score (EVGS).
3. To determine and describe the tone of each child using the Modified Ashworth Scale (MAS).
4. To determine and describe the lower limb muscle strength and core strength of each child using a handheld dynamometer (HHD).
5. To determine and describe the lower limb sensation of each child using the Brief Peripheral Neuropathy Screen (BPNS) and pin-prick sensation test.
6. To determine whether there is an association between co-morbidities, muscle strength, muscle tone, lower limb sensation, and anthropometric information and gait pattern in children with spastic diplegia.

1.7 Conclusion

Muscle strength, muscle tone, lower limb sensation and co-morbidities play a role in specific gait patterns in children with spastic diplegia. Few studies have been done in SA and findings in this study will help improve clinical practice and grow research in the country.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This literature review will provide an outline of cerebral palsy and focus on spastic diplegia. It will provide information on the outcome measuring tools used in this study to assess factors that affect gait pattern in a South African school setting. Literature was gathered from January 2020 to December 2021. Search engines used to source this literature were PubMed, ScienceDirect, and Google Scholar. The following words and phrases were used when searching for literature: cerebral palsy, spastic diplegia, gait pattern, sensation, muscle strength, muscle tone, comorbidities, HIV, epilepsy. Only articles written in English were reviewed and no papers before 2000 were reviewed with exceptions for outcome measures and definitions that were formulated before this year.

2.2 Cerebral Palsy

2.2.1 Definition

Cerebral palsy (CP) is a familiar term in the healthcare sector. The definition has continuously been developed and transformed over the decades since its first inception in 1861. The umbrella term was initially an etiologic diagnosis but has since developed to a clinical descriptive term (Bax et al., 2005). The most recent definition was developed by Rosenbaum et al. (2007):

"Cerebral palsy describes a group of permanent disorders of the development of movement and postures causing activity limitations that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of CP are often accompanied by disturbances of sensation, perception, cognition, communication, and behaviour, by epilepsy and by secondary musculoskeletal problems." (Rosenbaum et al., 2007: 9)

2.2.2 Prevalence

Based on a systematic review in a rural setting in sub-Saharan Africa, the prevalence of CP is between two to 10 per 1 000 children (Donald et al., 2014b). Globally CP prevalence varies from two to two point five per 1 000 babies born (Eunson, 2012). This is due to wide-ranging development across the world. Some studies show that the prevalence is on decline in high-income countries (Korzeniewski et al., 2018). There is a lack of information on the data of prevalence in developing countries (Donald

et al., 2014b; Eunson, 2012). Despite the advances in healthcare, CP remains a problem globally. This could also be due to the fact there are many very premature babies surviving that now face the long-term risk of neurological sequelae (Tsuji et al., 2014).

2.2.3 Aetiology and Risk Factors

The development of CP can occur prenatally, perinatally and postnatally. According to Krigger (2006) seventy to eighty percent of CP is as a result of prenatal causes. The exact causes are mostly unknown. Cerebral palsy that occurs prenatally and perinatally can be caused by infections in utero, malformations in utero and birth asphyxia during delivery. In utero, viruses such as HIV and the Zika virus can infect the foetus and result in CP (Graham et al., 2016; Naik et al., 2018). Periventricular leukomalacia (PVL) and periventricular haemorrhagic infarction (PVHI) are common white matter brain injuries seen in preterm babies. PVL commonly occurs in utero and PVHI occurs shortly after birth, and both brain injuries lead to CP (Eunson, 2012; Tsuji et al., 2014). The pathogenesis of PVL and PVHI differ as PVL is related closely to arterial infarction, whereas PVHI is closely related to a venous infarction (Tsuji et al., 2014).

Postnatally CP can develop from infections such as bacterial meningitis, viral encephalitis, and hyperbilirubinemia. Near-drowning, vehicle accidents or trauma to the developing brain after birth can also lead to CP (Eunson, 2012; Krigger, 2006).

The most common risk factors for CP are prematurity, low birth weight, multiple births, and perinatal infection (Eunson, 2012). In Southern Africa the most common risk factors are low birth weight and central nervous system infections (Donald et al., 2014b).

There is a four times higher chance of developing CP in multiple births when compared to single births. This increased risk is due to the lower gestational age and birth weight (Korzeniewski et al., 2018).

Infections transmitted from a mother to their fetus can lead to CP. The systemic inflammatory response may cause subsequent insults to the brain. Infections such as toxoplasmosis, rubella, and herpes simplex virus during pregnancy have been associated with increased risks of CP. Microcephaly causing CP has been linked to the result of perinatal mother-to-child infection of the chikungunya virus infection (Korzeniewski et al., 2018).

Premature birth is a high-risk factor for CP and accounts for almost half of the diagnoses of CP in high-income countries. The rate is much higher for lower income countries such as South Africa. Low birth weight is associated with prematurity and there is a correlation between the

two and CP. The more preterm the new-born is, the higher the risk of developing CP (Korzeniewski et al., 2018). Despite prematurity and low birthweight being the highest risk factors for CP, most children with CP are born at term (Elsingergy et al., 2021).

2.2.4 Diagnosis of CP

There are advanced tools used to diagnose CP within the first five months of life, including magnetic resonance imaging (MRI) and Prechtl Qualitative Assessment of General Movements. MRI is considered the gold standard diagnostic modality where advanced images of the brain are taken and evaluated for brain injuries (Elsingergy et al., 2021). The Prechtl's Qualitative Assessment of General Movements is a diagnostic tool that assesses neonates general movements and identifies those at risk for CP or other developmental disabilities (Donald et al., 2014b). Without utilising these tools, a diagnosis is first suspected when there is a failure to reach a milestone at an expected age (Patel et al., 2020).

2.2.5 Clinical Features of CP

Delayed motor development, abnormal posture, abnormal muscle tone (decreased/increased or fluctuating) and hyperreflexia are all characteristics associated with CP (Krigger, 2006).

Visual and auditory impairments, epilepsy and difficulties with sensation, perception, cognition, communication, and behaviour are often associated with CP (Graham et al., 2016). According to Donald (2014b), epilepsy is the most common co-morbidity in Africa.

Reduced height, weight and head circumference are common clinical features in children with CP. Feeding difficulties are the main contributing factor to this as it leads to reduced nutritional intake and growth (Gulati & Sondhi, 2018). Non-nutritional causes such as low birth weight, reduced weight bearing, immobility and endocrine dysfunction may also contribute to the lack of growth (Andrew & Sullivan, 2010; Strand et al., 2016). Endocrine dysfunction can often lead to reduced growth hormone production and result in a shorter final height during the pubescent phase of life. (Andrew & Sullivan, 2010; Graham et al., 2016)

2.2.6 Classification of CP

CP is classified according to the type of movement pattern and the distribution of this movement pattern. CP can be subdivided into three groups based on clinical features, namely spastic, dyskinetic or ataxic features. Spastic features account for between seventy and eighty percent of those with CP and comprise muscular hypertonicity, weakness, hyperreflexia, and tremors. Dyskinetic features account for between ten to twenty percent of those with CP and

comprise abnormally slow, writhing movements of body parts and are exacerbated when the person is challenged. Ataxic features affect five to ten percent of those with CP and present with poor co-ordination and balance (Krigger, 2006).

The anatomical distribution or area of the body that is affected forms part of the classification of CP. Monoplegia is when one limb is affected, hemiplegia is when one side of the body is affected, diplegia is when both lower limbs are affected, triplegia is when three limbs are affected, and quadriplegia is when all four limbs are affected (Graham et al., 2016). Figure 2.1 is a visual representation of the anatomical distribution of the different types of CP.

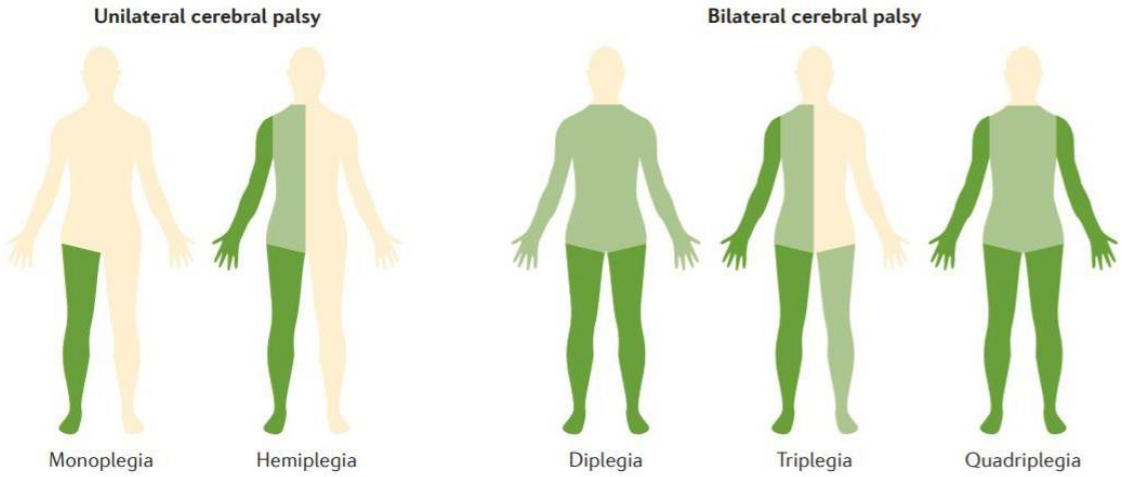


Figure 2.1 Topographical description of cerebral palsy: unilateral and bilateral cerebral palsy (Graham et al., 2016)

2.2.7 Gross Motor Function Classification Scale (GMFCS)

The GMFCS is a five-level system used to objectively classify children with CP in terms of their functional ability and limitations. Children classified as level I are the most independent in terms of motor function and children classified as level V are the least (Wood et al., 2000; Palisano et al., 2008). When the scale was developed by Palisano in 1997, the levels were described within age bands: below the age of two years old, between two and four years old, between four and six years old and between six and 12 years old. The GMFCS was expanded and revised by Palisano et al. (2008) and became the GMFCS (E&R) to include age band 12 to 18. Including this age band in the scale would account for the pubescent changes that occur in these later years.

Table 2.1 GMFCS (E&R) (Palisano et al., 2008)

Level I	Walks without Limitations
Level II	Walks with Limitations
Level III	Walks Using a Handheld Mobility Device
Level IV	Self-mobility with Limitations; May Use Powered Mobility
Level V	Transported in a Manual Wheelchair

Ko et al. (2011) looked at the interrater and intrarater reliability of the GMFCS amongst 71 children with CP using video recordings. Each participant was divided into three groups according to their age group based on the GMFCS guidelines. Eleven physiotherapists scored the video recordings of the 71 children to test interrater reliability and two of the therapists rescored the same video recordings to test intrarater reliability. Reliability for the GMFCS across all age groups was high. The interrater Intraclass Correlation Coefficient (ICC) = 0.994, 0.993 and 0.996 for each group and the intrarater ICC=0.972–0.996. Palisano et al. (1997) supported these findings in a similar study where interrater reliability of the GMFCS were found to be high (Kappa of 0.75).

Ko et al. (2011) also assessed the validity of the GMFCS to the Paediatric Evaluation of Disability Inventory (PEDI) which looked at self-care, mobility and social ability. The GMFCS level and mobility component of the PEDI correlated highly. High correlation between the Gross Motor Function Measure (GMFM) and GMFCS was also found and suggestive of good validity of the scale (Palisano et al., 2000).

The functional ability of an individual will peak at a certain age dependant on their GMFCS level. A large longitudinal study by Hanna et al. (2009) assessed 657 children with CP over several years to determine whether there is functional loss as they age. This study showed that children at a GMFCS level I and II had no functional loss over time, whereas children level III peaked at seven years 11 months and level IV and V peaked at six years 11 months.

Gross motor decline is evident as a person moves from adolescence to adulthood, which could be due to increased energy requirements, muscle contractures and stiffness (Hanna et al., 2009). Other researchers noted that the decline of ambulation could be due to fatigue, pain, and a lack of adapted physical activity (Damiano, 2006; Beckung et al., 2007; Opheim et al., 2013).

Increased body mass index (BMI) is a factor that should be closely looked at as a cause of gross motor decline in individuals with CP (Hanna et al., 2009).

The GMFCS (E&R) is a reliable tool that can assist healthcare professionals with goal setting, establishing prognoses and decision-making (Rosenbaum et al., 2007 Beckung et al., 2007; Silva et al., 2013; Ko et al., 2011). This classification system uses functional abilities and limitations as predictors of function as opposed to using age (Palisano et al., 2000).

2.3 Spastic Diplegia

Spastic diplegia is a subgroup of CP. This group will usually have gross motor difficulties in the lower limbs (Gulati & Sondhi, 2018). Spastic diplegia is the most common subgroup of CP and accounts for 35 percent of all children with CP (Patel et al., 2020).

A common cause of spastic diplegia is PVL and this cause can be identified with neuroimaging. PVL is an injury to the white matter of the brain that occurs most often in utero. The cell death and cyst formation of the area in the brain arises due to oedema in the periventricular white matter of the lateral ventricles. It is most often seen in premature infants but can also be present in full term infants who experience a hypoxic event perinatally (Tsuji et al., 2014; Shang et al., 2015). Both the motor corticospinal and thalamocortical pathways are affected in children with spastic diplegia, however the clinical presentation allows a good prognosis for independent ambulation (Patel et al., 2020).

Visual and auditory impairments, as well as epilepsy, are associated with PVL. A large cross-sectional study by Shang et al. (2015) assessed 408 children between the ages of five months and 10 years with periventricular leukomalacia and found that 26.96 percent had visual and auditory disorders.

2.3.1 Gait Pattern in Spastic Diplegia

Gait can be explained in a gait cycle. The gait cycle begins when one foot touches the ground and stops when that same foot touches for the next step. The gait cycle is divided into the stance phase and the swing phase and can be further subdivided in these phases according to the placement of the lower limb joints in motion. Based on the information obtained from the gait cycle, temporal and spatial characteristics can be calculated, such as the stride length, cadence, and speed (Sutherland & Davids, 1993; Armand, Decoulon & Bonnefoy-Mazure, 2016).

Gait analysis has fundamentally changed the approach in the treatment of children with CP (Gage, 1993; Shumway-Cook et al., 2003). Studies have shown that gait analysis is a valuable outcome measure for pre- and post-operative interventions (Gage, 1993; Shumway- Cook et al., 2003; Armand et al., 2016). Analysing gait can assist with the identification of impairments, however reliability of gait analysis to assist with decision-making for orthopaedic management is questionable (Nieuwenhuys et al., 2016; Armand et al., 2016).

Sutherland and Davids (1993) identified four main categories of gait abnormalities in children with spastic diplegia based on the position of the knee joint, namely jump knee, crouch knee, stiff knee and recurvatum knee. The jump knee category is described as increased knee flexion in early stance phase, with initial double support. The knee extension corrects to near normal in mid to late stance phase and knee extension is reduced in late swing phase. The crouch knee category is described as increased knee flexion throughout the stance phase and variable position during swing phase. The stiff knee category is described as excessive knee extension throughout swing phase with variable position during stance phase. The recurvatum knee category is described as increased knee extension in mid to late stance phased, with variable knee position during swing phase. This classification system was established through the assessment of 588 patients with spastic diplegia. Physical assessment information, motion parameters, electromyography data and force plate data were used to establish these groups. The drawback of this system is that every individual does not definitively fall into one of the groups, and a few patients did not fit the description outlined.

Two decades later Rodda et al. (2004) formulated a five-level classification system of sagittal gait patterns in patients with spastic diplegia. This system was created after a cross-sectional study of 187 children between the ages of four and 18 years old with spastic diplegia was conducted. A repeatability study was conducted concurrently and proved the classification system to be reliable. The classification of gait is based on the location of the ankle joint, followed by the knee, hip and pelvis.

The first group, “true equinus”, is when the ankle is in the equinus position and the knee extends fully or is in a mild hyperextension. In this position the hip will be fully extended, and the pelvis will be in a normal position or in an anterior tilt.

The second group, “jump gait”, is when the ankle is in equinus position, predominantly in the late stance phase. In the early stance phase the knee and hip are excessively flexed and then

extend to a certain degree, without fully extending. The pelvis will be in the normal position or in an anterior tilt throughout gait.

The third group, “apparent equinus”, is when the ankle is in normal range and the hip and knee are excessively flexed during the stance phase. The pelvis will be in the normal position or in an anterior tilt throughout gait.

The fourth group, “crouch gait”, is when the ankle is in excessive dorsiflexion during stance phase, while the hip and knee are in excessive flexion. The pelvis will be in the normal position or in an anterior tilt throughout gait.

The fifth group, “asymmetric gait”, is when the subject’s two lower limbs display different patterns. Each leg would fall under a separate group from one to four, e.g. one leg falls under “crouch gait” and the other leg falls under “jump gait”.

From group one across to group four there is decreasing equinus, increasing proximal contractions and the direction of the ground reaction force moves from being in front of the knee to behind it. Group five provided a category for those that were unable to fit the description of group one to four. This study found that spasticity and contractures in the flexor muscle group of the hip, knee and ankle joints affect gait pattern and changes in the muscles that were involved occurred distal to proximal (Rodda et al., 2004).

Rodda et al. (2004) and Sutherland and Davids (1993) provided similar classification systems. Sutherland and Davids (1993) categories are based on the knee joint position and are easier to use on a larger scale (de Morais Filho et al., 2014), whereas Rodda et al. (2004) provided a more descriptive classification system and looked at all joints, starting at the ankle joint.

Muscle weakness plays a huge role in gait pattern. A child presenting in crouch gait may be pulled into this position due to weakness and not only due to spasticity or contractures. Ultimately, muscle spasticity, contractures, and weakness play a role in determining gait pattern (Rodda et al., 2004).

Crouch and asymmetrical gait are the most common gait patterns seen in young adults with spastic diplegia (Opheim et al., 2013). True equinus and jump gait are patterns more common in younger children when compared to crouch gait and apparent equinus. This is suggestive of a natural progression of gait pattern in children with spastic diplegia (Rodda et al., 2004). Current literature suggests that there is natural progression of increased knee flexion in crouch gait (O’Sullivan et al., 2018) which highlights the progression in gait pattern with age (Rodda

et al., 2004).

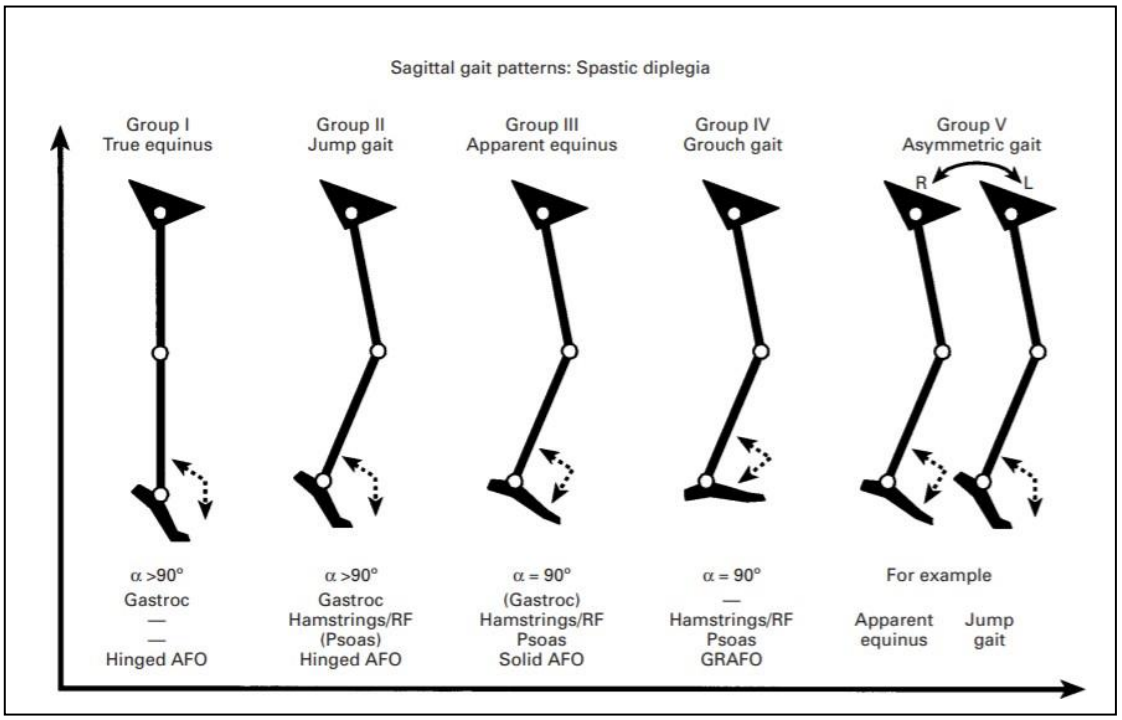


Figure 2.2 Sagittal gait patterns in spastic diplegia (Rodda et al., 2004)

A study done by Pauk et al. (2016) compared the gait parameters of typically developing children to children with spastic diplegia either with or without AFOs. The stride length and velocity of children with spastic diplegia using AFOs was more like normal developing children when compared to children with spastic diplegia not using AFOs. AFOs proved to be a factor that improved the gait pattern of children with spastic diplegia.

The type of AFO prescribed depends on the gait presentation (Pauk et al., 2016; Rodda et al., 2004). Solid AFOs help to assist with knee extension during the initial contact of the gait cycle whereas ground reaction type AFOs counteract the forward movement of the tibia and help keep the ground reaction force in front of the knee. Both these AFOs assist children with spastic diplegia who often appear to have a crouch gait (Pauk et al., 2016).

2.3.2 Muscle Strength and Muscle Tone in Spastic Diplegia

Muscle weakness and increased muscle tone are recognisable problems in children with spastic diplegia (Ross & Engsberg, 2007; Thompson et al., 2011).

Originally spasticity was believed to be the cause of functional limitations and addressing muscle strength was overlooked. A retrospective, cross-sectional study by Ross and Engsberg (2007) looked at the relationship between strength, spasticity and gross motor function and gait of children with spastic diplegia. Ninety-seven participants between the ages of four and 23

years old with an GMFCS level between I and III were subjected to a once-off assessment. Findings showed that strength accounted for the most variance in the gross motor function (69% in the GMFM-66), whereas spasticity accounted for the least (eight percent in the GMFM-66). Muscle strength was related to gross motor function and spasticity was not. A limitation of the study is that results are not generalisable for children and adults with severe types of CP.

Thompson et al. (2011) looked at the isometric lower limb muscle strength and how was it measured in fifty ambulant children with spastic diplegia. The muscle strength from these children were compared with fifteen control children. All muscles in the children with spastic diplegia were significantly weaker ($p<0.05$) than the control group, with the knee extensors being the weakest of the muscle groups.

A study by Heyrman et al. (2014) investigated the truncal movements of children with spastic diplegia during gait. Findings proved that lower limb muscle strength may not be the sole cause of altered trunk movements as previously assumed. Trunk control deficit or core muscle weakness may be a contributing factor in gait pattern disparities in children with CP (Heyrman et al., 2014).

Core muscle strengthening can improve gait, balance and gross motor function in patients with neurological fallout (Cabanas-Valdés et al., 2016; Shemy, 2018; Huang et al., 2020). Shemy (2018) looked at the efficacy of core stability training on the endurance of trunk muscles and gait pattern in children with CP. Thirty children with hemiplegic CP completed a physiotherapy programme designed to target the core muscles. After the programme, all children's core muscle endurance and gait parameters improved. The limitations of this study were that it had a small sample size which reduced its generalisability and only children with hemiplegic CP were used.

A study by Anjum et al. (2019) assessed the effects of progressive muscle strengthening on gross motor function in forty-five children with spastic diplegia in Pakistan. The quasi-experimental study used the GMFM-88 as an outcome measure and found that there was a significant improvement in gross motor function following a twelve-week strengthening programme.

2.3.3 Lower Limb Sensation in Children with Spastic Diplegia

There is emerging evidence that children with CP may present with lower limb somatosensory

deficits (Mclaughlin et al., 2005; Zarkou et al., 2020, 2021).

Focus on upper limb sensory deficits in children with CP and overlooking the lower limb, caused McLaughlin et al. (2005) to investigate lower limb sensation and the feasibility of sensation testing in children with CP. In this study 62 children with CP were compared to 65 typically developing children. Light touch, pain, proprioception, vibration sense (128Hz) and direction of scratch were assessed. Results showed that 52 percent of children with CP completed all items of the sensory assessment, compared to 85 percent of the typically developing children. Sensation scores were lower in children with CP, especially for the direction of scratch ($p<0.001$), toe position ($p=0.01$) and vibration sense ($p=0.01$). This study was one of the first to prove that there are somatosensory deficits in the lower limbs in children with CP, especially those with spastic diplegia. It highlighted the feasibility and importance of sensation testing in the lower limbs.

A recent small pilot study by Zarkoua et al. (2021) assessed the foot and ankle somatosensory function in children with spastic diplegia. Light touch pressure, two-point discrimination, vibration, joint position and kinesthesis were investigated. A 128Hz tuning fork was used to assess vibration and proprioception was tested by moving the joints to a certain degree with the use of a digital goniometer (Medigauge, Westford, MA). Ten children with spastic diplegia were compared to eleven typically developing children. The children with spastic diplegia were unable to perceive the vibration stimulus correctly or understand where their joints were in space. Although the sample size in this study was small, it suggests that children with spastic diplegia may have ankle and foot tactile and proprioceptive deficits.

The somatosensory system is essential in providing feedback for motor planning. Another study by Zarkoua et al. (2020) investigated the relationship between lower limb sensation and function in children with CP. The study completed the somatosensory assessment of the lower limb of 10 children with CP and looked at the relationship between these findings and balance and motor performance. The Balance Evaluation System Test and postural sway measures during a standing task were used to assess balance and motor performance was evaluated using a battery of clinical assessments. Findings showed a strong relationship between somatosensory deficits and balance and motor performance. It also emphasised the importance of combining sensory and motor components into therapy to improve functionality.

Peripheral neuropathies can cause numbness, pain, cramping, tingling, or burning. This condition is commonly caused by HIV or select anti-retroviral therapy (ARVs) (Benjamin-

Damons, 2019; Amiji et al., 2021).

Peters et al. (2014) investigated the clinical assessment for peripheral neuropathies using the neuropathy symptom score (NSS) and the neuropathy disability score (NDS). The study was set in rural South Africa and 182 children with HIV on ARVs participated. Twenty four percent of the children in this study were diagnosed with a peripheral neuropathy. It is evident there is a high prevalence of peripheral neuropathies in the HIV-infected paediatric population in South Africa (Peters et al., 2014; Benjamin-Damons, 2019).

In a study by Benjamin-Damons (2019), 135 HIV infected children were assessed for peripheral neuropathies using the BPNS. Twenty six percent were found to have had peripheral neuropathies. These findings are akin to those of the authors Peters et al. (2014) which showed 24% prevalence of peripheral neuropathies, however had a slightly larger sample size.

A more recent study by Amiji et al. (2021) assessed 383 HIV infected children in Tanzania for peripheral neuropathies. Children between the ages of five and 18 were assessed using the Paediatric Modified Total Neuropathy Score. This tool comprises an objective and subjective component. The objective component assessed light touch, pin prick, vibration, strength, and reflexes. Just over 14% of participants in this study were positive for peripheral neuropathies, reinforcing that this is a common condition in children with HIV.

Sensory deficits have been identified in children with spastic diplegia, as well as children with HIV, but research has not identified whether these sensory deficits affect gait pattern.

2.3.4 Co-morbidities in Children with Spastic Diplegia

2.3.4.1 Epilepsy

Approximately 40 percent of children with CP are diagnosed with epilepsy (Graham et al., 2016; Gulati & Sondhi, 2018). Changes in the brain's electrical activity cause seizures. The risk of epilepsy increases with severity of motor impairment of the child (Singhi et al., 2002). Although ambulant children with spastic diplegia have a less severe motor impairment and are therefore at a lower risk, there is still a small percentage of children who are diagnosed with epilepsy (Singhi et al., 2002). Anti-epileptic medication is used to control epileptic seizures. Medication is prescribed according to the frequency and severity of the seizures (Singhi et al., 2002; Shang et al., 2015). Common side effects of anti-epileptic medication, especially in children, is drowsiness (Mutanana, Tsvere & Chiweshe, 2020). Research has also shown that anti-epileptic medication may cause decreased bone density and increased fracture risk (Pavone

et al., 2021). These side effects need to be considered with children with CP and the benefits need to outweigh the risks.

2.3.4.2 Human Immunodeficiency Virus

HIV in the paediatric population remains a challenge despite advances in prevention of mother-to-child transmission (PMCT). According to UNAIDS (2020) between 1.2 and 2.2 million children between the ages of 0 and 14 are infected with HIV.

The human immunodeficiency virus can invade the central nervous system (CNS) whilst the foetus is in utero or in early infancy. The neuronal injury caused by the virus commonly disrupts the neurodevelopment of the infant which can manifest in cognitive, motor and language delays (Whitehead, Potterton & Coovadia, 2014). HIVE is the most common primary HIV-related CNS complication (Naik et al. 2018). When compared to adults, the developing brain is more vulnerable to early and more severe infection of the virus (Donald et al., 2015). A study in South Africa by Donald et al. (2015) looked at the HIVE in a South African clinic. Of the 87 children who participated, 64% were diagnosed with spastic diplegia and 20% had experienced at least one seizure. HIV is prevalent in South Africa and may be the cause of many of the cases of children with spastic diplegia.

Gait pattern and physical status of HIVE spastic diplegia was explored in a study by Langerak (2014). A 3DGA and a physical assessment were used to assess gait and the lower extremities of 14 children. Gait pattern was first described in this study for spastic diplegia HIVE children. Two groups were identified in the study based on distinct gait patterns: one group had a gait pattern like that of a normally developing child and the second group had a more pathological gait. The pathological gait group displayed notable impairments in the knee and ankle joints. The knee was in flexion throughout the gait cycle with reduced range of movement and a delayed peak swing in mid- to terminal swing. The ankle remained in plantar flexion throughout the phases of gait. Muscle tone was assessed in both groups and showed that the pathological gait group had greater increase of muscle tone when compared to the other group. When assessing muscle strength, both groups presented with increased impairments from proximal to distal (except for hip flexion).

Spastic diplegia is a common presentation in children with HIVE (Naik et al., 2018). A cross sectional study by Naik et al. (2018) compared 33 HIV-infected participants with spastic diplegia to 31 HIV-uninfected participants with spastic diplegia. Participants were between the ages of four and 16, with a GMFCS level I to IV. A once-off assessment of participants was

performed at four facilities across Johannesburg, South Africa. Gross motor function and mobility was assessed using the GMFM-66 and Functional Mobility Scale (FMS). Muscle tone was assessed using the MAS and muscle strength was assessed using a handheld dynamometer. Findings showed that children with HIVE spastic diplegia presented with milder tone proximal to distal and were weaker in muscle strength in comparison to their uninfected counterparts. Children with spastic diplegia as a result HIVE presented slightly differently to those children with spastic diplegia as a result of CP (Naik et al., 2018).

2.4 Outcome Measures and Measuring Devices

Outcome measures and measuring devices were selected to assess muscle tone, muscle strength, lower limb sensation and gait in children with spastic diplegia.

2.4.1 Edinburgh Visual Gait Score (EVGS)

Read et al. (2003) developed a visual gait analysis scoring system to use in children with CP. This scoring system involves recording a walking child with a video camera and analysing this footage thereafter. Each limb is assessed and scored between 0 and 2 according to the movement deviation from normal. 3DGA has always been the gold standard tool for analysing gait; however, it is not easily accessible and exorbitant in cost. Read et al. (2003) created this tool in order to provide a simple, cost-effective, and quantitative gait analysis scoring system that would be easily accessible. The authors of this study video recorded patients walking before and after surgical intervention as part of a three-dimensional Vicon (Oxford, UK) gait analysis system study. The comparative results between the EVGS score and the Vicon scores correlated well and were in perfect agreement for almost two thirds of the first 10 scores. This correlation verified good validity of the EVGS. All observers for the EVGS analysis made two assessments of the children preoperatively and demonstrated intraobserver reliability. Interobserver reliability was attained as Kappa values were positive for all 17 items.

A study by del Pilar Duque Orozco et al. (2016) also compared 3DGA to EVGS and had similar findings. This study used a variety of observers from highly experienced, to observers with no experience. Interobserver agreement was 60 to 90% (Kappa values 0.18–0.85) for the 17 items in the EVGS and intra-observer agreement was 64 to 92%. The overall agreement between EVGS and 3DGA was 52 to 73%. In both studies the reliability of the EVGS scoring was greater in items that were analysing distal joints (foot, ankle and knee). The results showed that all the observers were reliable, however those with the most experience, were slightly more reliable.

Ong, Hillman and Robb (2008) looked at the reliability and validity of inexperienced observers using the EVGS. The assessments were done twice to provide inter- and intra-reliability of the observers and data was compared to that of 3DGA for validity. The co-efficient of reliability for intra-observer agreement was 5.15 for inexperienced observers and 4.21 for experienced observers. When comparing the data to the 3DGA, the complete agreement for inexperienced observers was 52% and 64% for experienced observers. Inexperienced observers are relatively reliable when using the EVGS assessment tool. Ong, Hillman and Robb (2008) supported findings in del Pilar Duque Orozco et al. (2016) and Read et al. (2003) that data is most similar and reliable from items in the distal joints (foot and ankle).

Using the EVGS to quantify the quality of gait is important. A recent study by Akkaya and Elbasan (2021) looked at the effects of lower limb sensation on gait in children with CP. Using the EVGS they were able to compare the lower limb sensation results to the quality of gait and assess whether there was a direct association. The EVGS is also an important tool pre and post intervention and allows a more quantitative assessment as opposed to a qualitative assessment. The responsiveness of the EVGS to lower limb surgery was investigated and found to be effective in quantifying improvement in gait quality (Read et al., 2003; Gupta and Raja, 2012). Post-surgical comparison of the EVGS score showed large improvements in the ankles and knees, moderate to large effects at the hip, small improvements at the hip joint and no improvements in the trunk. EVGS scores improved from distal to proximal joints (Gupta & Raja, 2012). The nature of most of the surgical interventions on these patients could be responsible for this pattern, however research has shown proximal joint scores in the EVGS to be less reliable.

Wood, Firth and Potterton (2018) used the EVGS along with the GMFM-66 and FMS to assess whether single event multilevel surgery (SEMLS) improved gait and function in ambulant children with spastic diplegia. A prospective study was conducted on 10 children and the EVGS scores showed a mean improvement of 6.4 following surgery. Although not clinically significant, it was a slight improvement in gait. Another limitation of this study was that the sample size was very small and therefore lacked generalisability. The secondary aim of this study was to assess whether SEMLS had similar affects in children with diplegia secondary to CP and HIVE. Of the 10 children that participated in this study, six had HIVE but improvements in both groups were similar.

A recent study by Aroojis, Sagade and Chand (2021) investigated the usability and feasibility of the EVGS as a tool in a busy clinical setting. Inter- and intrarater reliability of various components of the EVGS were assessed between two observers. The intra-observer and inter-observer reliability were between 65–98.3% and 61.7–92.5% respectively. Findings proved that using a handheld smartphone camera with slow motion technology and a motion analysis application, is effective and simple to use when calculating the EVGS scores.

2.4.2 Modified Ashworth Scale (MAS)

The MAS provides a nominal measure of a muscle's resistance to passive stretch (Pandyan et al., 1999). The examiner will move a joint through its full range of movement and rate the resistance of the muscle according to the scale (Bohannon & Smith, 1987). The original Ashworth Scale (AS) was a five-point rating scale that assessed spasticity from 0 to 4. Bohannon and Smith (1987) later modified this scale to include a +1 and redefined the description of each level, thus creating a six-point rating scale. The MAS requires no equipment which makes it easy to use in a clinical setting.

Mutlu, Livanelioglu and Gunel (2008) looked at the interrater and intrarater reliability of both the original AS and the MAS in children with spastic diplegia. A sample of 38 children was used and the interrater and intrarater reliability was evaluated using the ICC. The interrater reliability score ranges were higher for the MAS (0.61–0.87 ICC) compared to the AS (0.54–0.78 ICC). The intrarater reliability for the MAS was also slightly higher than AS but both tools ranged from having poor to good ICC, signifying that the same physiotherapist using the tool, obtained different results for the test-retest.

A similar yet smaller study by Clopton et al. (2005) which included 17 children, found that the hamstrings and elbow flexor muscle groups had good interrater scores (>0.75 ICC) whereas other muscle groups had poor scores (<0.50 ICC) using the MAS. Intrarater scores were also good for the hamstrings muscle (>0.75 ICC) and moderate scores for other muscles (0.50 to 0.75 ICC).

A study by Gregson et al. (1999) compared the MAS to the Tone Assessment Scale when used on stroke patients in an acute setting. It found that the MAS was a reliable measurement tool (Kappa=0.84 for interrater and 0.83 for intrarater comparisons). Li, Wu and Li (2014) had similar findings in their study when assessing the test-retest reliability and interrater reliability

of the MAS, however reliability was higher in the upper limb (elbow flexors) compared to the lower limb (plantar flexors).

Despite good reliability results from these studies there is an overriding amount of research that has emphasised that caution must be taken when using the MAS as a measuring tool (Clopton et al., 2005; Yam & Leung, 2006; Mutlu et al, 2008). There are however few other clinically feasible options for assessing muscle tone.

2.4.3 Muscle Strength using a Handheld Dynamometer (HHD)

The HHD is a device that is used to measure muscle strength. The HHD can be applied using one of two methods, the "break-method" or the "make-method". In the make-method, the participant exerts maximum effort against the stationary device and in the break-method, the force is applied by the examiner too and the participant resists or works against this force. Verschuren et al. (2008) assessed the inter-tester reliability of both methods and found unfavorable results. The ICC, the coefficient of variation (CV) and standard error of measurement (SEM) values were used to assess reliability in this study. For the break-method ICC values ranged from 0.42–0.73 and for the make-method 0.49–0.82. The SEM and CV (%) values for the break-method ranged from 27.9–58.9 and 22.2–35.3% and for the make-method 30.6–52.7 and 16.2–56.2%. The make-method was shown to be more reliable than the break-method for the following muscle groups: hip extensors, hip abductors, knee extensors and knee flexors. This suggests that the make-test is the preferable method when using the HHD to test muscle strength in children with CP (Berry, Giuliani & Damiano, 2004; Verschuren et al., 2008).

Taylor, Dodd and Graham (2004) investigated the test-retest reliability of the HHD when used to measure muscle strength in children with CP. Berry et al. (2004) performed a similar study and both studies found good reliability with their own limitations.

Taylor et al. (2004) assessed 10 children with spastic diplegia twice over a six-week period. Five lower limb muscle groups were assessed, namely: hip flexors, extensors, abductors, knee extensors and ankle plantarflexors. The mean force value for each muscle group on the left and the right were combined when determining the reliability for each muscle test. All ICC scores were above 0.81 and proved high reliability, however, there were measurement errors for some tests, specifically the hip extensor test which was found to be unreliable. Uncertainty arose as to whether the ICC scores provide a good evaluation of reliability.

Berry et al (2004) measured the muscle strength in 15 children with spastic diplegia and quadriplegia one to two weeks apart and looked only at the hip abductors, knee flexors and extensors. The GMFM scores of each child were assessed and comparison between strength and GMFM scores were assessed. Hip abductor and knee flexor strength were related to the GMFM scores but not the knee extensor strength. The SEM in absolute newtons and the ICC scores were used to assess the reliability of the HHD. Excluding the left knee flexion, the ICCs for the intersession and intrasession were 0.84 and above. The SEM ranged from 6.72 to 25.26 newtons. The SEM emphasises the importance of repeating tests when using a HHD to allow for an average and account for the variability in results. However, the SEM depends on anthropometric information and can be difficult to interpret strength changes and use as a comparison when looking at other studies(Crompton, Galea & Phillips, 2007).

Normative values for muscle strength in typically developing children are required to assess whether a child with CP has weakness. There have been many studies done to provide a normative data set for the purpose of identifying weaknesses in children with these types of impairments (Macfarlane, Larson & Stiller, 2008; Hébert et al., 2015).

Macfarlane, Larson and Stiller (2008) established the isometric force reference values for healthy six- to eight-year-old children, as well as determined whether anthropometric information and physical activity have an effect on strength. 154 children participated in this study and the MicroFET 2 HHD was used to measure strength. The results provided an age-specific cut-off for strength values of each muscle. Strength increased with age and height in all muscles except the knee extensors and those who were physically active had four to six stronger muscle groups. Macfarlane et al. (2008) also emphasised the importance of ensuring that children with disabilities do not compensate and use other muscle groups by adapting the positions for muscle testing. A child with loss of joint range or balance deficits may also have difficulty assuming their position for testing.

Hébert et al. (2015) conducted a similar study to establish reference values for typically developing children and adolescents. 351 children between the ages of four and 17 years old participated in this study and the Chatillon push-pull HHD (FCE500, Ametek TCI Division, Chatillon Force Measurement Systems, Largo, Florida). Body mass, height and age were found to be strong predictors of muscle strength. Gender had an effect after 14 years due to pubescent changes in the body, which explains why in the study by Macfarlane et al. (2008) there were no effects of gender on strength due to the children being between the ages of six and eight.

McKay et al. (2017) established reference values for the strength of 12 muscle groups and flexibility and examined the effects that anthropometric and demographic factors have on strength. A thousand children and adults participated in this study and the Citec dynamometer (CT 3001; CIT Technics, Groningen, Netherlands) was used to assess muscle strength. Results showed that height was the most significant predictor of strength and in adolescents body mass, gender and age were the strongest independent predictors of strength.

2.4.4 Brief Peripheral Neuropathy Screening (BPNS) and Pin-prick Test

The BPNS encompasses several subjective and objective tests that assess sensation and the integrity of the sensory pathways thereof. Objectively it assesses the ankle jerk reflex and vibration sensation. If a patient can feel the vibration for 10 seconds, it is regarded as normal.

Cherry et al. (2005) assessed the performance and features of the BPNS in sensory neuropathies in the context of HIV infection. Eighty patients were assessed using this tool and were positive if they presented with the signs and symptoms. The most effective diagnostic symptom found was numbness when identifying those with a neuropathy. The BPNS proved to be a valid tool in identifying sensory neuropathies, however the study was done exclusively on adults and at the time of writing only a study by Benjamin-Damons (2019) has explored the use of this tool on children.

Benjamin-Damons (2019) investigated the prevalence of HIV-related sensory neuropathies in the paediatric population in South Africa. In this study the pin-prick test was added to the BPNS to improve the sensitivity of this screening tool. Benjamin-Damons (2019) found that 25.9% of children in the study were positive for sensory neuropathies. The case definition in this study being that the child must present with at least one bilateral sign (reduced/absent vibration sense, absent ankle jerk reflexes and reduced pin-prick sensation).

Peters et al. (2014) used the neuropathy disability score (NDS) in a similar cross-sectional study. In this study 182 HIV-infected children between the ages of five and 15 on ARVs in rural South Africa were assessed for peripheral neuropathies using both the neuropathy symptom score and NDS. The NDS comprises sensation test elements that were used in the Benjamin-Damons (2019) study, including vibration sense, pin-prick and ankle reflexes. In addition to these elements, Peters et al. (2014) included temperature sensation testing. The study found that there was a 24% prevalence of peripheral neuropathies in the sample and concluded that peripheral neuropathies are a common condition in children with HIV on ARVs.

Araujo, Nascimento and Garcia (2000) conducted a cross-sectional study to investigate peripheral neuropathies in the paediatric population. Thirty-nine HIV-infected participants between the ages of five and 14 were assessed. The assessment comprised a physical examination of reflexes, light touch, pain, temperature and vibration sense (using a 128Hz tuning fork). One third of the participants (34%) had signs and symptoms of peripheral neuropathies, including distal paraesthesia, diminished ankle jerks, and diminished vibration sense. This study highlighted the prevalence of peripheral neuropathies in the HIV-infected paediatric population.

According to Gulati and Sondhi (2018) at least 50% of children with CP have cognitive impairments which is why children with spastic diplegia may have difficulty understanding the subjective component of the BPNS. Although McLaughlin (2005) found qualitative sensation testing to be feasible in children with CP, many had difficulty responding to the questions.

Fine touch (tactile sensation), vibration sensation, two-point discrimination and proprioceptive information is carried via the dorsal column, medial lemniscal pathway. The spinothalamic tracts are responsible for carrying the sensory information including touch, pressure, pain, and temperature. The pin-prick test is assessing pain sensation and integrity of the non-myelinated pain fibres as they carry information via the spinothalamic tract. The vibration sensation and the ankle reflex typically diminish in patients with peripheral neuropathies, which is why they form the objective part of the BPNS. The BPNS is a simple tool that can easily be used in poorly resourced facilities (Cherry et al., 2005). Including the pin-prick test allows for a more comprehensive assessment of sensation as both columns of the sensory pathways are examined (Benjamin-Damons, 2019).

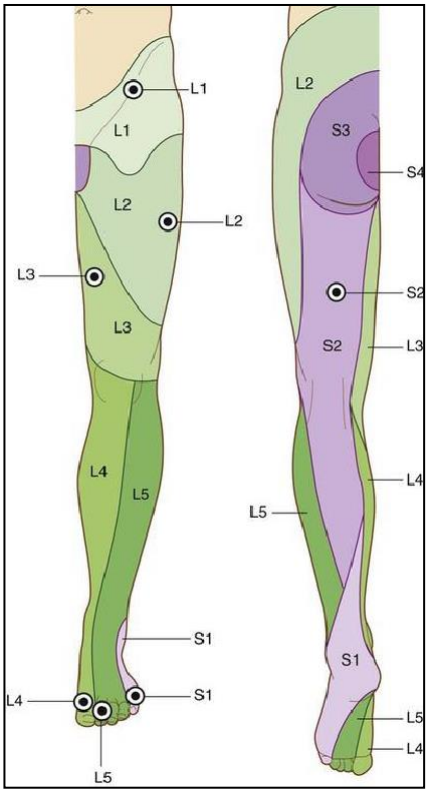


Figure 2.3 Dermatomal areas assessed when performing the pin-prick test (Clinical Gate, 2021)

2.5 Conclusion

Spastic diplegia as a result of CP is a complex condition that impairs neurodevelopment on multiple levels. Physical impairments in spastic diplegia create a distinctive walking pattern that makes this condition recognisable to therapists working in the field. Age is a factor that affects gait pattern as a natural progression of gait has been identified. Muscle strength, muscle tone and contractures have also been identified as causal factors for the specific gait pattern in spastic diplegia. There are, however, many other factors that are overlooked for having influence in gait.

Somatosensory loss in the lower limbs is prevalent in CP, however it is rarely considered during assessment or treatment planning. Sensation may affect gait pattern and further research is needed to investigate this.

There is high prevalence of HIV in the South African paediatric population, as well as peripheral neuropathies caused by the virus. Emerging research has shown that there is a distinct group of children with spastic diplegia caused by HIVE that have a different clinical

presentation. Co-morbidities such as HIV may be factors that affect gait pattern which need to be further explored.

It is important to explore these factors and establish whether they influence gait pattern. It is also valuable to support existing research that shows that age, muscle strength and muscle tone affect gait pattern.

CHAPTER 3 – Methodology

This chapter discusses the methodology used to conduct this study.

3.1 Study Design

A cross-sectional study design was used. This type of design was appropriate to disprove the null hypothesis. It was also cost and time effective by capturing data at a specific point in time. A once-off assessment of participants' gait pattern, muscle tone, muscle strength and lower limb sensation was conducted by the primary researcher.

3.2 Ethical Clearance

Ethical clearance was approved by the Human Research and Ethics Committee (Medical) at the University of Witwatersrand. The application number is M201040 and the Ethical Clearance certificate can be found attached (see appendix 1). Ethical clearance was approved prior to participant recruitment and data collection.

3.2.1 Permission to Conduct Research

Permission was granted to conduct the study by Forest Town School, West Rand CP and the Department of Education (see appendices 2, 3 and 4). Participants and parents or caregivers were given information sheets explaining the study (see appendices 5 and 6) with consent and assent forms attached (see appendices 7 and 8). Written consent and assent forms were granted from the participant and his or her primary caregiver. Anonymity and confidentiality were maintained. Participants were free to withdraw from the study at any time without consequences.

3.2.2 Ethical Considerations

Rights of the participants were considered as outlined in the Patients' Rights Charter (see appendix 9). Informed consent was achieved in this study. Information sheets were provided for participants, as well as their parents or caregivers, that explained how the study was going to be conducted and the purpose thereof. Consent was achieved through assent and consent forms. Separate consent for videography was stipulated in the consent form. Parents or caregivers were required to fill in information sheets after they gave consent to do the study. The forms were written in English and if the participant did not understand the information, it was explained verbally by a physiotherapist fluent in Zulu. Additional medical history was obtained

from the learner profile at their school. All information in this study, including video graphic information, was kept confidential and all names of participants were coded to maintain anonymity. All coded information was stored on the primary researcher's laptop with security password. The guidelines stipulated in the Health Professionals Council of South Africa were followed throughout the study. Covid regulations as outlined in the South African Gazette were followed throughout this study.

3.3 Location

This study was conducted at Forest Town School and West Rand CP School. Assessments were conducted in private rooms within the physiotherapy department at each school. The students attending these schools have learning disabilities or both learning and physical disabilities. Both schools provide physiotherapy, occupational therapy and speech therapy for their students.

3.4 Study Population

3.4.1 Sample Size

The Covid-19 pandemic occurred during the time of this research preparation, therefore access to school records was not possible. Accessing these records would have enabled an exact population from which to calculate a sample size. Thirty participants were recruited to meet the requirements of the central limit theorem (Kwak & Kim, 2017).

3.4.2 Inclusion Criteria

Children were included to participate in this study if:

1. They presented with GMFCS level I, II, III
2. They presented with spastic diplegic CP
3. They attended Forest Town School or West Rand CP School
4. They were able to follow simple instructions

3.4.3 Exclusion Criteria

Children were excluded from this study if:

1. They received surgery or botox in the last six months prior to the date of assessment
2. They were over the age of 18 years

3.5 Outcome Measures and Measurement Devices

3.5.1 The Edinburgh Visual Gait Score

EVGS is an observational scoring system used to assess gait in children with CP. A walking child is recorded with a video camera and this footage is then analysed. Each limb is assessed and scored between 0 and 2 according to the movement deviation from normal. This assessment tool has shown to have good reliability and validity when compared to other gait assessment tools (Robinson et al., 2015; del Pilar Duque Orozco et al., 2016).

3.5.2 The Modified Ashworth Scale

The Modified Ashworth Scale (MAS) was used to measure spasticity or muscle tone in the lower limb muscles. It assesses the resistance of a muscle to passive stretch using a six-point rating scale (see table 3.1 below). Interrater and intrarater reliability is good for only a few muscle groups which suggests that caution must be taken when using this assessment tool (Clopton et al., 2005).

Grade	Description
0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part/s is/are moved in flexion or extension.
1+	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM.
2	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved.
3	Considerable increase in muscle tone, passive movement difficult.
4	Affected part(s) rigid in flexion or extension.

Table 3.1 The Modified Ashworth Scale (Bohannon & Smith, 1987)

3.5.3 Handheld Dynamometer

The handheld dynamometer (HHD) is a lightweight portable device used to measure the strength of an isometric muscle contraction. The device used in this study was the MicroFET2. The isometric muscle contraction is measured in newtons using this device. The device is held against an anatomical point and the child is instructed to push against it. The device was used on a low threshold to allow maximal sensitivity. The HHD has been shown to be reliable when used to test young individuals with CP (Taylor et al., 2004).

3.5.4 Brief Peripheral Neuropathy Screening Tool and Pin-prick Test

Brief Peripheral Neuropathy Screening Tool (BPNS) is a valid assessment tool used to detect peripheral neuropathies, specifically in HIV-infected individuals (Cherry et al., 2005). The pin-prick test is a neurological assessment tool that assesses pain, sensation, and neural integrity. Using the pin-prick test in addition to the BPNS highlights the importance of making sensation testing more comprehensive (Benjamin-Damons, 2019).

3.5.5 Anthropometric Data

The anthropometric measurements for each child were taken. Height and weight were measured in centimetres and kilograms using a tape measure and a digital scale. These measurements were changed into a standardised z-score using the WHO Anthro Software. The z-scores formulated allowed interpretation and comparison of the growth measurements against a “normal” growth population.

3.6 Procedure

3.6.1 Recruitment

The physiotherapists at Forest Town School and West Rand CP School identified eligible participants from their individual caseload for this study. The children that fit the inclusion criteria were invited to participate in this study telephonically. Each participant and caregiver received a written explanation of the study (appendices 5 and 6) and a consent form and assent form (appendices 7 and 8). All forms were written in English but there was a verbal translation option for those that did not understand. At Forest Town School 21 participants were invited and one was later removed as they no longer fit inclusion criteria. At West Rand CP School 15 participants were invited and five declined to participate.

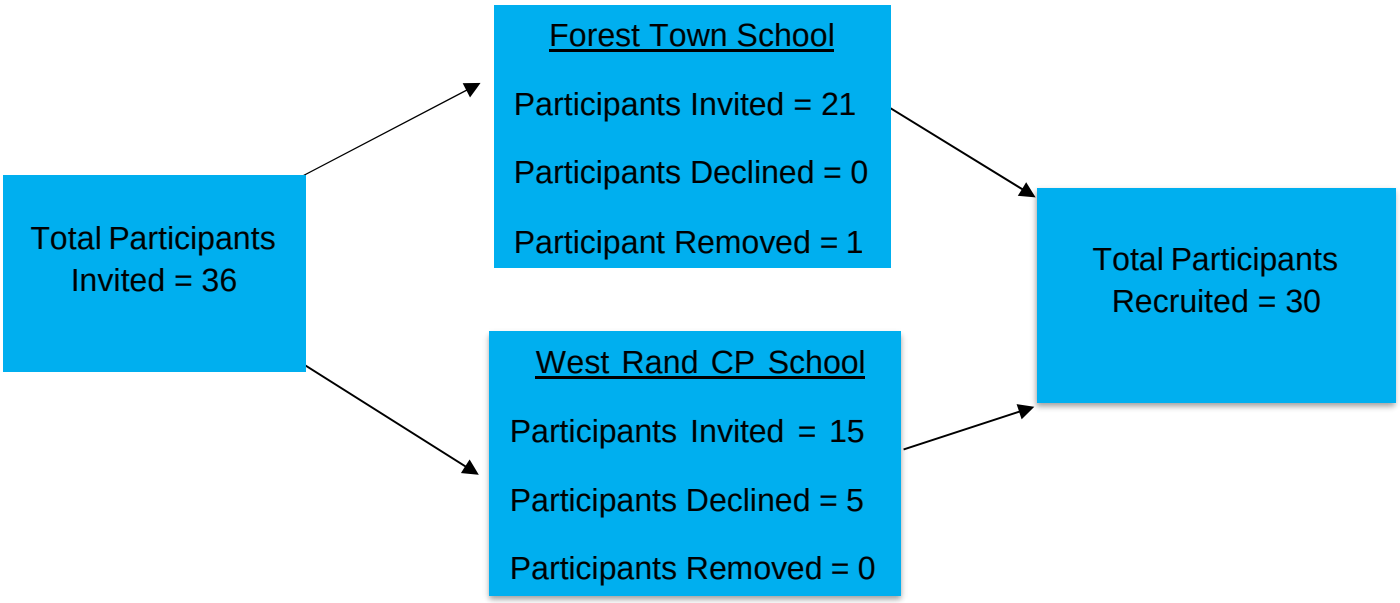


Figure 3.1 Summary of the Recruitment Process

Once consent and assent forms were signed, the parent or caregiver was given a date and time for their child's assessment. A questionnaire was sent home for the parents to complete in the interim (appendix 10). The caregiver was invited to attend the assessment being held at the school premises during school hours. The caregiver was reimbursed for travel expenses if they attended the assessment. Learner profiles of each child were used to obtain medical history and provide additional information that might have been missed in the questionnaire completed by the parents.

3.6.2 Medical History

Medical history was obtained from the questionnaire (appendix 10) completed by the parent or caregiver. Information included pregnancy, birth history, medication, medical and surgical history, developmental milestones and family history of illnesses or conditions. Additional information was provided by the child's learner profile at school. HIV status was listed in the medical and surgical history section of the questionnaire (appendix 10).

3.6.3 Measurements

All measurements were done by the primary researcher. The researcher had five years paediatric physiotherapy experience and knowledge at the beginning of this study. All the results were documented on a data collection sheet (appendix 11).

1. Anthropometric data was collected. Height was measured in centimetres with a tape measure. The child stood with their back against the wall with their heels as close to the wall

as possible. The child was able to hold onto their assistive device for support. The height was measured from the heel to the top of their head.

Weight was measured using a digital scale in kilograms. The child stood on the scale with minimal support to allow for accurate reading. The height-for-age, weight-for-age and BMI-for-age z-scores were calculated by using the WHO Anthro software.

2. Muscle tone of the lower limb muscles was assessed using the MAS. The primary researcher asked the child to relax during the assessment. The child lay in supine and the primary researcher passively applied movement at each joint bilaterally for one second for no more than three movements. The following muscle groups were examined: gastrocnemius muscle, soleus muscle, hamstrings muscle, hip adductor muscle and quadriceps muscle (see appendix 12 for detailed procedure).

3. Joint contractures were assessed after completion of muscle tone testing. Each child was positioned in prone or supine depending on which joint was being assessed. The joint was moved through its full range (see table appendix 13) and limited range of movement was documented. Only the lower limbs were assessed.

4. Muscle strength was examined using a handheld dynamometer (HHD) using the MicroFET2 Dynamometer (Hoggan Health Industries Inc, Draper, Utah). This device measured the force of each muscle group in newtons. A "make test" was used as the primary researcher asked the child to push against the stationary device as hard as possible over five seconds. Each test was performed twice and then an average was calculated. The following muscle groups were assessed: trunk flexor strength, trunk extensor strength, hip flexor strength, hip abduction strength, knee flexion strength, knee extension strength, ankle plantarflexion strength and ankle dorsiflexion strength (see appendix 14 for detailed procedure).

5. Video gait analysis was performed using the Edinburgh Visual Gait Score (EVGS) to assess the gait pattern of each child (see appendix 15). The primary researcher ensured that the child's joint was easily identifiable by ensuring the child was dressed appropriately. The child was asked to bring a pair of shorts or tights from home. If they were unable to bring their own shorts, the primary researcher was able to provide one. During the assessment the child was allowed to use an assistive device if required. The primary researcher positioned the camera on a tripod at the end of the room. The child was instructed to walk 10 metres from the opposite side of the room towards the camera for coronal footage as well as five metres across the room

for sagittal gait plane footage. The camera recorded the child walking, and this footage was analysed on the primary researcher's laptop using the scoring system.

6. Lower limb sensation was tested using the Brief Peripheral Neuropathy Screening (BPNS) tool and the pin-prick test. The BPNS tool consists of a vibration and a reflex component. The pin-prick test assessed the neural integrity of dermatomal areas in the leg. Overall lower limb sensation was based on whether there were positive signs in these assessments. (See appendix 16 for detailed procedure.)

The findings from this study are presented in chapter four.

CHAPTER 4 – Research Results

4.1 Introduction

In this chapter the results of the study will be presented.

4.2 Demographic, Anthropometric and Clinical Data

4.2.1 Gender

Figure 4.1 shows the distribution of gender: 60% of the participants were female (n=18) and 40% were male(n=12).

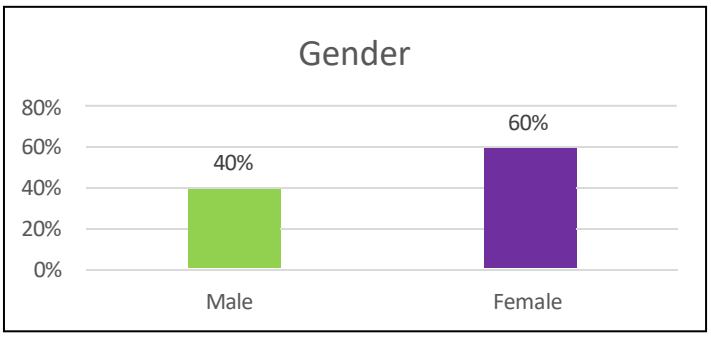


Figure 4.1 Gender

4.2.2 Participants, Age, Height, Weight and BMI

Table 4.1 depicts the descriptive information of the participants age, height, weight, and BMI.

Table 4.1 Demographic and anthropometric findings

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
						Statistic	Std. Error	Statistic	Std. Error
Age (years)	30	6.50	17.00	12.00	3.01370	-.152	.427	-1.255	.833
Height (cm)	30	108	159	135.53	14.881	-.370	.427	-1.004	.833
Weight (kg)	30	16.6	73.9	35.793	14.8195	.983	.427	.571	.833
BMI	30	13.0	30.5	18.157	4.6727	1.622	.427	2.076	.833
Valid N (listwise)	30								

Table 4.1 compares the age, height, weight and BMI scores. The Kurtosis shows that none of the values are skewed and all the demographic variables follow a normal distribution.

Table 4.2 shows the participant's height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ) and BMI-for-age z-scores (BAZ). Z-scores are calculated depending on age. Each was scored using either the WHO standards (0–5 years) or the WHO reference (5–19 years) (WHO, 2007). The WAZ reference data is not available in respect of children beyond 10 years of age due to pubertal growth spurt and, as a result, height being mistaken for excess weight. Eighteen participants were over the age of 10 therefore no WAZ scores available for these participants. Means, standard deviations, minimum and maximum values are included.

Table 4.2 Anthropometric z-scores

	N Valid	N Missing	Mean	Std. Deviation
WAZ	12	18	-0.10	3.17
HAZ	30	0	-1.29	3.15
BAZ	30	0	-0.03	1.57

Figure 4.2 Shows the BMI frequency of the participants. The mean BMI of the participants is 18.16, with a standard deviation of 4.673.

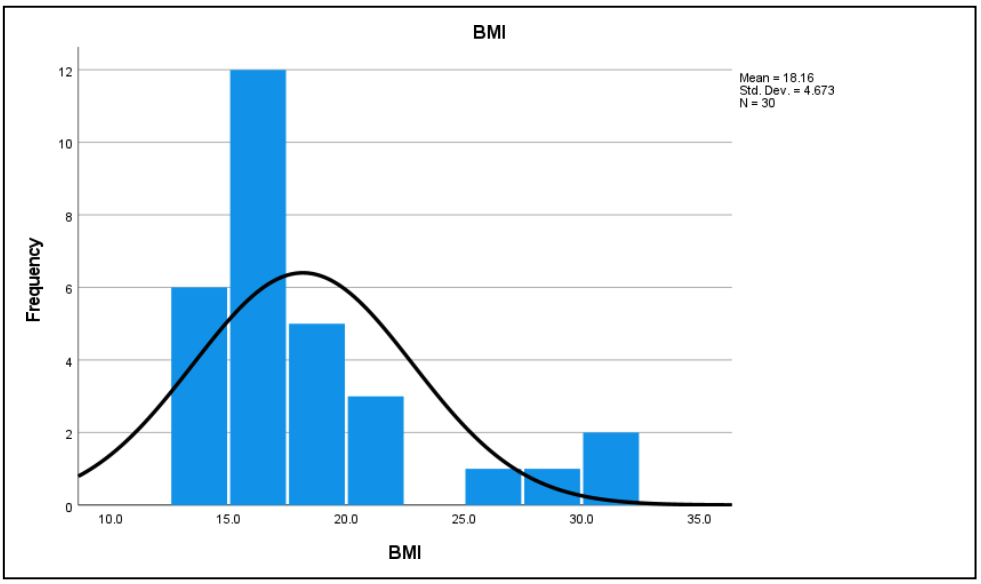


Figure 4.2 BMI distribution for all participants

The mean BMI of 18.16 indicates that the participants were underweight. A normal BMI is between 18.5 and 24.9.

Figure 4.3 shows the comparison of BMI by age to WHO data/anthropometric data.

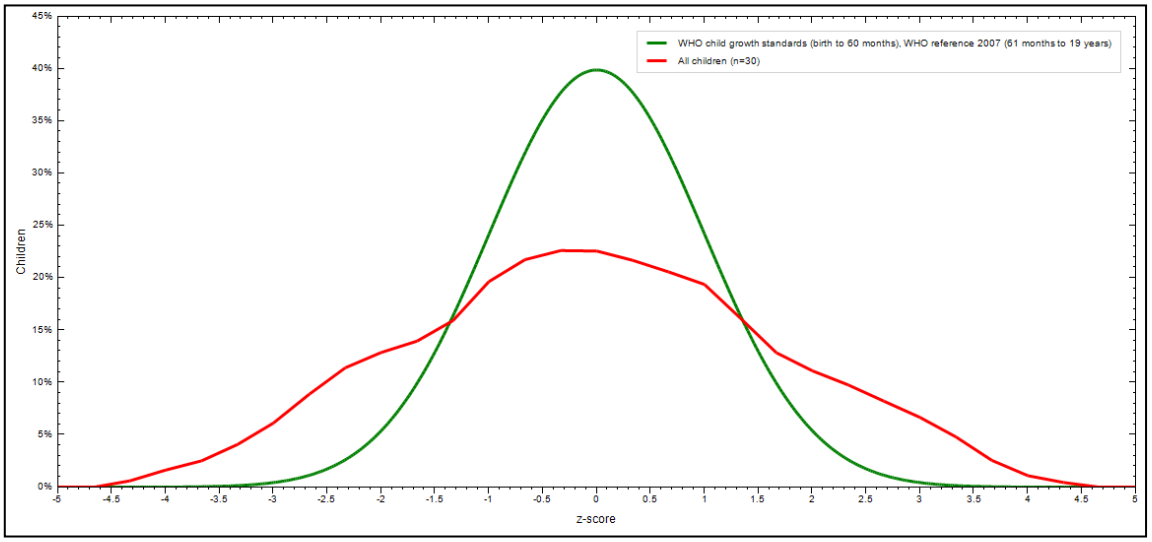


Figure 4.3 BMI by age to WHO data/anthropometric data (n=30)

Figure 4.3 highlights the widespread z-scores within the sample group as well as the reduced BMI by age when compared to the WHO child growth reference (WHO, 2007).

Figure 4.4 shows the comparison of BMI by age and gender on WHO data.

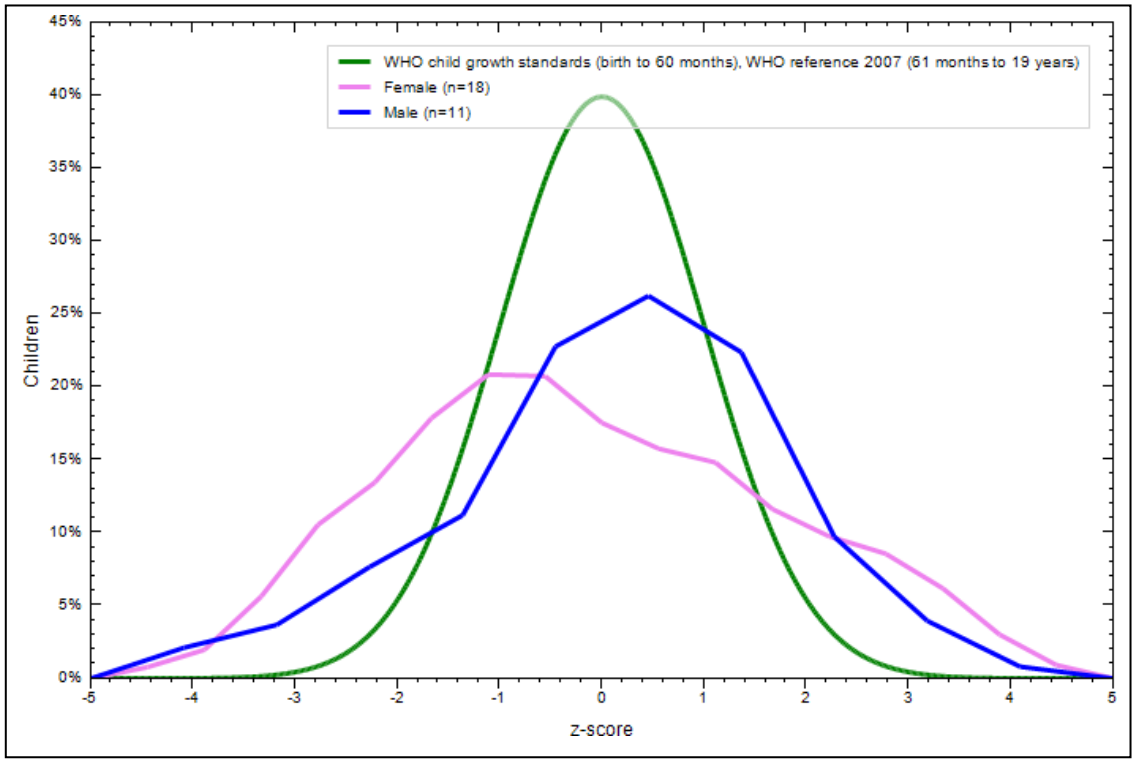


Figure 4.4 BMI by age and gender on WHO data (n=30)

Figure 4.4 highlights that the females in the study were more underweight than the males. It also highlights that both groups were underweight when compared to the WHO growth standards.

4.2.3 Birth History and Mode of Delivery

Table 4.3 shows the birth term and mode of delivery of the participants.

Table 4.3 Term and mode of delivery (n=30)

	Full Term	**Premature**	**Unknown Term**
N	13	14	3
%	43.3%	46.76%	10%
	Natural Delivery	**Caesarean Delivery**	**Unknown Delivery**
N	20	9	1
%	66.67%	30%	3.33%

For birth term, 43.33% (n=13) of the participants were born full term, 46.76% (n=14) were born prematurely and 10% (n=3) were unknown. For the mode of delivery, 66.67% (n=20) were born via natural delivery, 30% (n=9) were born via caesarean delivery and for 3.33% (n=1) the mode of delivery is unknown.

4.2.4 Medical, Surgical and Co-morbidities History

Table 4.4 displays the surgical and medical history of the participants as well as co-morbidity distribution.

Table 4.4 Surgical and Medical History (n=30)

Surgical History	**N**	**%**
None	8	26.7%
Botox	7	23.3%
Surgery	2	6.7%
Both botox and surgery	13	43.3%
Total	30	100%
Co-morbidities		
None	12	40.0%
HIV Positive	18	60.0%

Almost 27% (n=8) have no history of surgery or botox, 23.3% (n=7) have a history of botox, 6.7% (n=2) have a history of surgery and 43.3% (n=13) have a history of both botox and surgery. The majority of the participants had HIV 60% (n=18), and 40% (n=12) did not have any co-morbidities.

4.2.5 Assistive Device and Ankle Foot Orthosis

Table 4.5 shows the assistive device and AFO use of the participants.

Table 4.5 Assistive Device and AFO use

Assistive Device		
	N	**%**
None	8	26.7%
Elbow crutches	11	36.7%
Walker	11	36.7%
Ankle Foot Orthosis		
Has AFOs bilaterally	14	46.7%
Does not have AFOs bilaterally	16	53.3%

Almost 27% (n=8) did not use an assistive device, 36.67% (n=11) used elbow crutches and 36.67% (n=11) used a walking frame. Almost 47% (n=14) used AFOs and 54.33% (n=16) did not use AFOs.

4.2.6 Clinical Presentation

The clinical presentation of participants is displayed in table 4.6. In terms of ankle contractures, 26.7% (n=8) did not present with any and 73.3% (n=22) had contractures in either one or both of their ankles (3.3% (n=1) right ankle, 10% (n=3) left ankle and 60% (n=18) both ankles). Almost 67% (n=20) did not have knee contractures and 33.3% (n=10) had knee contractures in both knees.

Table 4.6 Lower Limb Contractures

Ankle Contracture		
	N	**%**
None	8	26.7%
R ankle	1	3.3%
L ankle	3	10.0%
Both	18	60.0%
Knee Contracture		
None	20	66.7%
Both	10	33.3%

Table 4.7 Distribution of participants in GMFCS level II and level III

GMFCS Level		
Level II	8	26.7%
Level III	22	73.3%

Table 4.7 shows that the GMFCS of participants was distributed between level II and level III. Almost 74% (n=22) were GMFCS level III and walked with a handheld mobility device and 26.7% (n=8) were GMFCS level II and walked with limitations without an assistive device.

4.2.7 Muscle Tone

The muscle tone scores were attained using the MAS. For statistical purposes the scores were converted from an interval scale to a nominal scale from 0 to 5. An MAS score of 0 equalled 0, 1 equalled 1, 1+ equalled 2, 2 equalled 3, 3 equalled 4 and 4 equalled 5. Gastrocnemius, soleus, hamstrings and adductor muscles are tabulated with average percentages in frequency table 4.8.

Table 4.8 Average frequencies expressed as percentages for tone in muscle groups (n=30)

Nominal Scale	Spasticity	Quadricep	Adductors	Hamstrings	Gastrocnemius	Soleus
0	**No increased tone (MAS 0)**	0%	3.3%	0%	0%	0%
1	**Mild (MAS 1)**	20%	40%	16.7%	23.3%	6.7%
2	**Mild/Moderate (MAS +1)**	30%	10%	13.3%	26.7%	60%
3	**Moderate (MAS 2)**	26.7%	30%	33.3%	23.3%	16.7%
4	**Severe (MAS 3)**	23.3%	16.7%	36.7%	26.7%	16.7%
5	**Very severe (MAS 4)**	0%	0%	0%	0%	0%

Table 4.8 shows that none of the participants had very severe tone in any of their muscle groups (MAS=4). The hamstrings muscle had the most increased tone, as 70% of the participants scored a 2 or 3 on the MAS. The soleus muscle had the least increased tone. 66.7% of the participants scored either a 1 or 1+ on the MAS. A trend of increased tone being more proximal than distal is noted.

Tone was further divided into proximal and distal muscles as shown in table 4.9. Gastrocnemius and soleus muscles were grouped as distal muscle tone and hamstrings, quadriceps and adductor muscles were grouped as proximal muscle tone.

Table 4.9 Average frequencies expressed as percentages comparing proximal and distal muscle tone groups

Nominal Scale	Spasticity	Proximal Tone	Distal Tone
0	**No increased tone (0)**	0%	0%
1	**Mild (1)**	13.3%	6.7%
2	**Mild/Moderate (+1)**	33.3%	43.3%
3	**Moderate (2)**	40%	30%
4	**Severe (3)**	13.3%	20%
5	**Very severe (4)**	0%	0%

Table 4.9 shows that 40% of participants had moderate tone proximally (MAS=2) and 43.3% had mild to moderate tone distally (MAS=+1).

4.2.8 Muscle Strength

Muscle strength data (mean, standard deviation, minimum and maximum values) for the participants are given in table 4.10. Skewness and Kurtosis have been calculated and show that the data is normally distributed. Values of muscle strength are represented in newtons (N).

Table 4.10 Average muscle strength values in newtons (N).

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
						Std. Error		Std. Error
Trunk Flexion	17.05	55.65	34.01	11.46	.39	.43	-.94	.83
Trunk Extension	18.85	71.35	37.49	12.87	.97	.43	.99	.83
Right Hip Abduction	4.40	41.10	22.73	8.94	.17	.43	-.25	.83
Left Hip Abduction	7.50	51.15	22.42	9.94	1.05	.43	1.49	.83
Right Dorsiflexion	5.20	27.05	14.99	4.84	.38	.43	.32	.83
Left Dorsiflexion	6.85	37.55	14.87	6.94	1.76	.43	3.31	.83
Right Plantarflexion	.00	29.80	7.51	7.31	1.14	.43	1.51	.83
Left Plantarflexion	.00	32.00	7.43	8.01	1.47	.43	2.10	.83
Right Knee Flexion	.00	64.30	24.22	14.80	.60	.43	.24	.83
Left Knee Flexion	.00	54.05	22.85	12.44	.25	.43	.13	.83
Right Knee Extension	17.50	90.20	48.79	18.02	.61	.43	-.09	.83
Left Knee Extension	25.05	77.80	46.51	14.32	.56	.43	-.43	.83
Right Hip Flexion	11.95	52.40	33.06	11.76	-.02	.43	-1.00	.83
Left Hip Flexion	14.65	62.90	32.01	12.41	.75	.43	-.13	.83

Table 4.10 shows that knee extension had the highest muscle strength. The quadriceps muscle responsible for knee extension had a mean score of 46.51N on the left and 48.79N on the right side. The plantarflexor muscles had the lowest muscle strength. The gastrocnemius and soleus muscle responsible for plantarflexion had a mean score of 7.43N on the left and 7.51N on the right side.

4.2.9 Brief Peripheral Neuropathy Screening and Pin-prick Test

The results of the BPNS and the pin-prick test are presented in figure 4.5. In order to test positive, participants had to have at least two symptoms in either or both legs. Symptoms were either reduced sensation to the pin-prick test, reduced awareness of the vibration sense or reduced ankle reflexes.

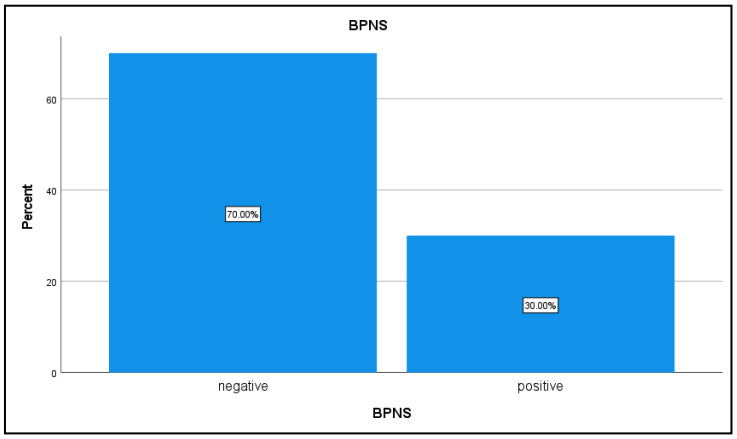


Figure 4.5 BPNS distribution amongst participants

Figure 4.5 shows that 70% (n=21) of the participants were negative for the BPNS and pin-prick test and 30% (n=9) of the participants were positive for the BPNS and pin-prick test.

The dermatomal areas affected are tabulated below in table 4.11. This table shows the frequency of the affected dermatomal areas, S2 (33.3%), S1 (20.8%), L5 (33.3%) and L4 (12.5%).

Table 4.11 Dermatomal areas affected

Dermatomal Area	Percentage (%)	Number affected
L3	0	0
L4	12.5	3
L5	33.3	8
S1	20.8	5
S2	33.3	8
Total Areas Affected:		24

4.2.10 EVGS Scores

Table 4.12 describes the EVGS scores for the right leg, left leg and the average of the two scores.

Table 4.12 EVGS Scores

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
EVGS Right Leg	30	7	29	19.57	5.870	-.316	.427	-.762	.833
EVGS Left Leg	30	9	30	19.80	5.301	-.028	.427	-.747	.833
EVGS Average	30	8.0	29.0	19.683	5.4433	-.157	.427	-.781	.833

Table 4.12 shows that the mean score is 19.68, and standard deviation 5.44. The mean score of 19.68 indicating high abnormality in gait pattern. According to the skewness and kurtosis values as shown in table 4.12, the EVGS is normally distributed as it falls within a standard deviation of three points.

4.2.11 Rodda Classification

Figure 4.6 shows participant distribution amongst the Rodda Classification groups.

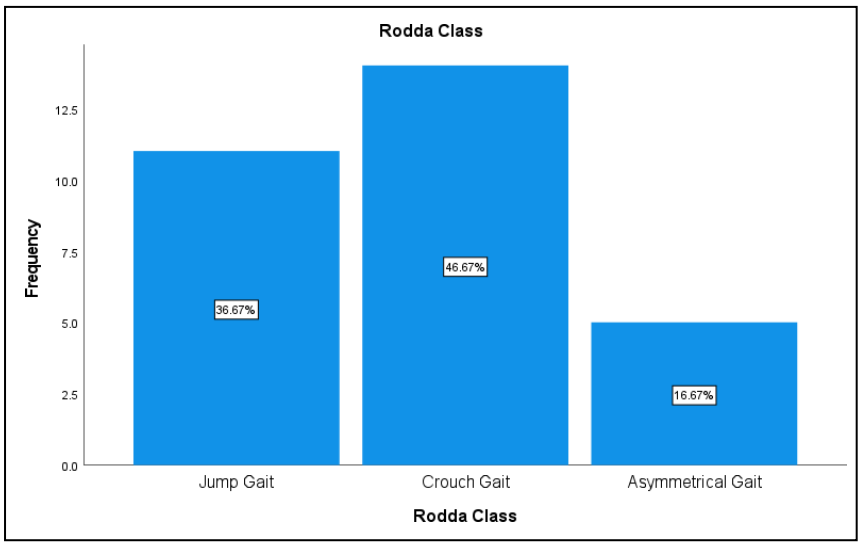


Figure 4.6 Rodda classification distribution

Almost 47% of participants had crouch gait (n=14), 36.67% (n=11) had jump gait, and 16.67%(n=5) had an asymmetrical gait. None of the participants had a true equinus or apparent equinus gait pattern.

4.3 Correlation Between Factors

Statistical tests were used to determine whether there were relationships between the factors investigated.

4.3.1 Correlation Between Anthropometric Information and EVGS

Correlations between EVGS and anthropometric scores were investigated using Pearson's correlation. The results are presented in table 4.13.

Table 4.13 Correlation between age, WAZ, HAZ, BAZ and EVGS average

		Age	WAZ	HAZ	BAZ	EVGS Av
Age	Pearson Correlation	1	.79**	.065	-.012	-.307
	Sig. (2-tailed)		.002	.735	.948	.098
	N	30	12	30	30	30
WAZ	Pearson Correlation	.793**	1	.919**	.427	-.060
	Sig. (2-tailed)	.002		.000	.166	.853
	N	12	12	12	12	12
HAZ	Pearson Correlation	.065	.919**	1	.055	.060
	Sig. (2-tailed)	.735	.000		.772	.755
	N	30	12	30	30	30
BAZ	Pearson Correlation	-.012	.427	.055	1	.002
	Sig. (2-tailed)	.948	.166	.772		.990
	N	30	12	30	30	30
EVGS Av	Pearson Correlation	-.307	-.060	.060	.002	1
	Sig. (2-tailed)	.098	.853	.755	.990	
	N	30	12	30	30	30
**. Correlation is significant at the 0.01 level (2-tailed).						

There is a significant positive correlation between age and WAZ (Pearson correlation coefficient 0.79). There is also a significant and strong positive correlation between WAZ and

HAZ (Pearson correlation coefficient 0.919). There is no correlation found between EVGS average scores and anthropometric scores.

4.3.2 Correlation Between BMI and Rodda Classification

Correlation between the Rodda Classification and BMI were investigated using the Pearson Correlation Chi-Squared tests. Table 4.14 shows the crosstabulation between Rodda Classification and BMI.

Table 4.14 Rodda Classification and BMI (n=30)

			BMI Group				Total
			Underweight <18.5	Normal 18.5–24.9	Overweight 25–29.9	Obese 30>	
Rodda Class	Jump Gait	Count	10	0	0	1	11
		% within Rodda Class	90.9%	0.0%	0.0%	9.1%	100.0 %
		% of Total	33.3%	0.0%	0.0%	3.3%	36.7%
	Crouch Gait	Count	6	5	2	1	14
		% within Rodda Class	42.9%	35.7%	14.3%	7.1%	100.0 %
		% of Total	20.0%	16.7%	6.7%	3.3%	46.7%
	Asym-metrical Gait	Count	5	0	0	0	5
		% within Rodda Class	100.0%	0.0%	0.0%	0.0%	100.0 %
		% of Total	16.7%	0.0%	0.0%	0.0%	16.7%
Total		Count	21	5	2	2	30
		% within Rodda Class	70.0%	16.7%	6.7%	6.7%	100.0 %
		% of Total	70.0%	16.7%	6.7%	6.7%	100.0 %

Crosstabulation of Rodda Classification and BMI, as shown in table 4.14, shows that almost all of the participants with jump gait (90.9%) and asymmetrical gait (100%) were in the underweight category. Overall, 70% of the participants were underweight with a BMI of less than 18.5, 16.7% were normal weight and only 6.7% were overweight or obese.

Table 4.15 Relationship between weight and Rodda Classification

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.238[a]	6	.081
Likelihood Ratio	14.335	6	.026
Linear-by-Linear Association	.196	1	.658
N of Valid Cases	30		
a. 10 cells (83.3%) have expected count less than 5. The minimum expected count is 0.33.			

Table 4.15 shows that there was no significant correlation between weight and Rodda Classification (Pearson Chi-Square 0.081).

4.3.3 Correlation Between Age and EVGS Score

The correlation between age and EVGS score is shown in table 4.16.

Table 4.16 Correlation between age and EVGS average score

		Age	EVGS Average
Age	Pearson Correlation	1	-.307
	Sig. (2-tailed)		.098
	N	30	30
EVGS Average	Pearson Correlation	-.307	1
	Sig. (2-tailed)	.098	
	N	30	30

The mean age of the sample was 11.99 years old (std. deviation 3.01) and the mean EVGS was 19.68 (std. deviation 5.44). Although it is not significant, there is a weak and negative relationship (P=0.098) suggesting that the younger the child, the higher their EVGS score may be, indicating more gait disturbances.

4.3.4 Correlation Between Age and Rodda Classification

Table 4.17 shows that there is no significant relationship between age and Rodda Classification as calculated with the Chi-Square tests (P=0.50).

Table 4.17 Relationship between age and Rodda Classification

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	7.302[a]	8	.504
Likelihood Ratio	7.939	8	.439
Linear-by-linear Association	1.977	1	.160
N of Valid Cases	30		
a. 14 cells (93.3%) have expected count less than 5. The minimum expected count is 0.17.			

The Rodda Classification and age group crosstabulation is shown in table 4.18.

Table 4.18 Rodda Classification and age group crosstabulation

			Age Group					Total
			4–6 years	7–9 years	10–12 years	13–15 years	16–18 years	
Rodda Class	Jump Gait	Count	1	5	1	3	1	11
		% within Rodda Class	9.1%	45.5%	9.1%	27.3%	9.1%	100.0%
		% of Total	3.3%	16.7%	3.3%	10.0%	3.3%	36.7%
	Crouch Gait	Count	0	2	3	7	2	14
		% within Rodda Class	0.0%	14.3%	21.4%	50.0%	14.3%	100.0%
		% of Total	0.0%	6.7%	10.0%	23.3%	6.7%	46.7%
	Asymmetrical Gait	Count	0	1	2	2	0	5
		% within Rodda Class	0.0%	20.0%	40.0%	40.0%	0.0%	100.0%
		% of Total	0.0%	3.3%	6.7%	6.7%	0.0%	16.7%
Total		Count	1	8	6	12	3	30
		% within Rodda Class	3.3%	26.7%	20.0%	40.0%	10.0%	100.0%
		% of Total	3.3%	26.7%	20.0%	40.0%	10.0%	100.0%

If you disregard the asymmetrical gait from the data, there are age and gait pattern trends found in the jump gait and crouch gait patterns as shown in table 4.18. Almost 65% of participants (n=9) with crouch gait were between the ages of 13 and 18 years old. Almost 64% of participants (n=7) with jump gait were between the ages of four and 12 years old.

Table 4.19 Relationship between age and gait pattern

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.930[a]	4	.295
Likelihood Ratio	5.386	4	.250
Linear-by-linear Association	3.239	1	.072
N of Valid Cases	25		
a. 9 cells (90.0%) have expected count less than 5. The minimum expected count is 0.44.			

Table 4.20 Directional measures between age and gait pattern

			Value
Nominal by Interval	Eta	Age Dependent	.363
		Gait Dependent	.771

Chi-Square test results and directional measures as shown in table 4.19 and 4.20 respectively indicate that there is a weak relationship between age and gait when asymmetrical gait category is removed from the results.

4.3.5 Correlation Between Co-morbidities and Rodda Classification

Children across all three gait pattern groups had HIV, as shown in table 4.21.

Table 4.21 Rodda Classification and Co-morbidity

			Co-morbidity		Total
			None	HIV	
Rodda Class	Jump Gait	Count	4	7	11
		% within Rodda Class	36.4%	63.6%	100.0%
		% of Total	13.3%	23.3%	36.7%
	Crouch Gait	Count	6	8	14
		% within Rodda Class	42.9%	57.1%	100.0%
		% of Total	20.0%	26.7%	46.7%
	Asymmetrical Gait	Count	2	3	5
		% within Rodda Class	40.0%	60.0%	100.0%
		% of Total	6.7%	10.0%	16.7%
Total		Count	12	18	30
		% within Rodda Class	40.0%	60.0%	100.0%
		% of Total	40.0%	60.0%	100.0%

There was no significant relationship between Rodda Classification and comorbidities. There is likely no relationship due to very small sample size.

4.3.6 Correlation Between BPNS and EVGS Scores

Directional and symmetric measures between BPNS and EVGS are shown in table 4.22 and 4.23 respectively.

Table 4.22 Directional Measures Between BPNS and EVGS

			Value
Nominal by Interval	Eta	BPNS Dependent	.888
		EVGS Average Dependent	.118

Table 4.23 Symmetric Measure BPNS and EVGS

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Interval by Interval	**Pearson's R**	-.118	.173	-.626	.536[c]
Ordinal by Ordinal	**Spearman Correlation**	-.097	.178	-.515	.611[c]
N of Valid Cases		30			
a. Not assuming the null hypothesis.					
b. Using the asymptotic standard error assuming the null hypothesis.					
c. Based on normal approximation.					

There was no significant correlation between BPNS and EVGS scores.

4.3.7 Correlation Between BPNS and HIV

The correlation between BPNS and HIV is shown in table 4.24.

Table 4.24 Comorbidity and BPNS crosstabulation

		BPNS				Total	
		Negative		Positive			
		N	%	N	%	N	%
Comorbidity	**None**	11	52.4%	1	11.1%	12	40.0%
	HIV	10	47.6%	8	88.9%	18	60.0%
Total		21	100.0%	9	100.0%	30	100.0%

There was a significant relationship between the BPNS and HIV (P=0.034). Almost 90% (88.9%) of children who tested positive in the BPNS test had HIV comorbidity.

The Pearson Chi-Square test between comorbidity and BPNS is shown in table 4.25.

Table 4.25 Pearson Chi-Square test between comorbidity and BPNS

		BPNS
Comorbidity	Chi-square	4.471
	df	1
	Sig.	.034[*, b]
Results are based on nonempty rows and columns in each innermost subtable.		
*. The Chi-square statistic is significant at the 0.05 level.		
b. More than 20% of cells in this sub table have expected cell counts less than 5. Chi-square results may be invalid.		

Due to the small sample in this sub-analysis, the Chi-square results may not be generalisable.

4.3.8 Correlation Between Muscle Strength and Gait

Muscle strength was grouped into proximal and distal to evaluate whether there was correlation with gait pattern as outlined in the Rodda Classification system. The results are presented in table 4.26.

Table 4.26 Correlation between muscle strength and EVGS average scores

		Muscle Strength Distal	Muscle Strength Proximal	EVGS Average
Muscle Strength Distal	Pearson Correlation	--		
	N	30		
Muscle Strength Proximal	Pearson Correlation	.661**	--	
	Sig. (2-tailed)	.000		
	N	30	30	
EVGS Average	Pearson Correlation	-.420*	-.455*	--
	Sig. (2-tailed)	.021	.012	
	N	30	30	30
**. Correlation is significant at the 0.01 level (2-tailed).				
*. Correlation is significant at the 0.05 level (2-tailed).				

The correlation between gait and proximal strength is r=0.115, which is very weak but positive. The correlation between gait and distal muscle strength is r=0.13, which is also very weak but positive. This is indicative of muscle strength having an influence in the type of gait pattern presentation.

When assessing the correlation between muscle strength proximally and distally, there was a significant positive and strong relationship (P<0.000; r=0.661). This indicated that if a child was strong distally, they would be strong proximally and vice versa.

There is a significant negative moderate relationship between muscle strength distally and EVGS average scores (r=-0.420; p=0.021). There is a relationship between muscle strength proximally and EVGS scores (r=-0.455; p=0.021). When combining the strength to describe global muscle strength, this indicates that the stronger the child, the better the EVGS score. The lower the EVGS score, the better the gait pattern presentation.

4.3.9 Correlation Between Muscle Tone and Gait

To determine whether there was an association between muscle tone to gait, muscle groups were divided into distal and proximal groups. 43.3% (n=13) scored +1 on the MAS in distal muscle groups and 40% (n=12) scored 2 in proximal muscle groups.
Figure 4.7 displays the distribution of tone distally.

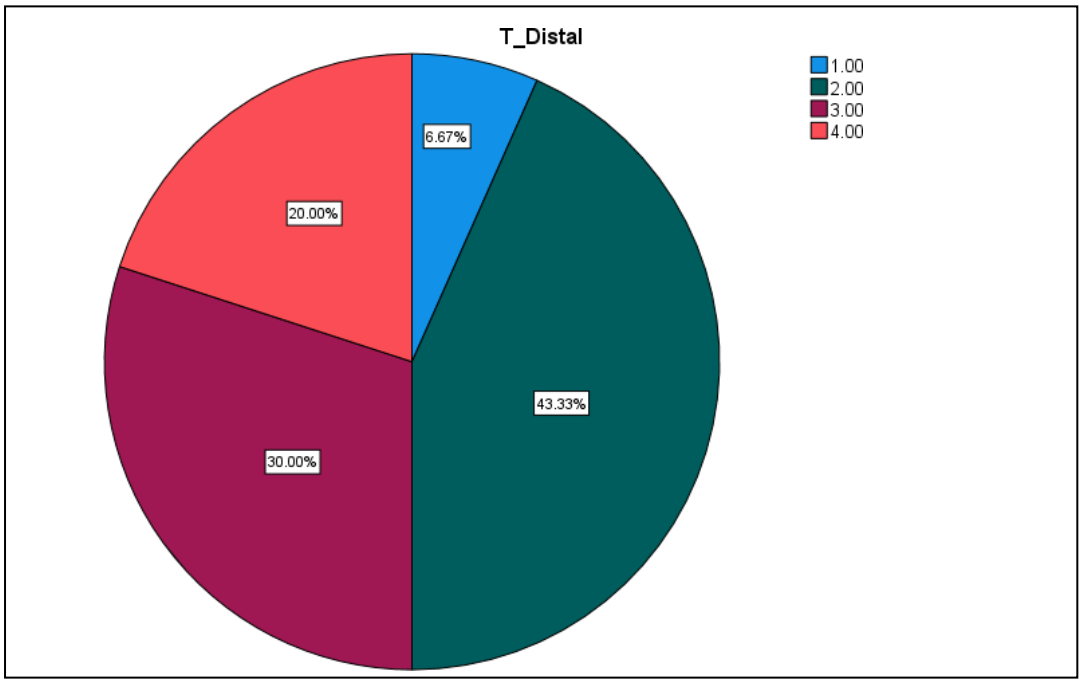


Figure 4.7 Distal Muscle Tone Distribution

Figure 4.8 displays the distribution of tone proximally.

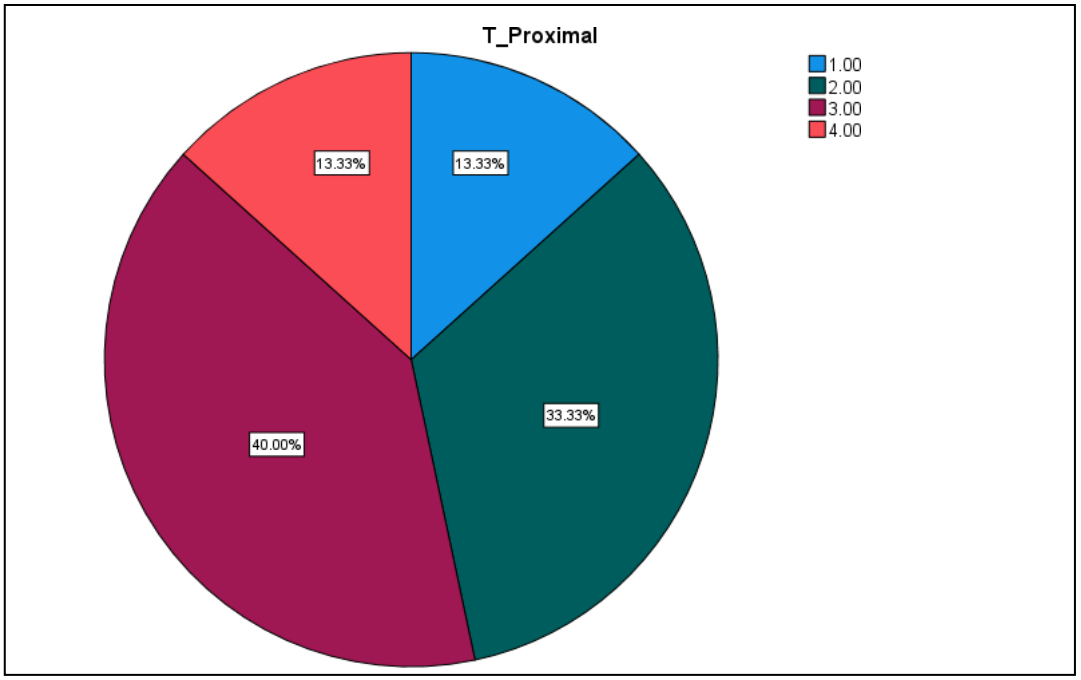


Figure 4. 8 Proximal Muscle Tone Distribution

Table 4.27 shows the crosstabulation of proximal tone and gait pattern. There is no relationship with proximal muscle tone and gait pattern (P=0.703).

Table 4.27 Proximal tone and gait pattern crosstabulation

		Gait Pattern						Total	
		Jump Gait		Crouch Gait		Asymmetrical Gait			
		N	%	N	%	N	%	N	%
Tone Proximal	1.00	2	18.2%	1	7.1%	1	20.0%	4	13.3%
	2.00	3	27.3%	4	28.6%	3	60.0%	10	33.3%
	3.00	4	36.4%	7	50.0%	1	20.0%	12	40.0%
	4.00	2	18.2%	2	14.3%	0	0.0%	4	13.3%
Total		11	100.0%	14	100.0%	5	100.0%	30	100.0%

When looking at the trends in table 4.27, the crouch gait pattern mostly scored a 2 on the MAS and the jump gait mostly scored a 1 on the MAS. An increase in tone was observed proximally in crouch gait when compared to jump gait.

Table 4.28 shows the crosstabulation of distal tone and gait pattern. There is no relationship between distal muscle tone and gait pattern as well (P=0.234).

Table 4.28 Distal tone and gait pattern crosstabulation

		Gait Pattern						Total	
		Jump Gait		Crouch Gait		Asymmetrical Gait			
		N	%	N	%	N	%	N	%
Tone Distal	1.00	0	0.0%	1	7.1%	1	20.0%	2	6.7%
	2.00	3	27.3%	9	64.3%	1	20.0%	13	43.3%
	3.00	4	36.4%	3	21.4%	2	40.0%	9	30.0%
	4.00	4	36.4%	1	7.1%	1	20.0%	6	20.0%
Total		11	100.0%	14	100.0%	5	100.0%	30	100.0%

When looking at the trends in table 4.28, the majority of those with jump gait had increased muscle tone distally as 72.8% scored a 2 or 3 on the MAS, whereas 71.4% of those with crouch gait scored a 1 or 1+ on the MAS.

4.4 Summary of Results

The most important results of this study are as follows:

- There were 73.3% participants that were classified as GMFCS level III and the most common gait pattern of the participants was crouch gait (46.67%).
- The mean BMI of participants was 18.16, which fell in the underweight category.
- There is a negative moderate relationship between muscle strength and EVGS average score.
- There is no significant relationship between muscle strength and gait pattern, however positive and weak correlation.
- The weak and negative relationship between age and EVGS scores suggests that the younger the child, the higher their EVGS score is, indicating an improvement of gait pattern as a child ages.
- There is no significant relationship between age and gait pattern, however if "asymmetrical gait" is removed and jump and crouch gait compared, younger children presented with jump gait and older children presented with crouch gait.
- There is no significant relationship between muscle tone and gait. However, the following trends were noted:
    - Crouch gait scored mostly 2 on MAS for proximal tone
    - Jump gait scored mostly 1 on MAS for proximal tone

    - Crouch gait scored mostly 2–3 on MAS for distal tone
    - Jump gait scored mostly 1–1+ on MAS for distal tone
    - Therefore: Crouch gait had greater tone proximally and jump gait had greater tone distally.
- 30% of participants were positive for the BPNS, which confirmed lower limb sensory deficits
- Majority of participants had the comorbidity HIV (60%).
- A significant relationship between those testing positive for BPNS and having HIV. Almost 90% of those that tested positive in the BPNS had HIV (P=0.034).

4.5 Conclusion

Descriptive and inferential statistics have been presented in this results chapter. The interpretation of these results will be discussed in the following chapter.

CHAPTER 5 – Discussion

5.1 Introduction

The secondary aim of this study was to determine and describe the anthropometric information, co-morbidities, muscle strength, muscle tone, lower limb sensation and gait pattern of children with spastic diplegia. The primary aim of this study was to assess whether there was a relationship between these factors and gait pattern. This chapter intends to discuss and interpret the results of this study. Limitations and implications for further research will also be discussed.

5.2 General

5.2.1 Gender

CP is usually more commonly seen in males (Romeo et al., 2016). Males are more often born preterm which makes them more susceptible to brain injuries (Johnston & Hagberg, 2007). Research has also suggested that there is greater cerebral structure vulnerability in males, while the hormone estrogen in females offers more protection against white matter injuries (Johnston & Hagberg, 2007; Romeo et al., 2016). Sixty percent of the participants in this study were female. Given the high number of HIV-positive participants in the sample, it would suggest that their spastic diplegia is in fact an HIV encephalopathy. This could explain why the sex of the participants was not majority male. HIV transmission can occur in utero, and this is independent of the sex of the foetus. In both studies by Naik et al. (2018) and Langerak et al. (2014) there was a similar even distribution of males and females in the HIVE groups. The even distribution in these HIV groups supports that HIVE causing spastic diplegia is independent from sex. In the Naik et al. (2018) study the HIV-uninfected group was predominantly male (80.6%), which is in line with research that finds CP most commonly occurring in males.

5.2.2 Anthropometric Information

The mean BMI of the participants was 18.16, which falls into the underweight category. When comparing the BMI by age and gender to WHO data growth standards (WHO, 2007), both male and female participants fell well below the normal growth standard line. These findings are in line with research which has shown that non-nutritional and nutritional factors play a role in the height and weight of children with CP (Andrew & Sullivan, 2010).

Gathering anthropometric data has proved to be difficult with children with CP (Andrew & Sullivan, 2010). To measure height, the participant must be able to fully extend their legs. A participant with muscle weakness, increased muscle tone or joint contractures may find it

difficult to fully extend their legs. This would cause a reduced height measurement and inaccurate reading. Measurement of weight with a participant being unable to stand independently due to poor balance could have also affected the accuracy of the scale reading. Almost 74% of participants in this study were GMFCS level III, and needed an assistive device to mobilise, which meant that standing on a scale for weight reading and against a wall for a height reading were difficult tasks.

5.2.3 Co-morbidity History

None of the participants had epilepsy as a co-morbidity. Epilepsy is more prevalent in children with severe forms of CP (Graham et al., 2016). Considering all participants were ambulant, it is expected that epilepsy would not be found in this sample group.

Sixty percent of the participants were HIV positive. The prevalence of HIV is high in South Africa (Naik et al., 2018; UNAIDS, 2020). Spastic diplegia is a residual impairment of HIVE, which could explain the high number of HIV-infected participants in this study.

HIV can cause growth and skeletal deficits in adolescence, and a reduction in bone density (Arpadi, 2000; Rukuni et al., 2021). This could explain why most of the participants in this study were in the underweight BMI category.

There was a high incidence of prematurity amongst the participants, with 46.7% having been delivered preterm. Prematurity is a known risk factor for CP (Donald et al., 2014; Graham et al., 2016) and research has shown that HIV-infected mothers have double the risk of delivering a child prematurely than an uninfected mother (Elenga, Djossou & Nacher, 2021).

5.2.4 Clinical Presentation

Participants of this study were distributed between GMFCS level II and level III. Almost 74% of participants had contractures in their ankles and 33.3% had contractures in their knees. More than half of the participants did not use AFOs. AFOs have been shown to improve gait pattern and ankle stability, as well as reduce the risk of contractures (Pauk et al., 2016). Perhaps if more of the participants wore AFOs, there would be a reduction in contractures and an improvement in gait pattern. The relationship between AFOs and gait pattern, however, was not evaluated in this study.

Almost 74% of the participants in this study either had botox, surgery or both interventions. Surgical intervention has shown to improve gait (Read et al., 2003; Wood et al., 2018). Botox and surgery interventions allow an improvement in joint range of motion, muscle activation

and gait pattern and thereby change the clinical picture of each participant. No surgical intervention will give the exact same result in every child.

5.3 Lower Limb Sensation

Thirty percent of participants were positive for the BPNS and pin-prick test, which confirmed lower limb sensory deficits. Participants had a combination of reduced pin-prick awareness, ankle reflexes and vibration sense. The dermatomal involvement frequency showed that S2 (33.3%), S1 (20.8%), and L5 (33.3%) were the most affected areas. McLaughlin et al. (2005) highlighted the somatosensory deficits in their lower extremities in children with CP. Findings in this study showed that children with CP had a lower sensory score for the direction of scratch ($p<0.001$), toe position ($p=0.01$) and vibration sense ($p=0.01$). More recent studies by Zarkou et al. (2020, 2021) have also identified sensory deficit in the lower limbs of children with spastic diplegia, which supports findings in this study. Zarkou et al. (2021) found that tactile sensory loss had a negative effect on gait.

The relationship between HIV and sensory neuropathy will be discussed further in section 5.7.

5.4 Rodda Classification and EVGS

The most common gait pattern of the participants was crouch gait (46.67%), followed by jump gait (36.7%) and asymmetrical gait (16.7%). Crouch gait has been described as the most common pattern in children with spastic diplegia, which is in line with this study's findings (O'Sullivan et al., 2018).

EVGS scores of participants showed that all gait patterns observed deviated from normal. The mean score was 19.68, which indicated an abnormal gait pattern. Research has shown that the EVGS is effective in assessing and quantifying whether surgical intervention in children with spastic diplegia has been successful (Gupta & Raja, 2012; Wood et al., 2018). Wood et al. (2018) found there to be mean improvement of 6.4 in the EVGS scores one-year post SEMLS. In the current study it added value by quantifying the severity of the abnormal gait pattern of the children.

5.5 Correlation Between Gait Pattern, Anthropometric Information and Clinical Presentation

A weak and negative relationship between age and EVGS scores suggests that the younger the child is, the higher their EVGS score will be. This suggests that their gait pattern improves as they age. In South Africa, children in developed areas attend schools with therapeutic facilities.

Physiotherapy intervention focuses on gait retraining and muscle strengthening (Huang et al., 2020). Apart from musculoskeletal development and pubescent changes with age, children are exposed to therapy at the school-going age of five. The improvement of gait with age in this study could be due to therapeutic intervention along with musculoskeletal changes.

There was no significant relationship between age and gait pattern in the Rodda Classification System. However, if the asymmetrical gait group is removed from the data and jump and crouch gait are compared, gait and age trends are noted. Asymmetrical gait pattern accounted for 16.7% of participants in the study. Asymmetrical gait describes a pattern that combines other patterns to create its own group. This highlights how unique children with spastic diplegia present and how difficult it is to categorise their gait pattern. This may be particularly true for the participants in this study as 60% of them had HIV which may have confounded the results as few studies have fully investigated gait in this group of children. The different presentation of muscle spasticity and strength in children with spastic diplegia HIVE as outlined in the study by Naik et al. (2018) would influence the findings in this study as most of the participants had HIV.

When comparing the jump and crouch gait groups, it was noted that younger children presented with jump gait and older children presented with crouch gait. This pattern progression with age is in line with the natural progression that has been identified (Rodda et al., 2004; O'Sullivan et al., 2018).

5.6 Correlation Between Gait Pattern, Muscle Tone and Muscle Strength

There was no significant relationship found between muscle tone and gait pattern, however there were trends noted when comparing crouch and jump gait pattern.

Crouch gait scored mostly 2 on MAS for proximal tone and mostly 2–3 for distal tone. Jump gait scored mostly 1 on MAS for proximal tone and 1–1+ for distal tone. Participants presenting with crouch gait had greater tone proximally and jump gait had greater tone distally. Considering the natural progression of gait in spastic diplegia, muscular changes occur from distal to proximal (Rodda et al., 2004). Jump gait was more apparent in younger individuals who had greater tone distally and crouch gait was more apparent in older individuals who had greater tone proximally, reinforcing these age-related changes. In the past, therapy has focused on reducing muscle tone in children with CP (Ross & Engsberg, 2007; Yan et al., 2015). In this study there was no significant relationship between muscle tone and gait pattern or gait quality. This supports findings by Ross and Engsberg (2007) that muscle tone does not influence gross motor function whereas muscle strength does.

Muscle weakness or imbalances and contractures can occur at multiple anatomical levels and contribute greatly to gait pattern (Rodda et al., 2004). There was a significant negative moderate relationship between muscle strength and EVGS scores. The less the gait pattern deviates from normal, the higher the muscle strength is. This indicates that muscle strength is an important factor in improving gait pattern. Ross and Engberg (2007) found that muscle strength was an important factor in improving gross motor function. There was no significant relationship between muscle strength and the type of gait pattern, which meant that muscle strength did not play a role in determining whether a child walked with jump, crouch or asymmetrical gait. Anjum et al. (2019) found that muscle strength training significantly improved gross motor ability in children with spastic diplegia.

As the gait pattern progresses, there is also a change of integrity of the plantarflexion and knee extension muscle couple. As the gait pattern progression moves from true equinus through to crouch, the muscle couple goes from being overactive to completely inactive and the ground reaction force moves from anterior to posterior of the knee (Rodda et al., 2004). AFO prescription and orthopaedic management need to carefully consider gait progression and these muscular changes.

5.7 Correlation Between Lower Limb Sensation and HIV

There was a significant relationship between those who tested positive in the BPNS and pin-prick test and those with HIV. Almost 90% of participants with lower limb sensation deficits had HIV (P=0.034). This supports research that has highlighted the prevalence of peripheral neuropathies in the HIV infected paediatric population in South Africa (Peters et al., 2014; Benjamin-Damons, 2019). Both studies found using the BPNS was cost effective and easily useable amongst participants. Mclaughlin et al. (2005) proved the feasibility of lower limb sensory assessments amongst children with CP. In this study the BPNS was used, which tested similar sensory components to Mclaughlin et al. (2005) and included vibration, direction of scratch, pain, light touch and proprioception.

5.8 Conclusion

All children in this study presented with abnormal gait which tended to improve as the children got older. Crouch gait was the most common gait pattern observed. Better muscle strength was associated with better gait quality, however gait was not associated with muscle tone. Sixty percent of the children in this study were living with HIV and these children were more likely

to present with peripheral neuropathy. These findings concur with O' Sullivan et al. (2018) who reported that crouch gait was one of the most common gait patterns in children with spastic.

The findings in this study showed that the less the gait pattern deviates from normal, the higher the muscle strength is. Naik et al. (2018) found that children with spastic diplegia HIVE were weaker than those uninfected with HIV. The prevalence of HIV in this study along with associated peripheral neuropathies highlights the importance of factoring HIV in treatment approach.

5.9 Limitations of this Study

A limitation of this study was that there was a small sample size with a broad range of ages. Natural progression of gait and musculoskeletal changes have been identified in children with spastic diplegia. It is difficult to compare a five-year-old child with spastic diplegia to a 16-year-old child with spastic diplegia as their gait pattern would have progressed and muscular and structural changes would have occurred. Surgery or botox can also change the clinical picture and would make it impossible to compare the participants. Participants that had had botox or surgery in the last 6 months were excluded from this study to mitigate this limitation. Studies have shown that gait improves following surgical intervention (Read et al., 2003; Wood et al., 2018). Children in his study who had undergone surgical intervention could have had higher scores than those who had not.

The asymmetrical gait pattern in Rodda Classification pooled or weakened results as this gait pattern may be a combination of different patterns. Using a simpler classification system like the Sutherland and Davids (1993) Classification, which does not include an asymmetrical group, would allow for better results.

3DGA is the gold standard assessment tool for gait analysis (Ong et al., 2008; Naik et al., 2018).The EVGS was an effective outcome measure to quantify gait pattern abnormalities, however there is reduced reliability when using this assessment tool for proximal joints when compared to the 3DGA (del Pilar Duque Orozco et al., 2016). EVGS lacked a descriptive component in gait analysis needed in this study. Using the scoring system of the EVGS, a child with excessive knee extension would score a 2 for an item and a child with excessive knee flexion would also score a 2 for the same item. This meant that two children with completely different gait abnormalities could have had the exact same EVGS scores.

5.10 Recommendations for Future Research

A larger sample size is required for future research to assess whether there is significant relationship between various factors and gait pattern. A small sample size of 30 participants in this study reduced the generalisability of the findings.

Future studies must compare children with spastic diplegia who are of the same age and GMFCS level. This would help eliminate the natural progression of spastic diplegic gait and bodily changes that occur over time. As participants were over the age of five years, most of them had had some form of surgical intervention. It would be beneficial to assess children who are of a young age or children that have not undergone surgical invention. This would assist with understanding how factors influence gait pattern.

Future research should investigate the gait differences in HIVE children with spastic diplegia and HIV-uninfected children with spastic diplegia. Peripheral neuropathies and lower limb sensory deficits could affect gait in children with spastic diplegia and further studies need to investigate this.

5.11 Clinical Implications

Peripheral neuropathies are prevalent in the paediatric population, especially in children with spastic diplegia. This condition must be considered when planning treatment in a clinical setting.

There was a relationship between age and gait pattern and gait quality. Gait quality improved as children aged and older children presented with crouch gait and younger children presented with jump gait. Age is an important factor to consider in treatment planning.

There was a moderate negative relationship between muscle strength and gait quality which suggests that focusing on muscle strengthening could directly improve gait quality in a clinical setting.

CHAPTER 6 – Conclusion

Over the years there have been many studies done to help understand what affects gait pattern in children with spastic diplegia, but there is a paucity of literature on the effects of HIV on gait in children with spastic diplegia. More than half of the sample used in this study had HIV, which highlights the prevalence of this comorbidity amongst children with spastic diplegic in South Africa. Almost 90% of the children who tested positive for peripheral neuropathies were HIV infected. Lower limb sensory deficits and discomfort caused by peripheral neuropathies could impact gait as well as the quality of life of these children. Further research is needed to support this, but it is important to consider this factor when formulating a treatment plan as a clinician.

There is a relationship between muscle strength and gait, but there is no relationship between muscle tone and gait. This suggests that focus in a clinical setting must be on muscle strengthening as opposed to reducing muscle tone.

A natural progression of gait pattern was highlighted in this study as younger children presented with jump gait pattern and older children with crouch gait pattern. Age is a factor to consider when working with children with spastic diplegia. Prescribing AFOs or surgical intervention must consider age as a factor as bone, muscle and body structure would change over time.

The gait quality of children with spastic diplegia was better in older children. These older children would have had longer exposure to therapeutic intervention in a South African school setting. Almost 74% of participants had had surgical or botox intervention. Both therapeutic and surgical intervention could help improve gait in children with spastic diplegia.

This study highlights factors that must be considered when managing children with spastic diplegia. In a therapeutic environment it is important to establish which factors affect the child in order to treat holistically. The results of this study contribute to the body of knowledge in the management of children with spastic diplegia.

Reference List

Abdel Ghany, W.A., Nada, M., Mahran, M.A., et al. (2016). 'Combined anterior and posterior lumbar rhizotomy for treatment of mixed dystonia and spasticity in children with cerebral palsy'. *Neurosurgery*, 79(3), pp. 336–334. doi: 10.1227/NEU.0000000000001271.

Akkaya, K.U. and Elbasan, B. (2021). 'An investigation of the effect of the lower extremity sensation on gait in children with cerebral palsy'. *Gait and Posture*, 85(6), pp. 25–30. doi: 10.1016/j.gaitpost.2020.12.026.

Amiji, I.A., Naburi, H.E., Kija, E., et al. (2021). 'Peripheral neuropathy in HIV-infected children attending care and treatment clinic, at Muhimbili National Hospital, Dar es Salaam: a cross sectional study'. *BMC Neurology*, 21(1), pp. 1–10. doi: 10.1186/s12883-021-02335-0.

Andrew, M.J., and Sullivan, P.B. (2010). 'Growth in cerebral palsy'. *Nutrition in Clinical Practice: Official Publication of the American Society for Parenteral and Enteral Nutrition*, *25*(4), pp. 357–361. doi: 10.1177/0884533610374061.

Anjum, S., Mehmood, Z. and Idrees, M. Q. (2019) 'The outcome of lower limb strength training in cerebral palsy children with spastic diplegia', *Khyber Medical University Journal*, 11(3), pp. 176-81. doi: 10.35845/kmuj.2019.18319.

Araujo, A.P., Nascimento, O.J. and Garcia, O.S. (2000). 'Distal sensory polyneuropathy in a cohort of HIV-infected children over five years of age'. *Pediatrics*, 106(3), pp. e35–e35. doi: 10.1542/peds.106.3.

Armand, S., Decoulon, G. and Bonnefoy-Mazure, A. (2016). 'Gait analysis in children with cerebral palsy'. *EFORT Open Reviews*, 1(12), pp. 448–460. doi: 10.1302/2058-5241.1.000052.

Aroojis, A., Sagade, B. and Chand, S. (2021). 'Usability and reliability of the Edinburgh Visual Gait Score in children with spastic cerebral palsy using smartphone slow-motion video technology and a motion analysis application: A Pilot Study'. *Indian Journal of Orthopaedics*, 55(4), pp. 931–938. doi: 10.1007/s43465-020-00332-y.

Arpadi, S.M. (2000). 'Growth failure in children with HIV infection'. *Journal of Acquired Immune Deficiency Syndromes (1999)*, 25(1), pp. 37–42. doi: 10.1097/00042560-

200010001-00006.

Banks, L.M., Zuurmond, M., Ferrand, R., et al. (2015). 'The relationship between HIV and prevalence of disabilities in sub-Saharan Africa: Systematic review (FA)'. *Tropical Medicine & International Health*, 20(4), pp. 411–429. doi: 10.1111/tmi.12449.

Bax, M., Goldstein, M., Rosenbaum, P., et al. (2005). 'Proposed definition and classification of cerebral palsy'. *Developmental Medicine and Child Neurology*, *47*(8), pp. 571–576. doi: 10.1017/s001216220500112x.

Be, N., Kim, K., Bishai, W., et al. (2009). 'Pathogenesis of Central Nervous System Tuberculosis'. *Current Molecular Medicine*, 9(2), pp. 94–99. doi: 10.2174/156652409787581655.

Beckung, E., Carlsson, G., Carlsdotter, S., et al. (2007). 'The natural history of gross motor development in children with cerebral palsy aged 1 to 15 years'. *Developmental Medicine and Child Neurology*, 49(10), pp. 751–756. doi: 10.1111/j.1469-8749.2007.00751.x

Benjamin, N., Potterton, J., Kamerman, P., et al. (2015). 'An investigation of peripheral neuropathy in children who are infected with HIV'. *Physiotherapy*, 101, pp. e139–e140. doi: 10.1016/j.physio.2015.03.284.

Benjamin-Damons, N.A. (2019). 'An investigation of HIV sensory neuropathy in children living with HIV'. Available from: https://wiredspace.wits.ac.za/handle/10539/28214

Bennett, B.C., Abel, M.F., Wolovick, A., et al. (2005). 'Center of Mass Movement and Energy Transfer During Walking in Children With Cerebral Palsy.' *Archives of Physical Medicine and Rehabilitation*, 86(11), pp. 2189–2194. doi: 10.1016/j.apmr.2005.05.012.

Berry, E.T., Giuliani, C.A. and Damiano, D.L. (2004). 'Intrasession and intersession reliability of handheld dynamometry in children with cerebral palsy'. *Pediatric Physical Therapy*, 16(4), pp. 191–198. doi: 10.1097/01.PEP.0000145932.21460.61.

De Blaiser, C., De Ridder, R., Willems, T., et al. (2018). 'Reliability and validity of trunk flexor and trunk extensor strength measurements using handheld dynamometry in a healthy athletic population'. *Physical Therapy in Sport*, 34, pp. 180–186. doi: 10.1016/j.ptsp.2018.10.005.

Bohannon, R.W. and Smith, M.B. (1987). 'Interrater reliability of a Modified Ashworth Scale of Muscle Spasticity'. *Physical Therapy*, 67(2), pp. 206–207. doi: 10.1093/ptj/67.2.206.

Cabanas-Valdés, R., Bagur-Calafat, C., Girabent-Farrés, M., et al. (2016). 'The effect of additional core stability exercises on improving dynamic sitting balance and trunk control for subacute stroke patients: A randomized controlled trial'. *Clinical Rehabilitation*, 30(10), pp. 1024–1033. doi: 10.1177/0269215515609414.

Cherry, C.L., Wesselingh, S.L., Lal, L., et al. (2005). 'Evaluation of a clinical screening tool for HIV-associated sensory neuropathies.' *Neurology*, *65*(11), pp. 1778–1781. doi: 10.1212/01.wnl.0000187119.33075.41.

Clinical Gate – 2021 [Cited September 2021]. Available from: https://clinicalgate.com/lower-limb-2/

Clopton, N., Dutton, J., Featherston, T., et al. (2005). 'Interrater and intrarater reliability of the Modified Ashworth Scale in children with yypertonia'. *Pediatric Physical Therapy*, 17(4), pp. 268–274. doi: 10.1097/01.pep.0000186509.41238.1a.

Crompton, J., Galea, M.P. and Phillips, B. (2007). 'Hand-held dynamometry for muscle strength measurement in children with cerebral palsy'. *Developmental Medicine and Child Neurology*, 49(2), pp. 106–111. doi: 10.1111/j.1469-8749.2007.00106.x.

Damiano D.L. (2006). 'Activity, activity, activity: rethinking our physical therapy approach to cerebral palsy'. *Physical Therapy*, 86(11), pp. 1534–1540. doi: 10.2522/ptj.20050397.

Donald, K.A., Walker, K.G., Kilborn, T., et al. (2015). 'HIV Encephalopathy: pediatric case series description and insights from the clinic coalface'. *AIDS Research and Therapy*, 12(2). doi: 10.1186/s12981-014-0042-7.

Donald, K.A., Samia, P., Kakooza-Mwesige, A., et al. (2014a). 'Pediatric cerebral palsy in Africa: A systematic review'. *Seminars in Pediatric Neurology*, 21(1), pp. 30–35. doi: 10.1016/j.spen.2014.01.001.

Donald, K.A., Hoare, J., Eley, B., et al. (2014b). 'Neurologic complications of pediatric Human Immunodeficiency Virus: Implications for clinical practice and management challenges in the African setting'. *Seminars in Pediatric Neurology*, 21(1), pp. 3–11. doi: 10.1016/j.spen.2014.01.004.

Elenga, N., Djossou, F. and Nacher, M. (2021). 'Association between maternal human immunodeficiency virus infection and preterm birth: A matched case-control study from a

pregnancy outcome registry'. *Medicine (United States)*, 100(4), pp. 0–5. doi: 10.1097/MD.0000000000022670.

Elsingergy, M., Worede, F., Venkatakrishna, S., et al. (2021). 'Magnetic resonance imaging diagnosis of causes of cerebral palsy in a developing country: A database of South African children'. *South African Medical Journal*, 111(9), pp. 910–916. doi: 10.7196/SAMJ.2021.v111i9.15666.

Eunson, P. (2012). 'Aetiology and epidemiology of cerebral palsy'. *Paediatrics and Child Health (United Kingdom)*, Elsevier Ltd, 22(9), pp. 361–366. doi: 10.1016/j.paed.2012.05.008.

Gage J.R. (1993). 'Gait analysis. An essential tool in the treatment of cerebral palsy'. *Clinical orthopaedics and related research*, (288), pp. 126–134.

Graham, H.K., Rosenbaum, P., Paneth, N., et al. (2016). 'Cerebral palsy'. *Nature Reviews. Disease Primers*, 2. doi: 10.1038/nrdp.2015.82.

Gregson, J.M., Leathley, M., Moore, A.P., et al. (1999). 'Reliability of the tone assessment scale and the modified Ashworth scale as clinical tools for assessing poststroke spasticity'. *Archives of Physical Medicine and Rehabilitation*, 80(9), pp. 1013–1016. doi: 10.1016/S0003-9993(99)90053-9.

Gulati, S. and Sondhi, V. (2018). 'Cerebral palsy: An overview'. *The Indian Journal of Pediatrics*, 85(11), pp. 1006–1016. doi: 10.1007/s12098-017-2475-1.

Gupta, S. and Raja, K. (2012). 'Responsiveness of Edinburgh visual gait score to orthopedic surgical intervention of the lower limbs in children with cerebral palsy'. *American Journal of Physical Medicine and Rehabilitation*, 91(9), pp. 761–767. doi: 10.1097/PHM.0b013e31825f1c4d.

Hanna, S.E., Rosenbaum, P.L., Bartlett, D.J., et al. (2009). 'Stability and decline in gross motor function among children and youth with cerebral palsy aged 2 to 21 years'. *Developmental medicine and child neurology*, *51*(4), pp. 295–302. doi: 10.1111/j.1469-8749.2008.03196.x

Hébert, L.J., Maltais, D.B., Lepage, C., et al. (2015). 'Hand-held dynamometry isometric torque reference values for children and adolescents'. *Pediatric Physical Therapy*, 27(4), pp. 414–423. doi: 10.1097/PEP.0000000000000179.

Heyrman, L., Feys, H., Molenaers, G., et al. (2014). 'Altered trunk movements during gait in children with spastic diplegia: Compensatory or underlying trunk control deficit?'. *Research in Developmental Disabilities*, Elsevier Ltd., 35(9), pp. 2044–2052. doi: 10.1016/j.ridd.2014.04.031.

Huang, C., Chen, Y., Chen, G., et al. (2020). 'Efficacy and safety of core stability training on gait of children with cerebral palsy: A protocol for a systematic review and meta-analysis'. *Medicine (United States)*, 99(2), pp. 1–5. doi: 10.1097/MD.0000000000018609.

Johnston, M.V. and Hagberg, H. (2007). 'Sex and the pathogenesis of cerebral palsy'. *Developmental Medicine and Child Neurology*, 49(1), pp. 74–78. doi: 10.1017/S0012162207000199.x.

Ko, J., Woo, J.H. and Her, J.G. (2011). 'The reliability and concurrent validity of the GMFCS for children with cerebral palsy'. *Journal of Physical Therapy Xcience*, *23*(2), pp. 255–258. doi: 10.1589/jpts.23.255.

Korzeniewski, S.J., Slaughter, J., Lenski, M., et al. (2018). 'The complex aetiology of cerebral palsy'. *Nature Reviews Neurology*. Springer US, 14(9), pp. 528–543. doi: 10.1038/s41582-018-0043-6.

Krigger, K.W. (2006). 'Cerebral palsy: An overview'. *American Family Physician*, 73(1), pp. 91–100.

Kwak, S.G. and Kim, J.H. (2017). 'Central Limit Theorem: The Cornerstone of Modern Statistics'. *Korean Journal Anesthesiology*, 70(2), pp. 144–156. doi: 10.4097/kjae.2017.70.2.144.

Langerak, N.G., Du Toit, J. Burger, M., et al. (2014). 'Spastic diplegia in children with HIV encephalopathy: First description of gait and physical status'. *Developmental Medicine and Child Neurology*, 56(7), pp. 686–694. doi: 10.1111/dmcn.12319.

Li, F., Wu, Y. and Li, X. (2014). 'Test-retest reliability and inter-rater reliability of the Modified Tardieu Scale and the Modified Ashworth Scale in hemiplegic patients with stroke'. *European Journal of Physical and Rehabilitation medicine*, 50(1), pp. 9–15.

Macfarlane, T.S., Larson, C.A. and Stiller, C. (2008). 'Lower extremity muscle strength in 6- to 8-year-old children using hand-held dynamometry'. *Pediatric Physical Therapy*, 20(2), pp. 128–136. doi: 10.1097/PEP.0b013e318172432d.

Mann, T.N., Laughton, B., Donald, K.A. et al., (2017). 'HIV encephalopathy with bilateral lower limb spasticity: Gross motor function and antiretroviral therapy'. *Developmental Medicine & Child Neurology*, 59(4), pp. 407–411. doi: 10.1111/dmcn.13377.

McKay, M. J., Baldwin, J. N., Ferreira, P., et al. (2017). 'Normative reference values for strength and flexibility of 1,000 children and adults'. *Neurology*, 88(1), pp. 36–43. doi: 10.1212/WNL.0000000000003466.

Mclaughlin, J.F., Felix, S. D., Nowbar, S., et al. (2005). 'Lower extremity sensory function in children with cerebral palsy'. *Pediatric Rehabilitation*, 8(1), pp. 45–52. doi: 10.1080/13638490400011181.

de Morais Filho, M.C., Kawamura, C.M., Lopes, J.A., et al. (2014). 'Most frequent gait patterns in diplegic'. *Acta Ortopedica Brasileira*, 22(4), pp. 197–201. doi: 10.1590/1413-78522014220400942.

Mutanana, N., Tsvere, M. and Chiweshe, M.K. (2020). 'General side effects and challenges associated with anti-epilepsy medication: A review of related literature'. *African Journal of Primary Health Care and Family Medicine*, 12(1), pp. 1–5. doi: 10.4102/PHCFM.V12I1.2162.

Mutlu, A., Livanelioglu, A. and Gunel, M.K. (2008). 'Reliability of Ashworth and Modified Ashworth Scales in children with spastic cerebral palsy'. *BMC Musculoskeletal Disorders*, 9, pp. 1–8. doi: 10.1186/1471-2474-9-44.

Naik, T., Potterton, J., Firth, G. et al. (2018). 'A comparison of the clinical presentation of with HIV infected (HIVE) to uninfected (CP) children with spastic diplegia in South Africa'. *Vulnerable Children and Youth Studies*, Taylor & Francis, 13(3), pp. 195–206. doi: 10.1080/17450128.2017.1417657.

Nieuwenhuys, A., Õunpuu, S., Van Campenhout, A., et al. (2016). 'Identification of joint patterns during gait in children with cerebral palsy: a Delphi consensus study'. *Developmental medicine and child neurology*, *58*(3), pp. 306–313. doi: 10.1111/dmcn.12892.

O'Sullivan, R. Horgan, F., O'Brien, T., et al. (2018). 'The natural history of crouch gait in bilateral cerebral palsy: A systematic review'. *Research in Developmental Disabilities*, Elsevier, 80(June), pp. 84–92. doi: 10.1016/j.ridd.2018.06.013.

Ong, A.M., Hillman, S.J. and Robb, J.E. (2008). 'Reliability and validity of the Edinburgh Visual Gait Score for cerebral palsy when used by inexperienced observers'. *Gait and Posture*, 28(2), pp. 323–326. doi: 10.1016/j.gaitpost.2008.01.008.

Opheim, A., McGinley, J.L., Olsson, E., et al. (2013). 'Walking deterioration and gait analysis in adults with spastic bilateral cerebral palsy'. *Gait and Posture*, Elsevier B.V., 37(2), pp. 165–171. doi: 10.1016/j.gaitpost.2012.06.032.

Palisano R., Rosenbaum P., Walter, S., et al. (1997). 'Development and reliability of a system to classify gross motor function in children with cerebral palsy'. *Developmental medicine and child neurology*, 39, pp. 214–23. doi: 10.1111/j.1469-8749.1997.tb07414.x

Palisano, R., Hanna, S., Rosenbaum, P., et al. (2000). 'Validation of a Model of Gross Motor Function for Children'. *Physical Therapy*, 80(10), pp. 975–985.

Palisano, R.J., Rosenbaum P.L., Bartlett, D., et al. (2008). 'Content validity of the expanded and revised Gross Motor Function Classification System'. *Developmental Medicine and Child Neurology*, 50(10), pp. 744–750. doi: 10.1111/j.1469-8749.2008.03089.x

Pandyan, A.D., Johnson, G.R., Price, C.I., et al. (1999). 'A review of the properties and limitations of the Ashworth and modified Ashworth Scales as measures of spasticity'. *Clinical Rehabilitation*, 13(5), pp. 373–383. doi: 10.1191/026921599677595404.

Patel, D.R., Neelakantan, M., Pandher, K., et al. (2020). 'Cerebral palsy in children: A clinical overview'. *Translational Pediatrics*, 9(1), pp. 125–135. doi: 10.21037/tp.2020.01.01.

Pauk, J., Ihnatouski, M., Daunoraviciene, K., et al. (2016). 'Research of the spatial-temporal gait parameters and pressure characteristic in spastic diplegia children'. *Acta of*

Bioengineering and Biomechanics, 18(2), pp. 121–129. doi: 10.5277/ABB-00393-2015-02.

Pavone, P., Gulizia, C., Le Pira, A., et al. (2021). 'Cerebral palsy and epilepsy in children: Clinical perspectives on a common comorbidity'. *Children*, 8(1), pp. 1–11. doi: 10.3390/children8010016.

Peters, R.P., Van Ramshorst, M.S., Struthers, H.E., et al. (2014). 'Clinical assessment of peripheral neuropathy in HIV-infected children on antiretroviral therapy in rural South Africa'. *European Journal of Pediatrics*, 173(9), pp. 1245–1248. doi: 10.1007/s00431-014-2303-9.

del Pilar Duque Orozco, M., Abousamra, O., Church, C., et al. (2016). 'Reliability and validity of Edinburgh visual gait score as an evaluation tool for children with cerebral palsy'. *Gait & Posture*, 49, pp. 14–18. doi: 10.1016/j.gaitpost.2016.06.017.

Read, H.S., Hazlewood, M.E., Hillman, S.J., et al. (2003). 'Edinburgh Visual Gait Score for use in cerebral palsy'. *Journal of Pediatric Orthopaedics*, 23(3), pp. 296–301. doi: 10.1097/00004694-200305000-00005.

Robinson, L.W., Clement, N., Fullarton, M., et al. (2015). 'The relationship between the Edinburgh Visual Gait Score, the Gait Profile Score and GMFCS levels I–III'. *Gait and Posture*. Elsevier B.V., 41(2), pp. 741–743. doi: 10.1016/j.gaitpost.2015.01.022.

Rodda, J.M., Graham, K.H., Carson, I., et al. (2004). 'Sagittal gait patterns in spastic diplegia'. *Journal of Bone and Joint Surgery – Series B*, 86(2), pp. 251–258. doi: 10.1302/0301-620X.86B2.13878.

Romeo, D.M., Sini, F., Brogna, C., et al. (2016). 'Sex differences in cerebral palsy on neuromotor outcome: a critical review'. *Developmental Medicine and Child Neurology*, 58(8), pp. 809–813. doi: 10.1111/dmcn.13137.

Rosenbaum, P., Paneth, N., Leviton, A., et al. (2007). 'A report: The definition and classification of cerebral palsy April 2006'. *Developmental Medicine and Child Neurology, Supplement*, *109*, pp. 8–14.

Ross, S.A. and Engsberg, J.R. (2007). 'Relationships Between Spasticity, Strength, Gait, and the GMFM-66 in Persons With Spastic Diplegia Cerebral Palsy'. *Archives of Physical Medicine and Rehabilitation*, 88(9), pp. 1114–1120. doi: 10.1016/j.apmr.2007.06.011.

Rukuni, R., Rehman, A.M., Mukwasi-Kahari, C., et al. (2021). 'Effect of HIV infection on growth and bone density in peripubertal children in the era of antiretroviral therapy: A cross-sectional study in Zimbabwe'. *The Lancet Child and Adolescent Health*, 5(8), pp. 569–581. doi: 10.1016/S2352-4642(21)00133-4.

Shang, Q., Ma, C.Y., Lv, N., et al. (2015). 'Clinical study of cerebral palsy in 408 children with periventricular leukomalacia'. *Experimental and Therapeutic Medicine*, 9(4), pp. 1336–1344. doi: 10.3892/etm.2015.2222.

Shemy, S.A. (2018). 'Trunk endurance and gait changes after core stability training in children with hemiplegic cerebral palsy: A randomized controlled trial'. *Journal of Back and Musculoskeletal Rehabilitation*, 31(6), pp. 1159–1167. doi: 10.3233/BMR-181123.

Shumway-Cook, A., Hutchinson, S., Kartin, D., et al. (2003). 'Effect of balance training on recovery of stability in children with cerebral palsy.' *Developmental medicine and child neurology*, *45*(9), pp. 591–602. doi: 10.1017/s0012162203001099.

Silva, D.B., Pfeifer, L.I. and Funayama, C.A. (2013). 'Gross Motor Function Classification System Expanded & Revised (GMFCS E & R): Reliability between therapists and parents in Brazil'. *Brazilian Journal of Physical Therapy*, 17(5), pp. 458–463. doi: 10.1590/S1413-35552012005000113.

Singhi P, Jagirdar S, Khandelwal N, et al. (2002). 'Epilepsy in children with cerebral palsy.' *Journal of Child Neurology*, 18(3), pp. 74-179. doi:10.1177/08830738030180030601

Stanger, M. and Oresic, S. (2003). 'Rehabilitation approaches for children with cerebral palsy: Overview.' *Journal of Child Neurology*, 18(1), pp. S79–S88. doi:10.1177/08830738030180001S0201.

Statistical Release. (2019). Publication 0302. South Africa. Available from: http://www.statssa.gov.za/publications/P0302/P03022019.pdf. [Accessed 21 Apr. 2020].

Strand, K.M., Dahlseng, M.O., Lydersen, S., et al. (2016). 'Growth during infancy and early childhood in children with cerebral palsy: A population-based study'. *Developmental medicine and child neurology*, *58*(9), pp. 924–930. doi: 10.1111/dmcn.13098.

Sutherland, D.H. and Davids, J.R. (1993). 'Common gait abnormalities of the knee in cerebral palsy'. *Clinical Orthopaedics and Related Research,* 288, pp. 139–147.

Taylor, N.F., Dodd, K.J. and Graham, H.K. (2004). 'Test-retest reliability of hand-held dynamometric strength testing in young people with cerebral palsy'. *Archives of Physical Medicine and Rehabilitation*, 85(1), pp. 77–80. doi: 10.1016/S0003-9993(03)00379-4.

Thompson, N., Stebbins, J., Seniorou, M. et al. (2011). 'Muscle strength and walking ability in diplegic cerebral palsy: Implications for assessment and management'. *Gait and Posture*, 33(3), pp. 321–325. doi: 10.1016/j.gaitpost.2010.10.091.

Tsuji, T., Okumura, A., Kidokoro, H., et al. (2014). 'Differences between periventricular hemorrhagic infarction and periventricular leukomalacia'. *Brain and Development*, 36(7), pp. 555–562. doi: 10.1016/j.braindev.2013.07.014.

UNAIDS AIDS Epidemic update – Global report 2020 [cited September 2021]. Available from http://www.unaids .org/en/resources/fact sheet

Verschuren, O., Ketelaar, M., Takken, T., et al. (2008). 'Exercise programs for children with cerebral palsy: A systematic review of the literature'. *American journal of physical medicine & rehabilitation*, 87(5), pp. 404–417. doi: 10.1097/PHM.0b013e31815b2675

Whitehead, N., Potterton, J. and Coovadia, A. (2014). 'The neurodevelopment of HIV-infected infants on HAART compared to HIV-exposed but uninfected infants'. *AIDS Care – Psychological and Socio-Medical Aspects of AIDS/HIV*, 26(4), pp. 497–504. doi: 10.1080/09540121.2013.841828.

World Health Organisation. (2007). WHO case definitions for surveillance of HIV and revised clinical staging and immunological classification of HIV-related disease 2007 [cited April 2021]. Available from: http://www.who.int

Wood, E and Rosenbaum, P. (2000). 'The gross motor function classification system for cerebral palsy: A study of reliability and stability over time'. *Developmental Medicine and Child Neurology*, 42(5), pp. 292–296. doi: 10.1017/S0012162200000529.

Wood, L., Firth, G. and Potterton, J. (2018). ‘Short-term outcomes of single event multilevel surgery for children with diplegia in a South African setting’. *SA Orthopaedic Journal*, 17(3), pp. 44–48. doi: 10.17159/2309-8309/2018/v17n2a8.

Yam, W.K. and Leung, M.S. (2006). ‘Interrater reliability of Modified Ashworth Scale and Modified Tardieu Scale in children with spastic cerebral palsy’. *Journal of Child Neurology*, 21(12), pp. 1031–1035.

Yan, X., He, L. and Zheng, Y. (2015). ‘Inter-rater reliability of modified Ashworth scale and modified Tardieu scale in children with spastic cerebral palsy’. *Chinese Journal of Rehabilitation Medicine*, 30(1), pp. 18–21. doi: 10.3969/j.issn.1001-1242.2015.01.005.

Zarkou, A., Lee, S., Prosser, L., et al (2020). ‘Foot and ankle somatosensory deficits affect balance and motor function in children with cerebral palsy’. *Frontiers in Human Neuroscience*, 14(February), pp. 1–12. doi: 10.3389/fnhum.2020.00045.

Zarkou, A. Lee, S., Prosser, L., et al. (2021). ‘Foot and ankle somatosensory deficits in children with cerebral palsy: A pilot study’. *Journal of Pediatric Rehabilitation Medicine*, 14(2), pp. 247–255. doi: 10.3233/PRM-190643.

Appendices

Appendix 1 Ethics Clearance Certification

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R49 Ms R Hanley

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M201040

NAME: (Principal Investigator)	Ms R Hanley
DEPARTMENT:	School of Therapeutic Sciences Department of Physiotherapy Medical School University
PROJECT TITLE:	*Factors that affect gait pattern in children with spastic diplegia in a South African school setting*
DATE CONSIDERED:	2020/10/30
DECISION:	Approved conditionally
CONDITIONS:	Approval applies to those study sites listed in Annex 1 to this Clearance Certificate Others may be added on receipt by the HREC (Med) of evidence of management approval
SUPERVISOR:	Dr N Benjamin-Damons
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2021/02/18

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized 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 submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **«Missing mail merge field»** and therefore reports and re-certification will be due in the month of **«Missing mail merge field»** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator — Date: 18/02/2021

Appendix 2 Forest Town School Approval Letter

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

Date: 14/12/2020
To: Mrs Ronalda Lucas - School Principal at Forest Town School

RE: Permission to Conduct Research Study

I am writing to request permission to conduct a research study at your school in February 2021. I am currently enrolled in the Masters for Physiotherapy at the University of Witwaterstrand and am in the process of writing my Master's Thesis. The study is titled *Factors that affect gait pattern in children with spastic diplegia in a South African school setting*. This study has been approved by the Gauteng Department of Education and provisionally approved by the Human Research Ethics Committee (pending stipulations including heads of school's approval).

This study will look at the gait pattern of children with spastic diplegia and identify factors that affect the way they mobilize. I hope that this study will give physiotherapists a better understanding as to where the child's impairments are and help with the direction of their treatment. The factors that will be closely looked at in this study are muscle tone, muscle strength, lower limb sensation, and co-morbidities.

Children that fit the inclusion criteria will be invited to participate in this study and consent will be obtained from both the caregiver and child if they are interested in participating in this study.

If approval is granted, the primary researcher will assess each child at school using safe and reliable assessment tools. All information shared will be treated confidentially.

Your approval to conduct this study will be greatly appreciated. I will follow up with a telephone call in the new year and would be happy to answer any questions or concerns that you may have at that time. You may contact me at my email address: rosie.hanley@gmail.com.

If you agree, kindly sign below and return the signed form to the email address provided. Alternatively, kindly submit a signed letter of permission on your institution's letterhead acknowledging your consent and permission for me to conduct this study at your institution.

Sincerely,

Rosemary Hanley
(Physiotherapist)

Scanned with CamScanner

Supervisor:

Professor Joanne Potterton, University of Witwaterstrand
Joanne.Potterton@wits.ac.za

Approved by:

RONALDA LUCAS | Signature | 14.12.2020

Print your name and title here | Date

GAUTENG DEPARTMENT OF EDUCATION
FOREST TOWN SCHOOL
15 -12- 2020
Private Bag X2, Parkview 2122
Tel: 011 646 0131

Scanned with CamScanner

Appendix 3 West Rand CP School Approval Letter

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

Supervisor
Professor Joanne Potterton, University of Witwatersrand
Joanne.Potterton@wits.ac.za

Date: 14/12/2020
To: School Principal at West Rand CP School

RE: Permission to Conduct Research Study

To Whom It May Concern

I am writing to request permission to conduct a research study at your institution in February 2021. I am currently enrolled in the Masters for Physiotherapy at the University of Witwatersrand and am in the process of writing my Master's Thesis. The study is titled *Factors that affect gait pattern in children with spastic diplegia in a South African school setting*. This study has been approved by the Gauteng Department of Education and provisionally approved by the Human Research Ethics Committee (pending stipulations including heads of school's approval).

This study will look at the gait pattern of children with spastic diplegia and identify factors that affect the way they mobilize. I hope that this study will give physiotherapists a better understanding as to where the child's impairments are and help with the direction of their treatment. The factors that will be closely looked at in this study are muscle tone, muscle strength, lower limb sensation, and co-morbidities.

Children that fit the inclusion criteria will be invited to participate in this study and consent will be obtained from both the caregiver and child if they are interested in participating in this study.

If approval is granted, the primary researcher will assess each child at school using safe and reliable assessment tools. All information shared will be treated confidentially.

Your approval to conduct this study will be greatly appreciated. I will follow up with a telephone call in the new year and would be happy to answer any questions or concerns that you may have at that time. You may contact me at my email address:

Approved by:

M.J. Coetzee

Print your name and title here

Signature

2021-03-17

Date

If you agree, kindly sign below and return the signed form to the email address provided. Alternatively, kindly submit a signed letter of permission on your institution's letterhead acknowledging your consent and permission for me to conduct this study at your institution.

Sincerely,

Rosemary Hanley
(Physiotherapist)

Appendix 4 Department of Education Approval Letter

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	08 December 2020
Validity of Research Approval:	08 February 2021– 30 September 2021 2019/712
Name of Researcher:	Hanley RKE
Address of Researcher:	Unit 2 Craighall Mews
	11 Marian Road
	Craighall Park
Telephone Number:	0848539766
Email address:	rosie.hanley@gmail.com
Research Topic:	Factors that affect gait pattern in children with spastic diplegia in a South African school setting
Type of qualification	MSc by dissertation
Number and type of schools:	2 LSEN School
District/s/HO	Johannesburg East and Johannesburg West

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

10/12/2020

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of COVID 19 pandemic researchers can ONLY collect data online, telephonically or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate. The approval letter will then indicate the type of arrangements that have been made with the school.***
4. ***The Researchers are advised to make arrangements with the schools via Fax, email or telephonically with the Principal.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

.....

Mr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 10/12/2020

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

Appendix 5 Child Information Sheet

Hello

My name is Rosie Hanley and I am a physiotherapist working at Forest Town School. I am also studying at the University of Witwaterstrand. For my studies I need to look at children like you and see how they walk. I want to figure out why you walk in the way that you do so that physios like myself can give you the best therapy possible.

I will assess you at school with your physio and it will take about one hour. I will do the following things:

- I will use a camera to see how you walk using a video gait analysis. I will ask you to walk a few metres and video you. It will take a few minutes and I won't share these videos with anyone else.
- I will look at how your muscles stretch using the Modified Ashworth Scale. I will ask you to lie down and I will look at how tight each muscle is. It will take about 15 minutes and if there is any pain or discomfort, please tell the researcher straight away.
- Muscle strength: I will see how strong your muscles are, using a handheld dynamometer. I will ask you to push against this piece of equipment to measure your strength. If there is any pain or discomfort, please tell the researcher straight away.
- Leg feeling will be tested using a BPNS and pin-prick test. I will put a small vibration and prick on your leg and ask how it feels. If there is any pain or discomfort, please tell the researcher straight away.
- Medical history questionnaire: I will ask your guardian/parent to do a questionnaire to get information about you.
- Your learner profile will be used to look at your medical history.

Your information will always be kept confidential and I will not share it with anyone else. Your name and photos won't be used in the study. You have the right to withdraw from this study at any point in time. This assessment will not affect your therapy and work at school.

If you would like to be a part of my study, your guardian/parent will sign the consent form and if you are over the age of six years, then you can sign the assent form attached.

If you have any questions please call to chat about it.

Thank you.

Rosie Hanley
Physiotherapist
0848539766

Supervisor: Joanne Potterton
Contact details: joanne.potterton@wits.ac.za

Human Research Ethics Committee

Chairperson: Professor Clement Penny

Number: 011 717 2301

Email: Clement.Penny@wits.ac.za

Appendix 6 Information Sheet for Parent/Caregiver/Guardian

Factors that affect gait pattern in children with spastic diplegia in a South African school setting

Dear Parent/Caregiver/Guardian

My name is Rosie Hanley and I am a physiotherapist working at Forest Town School. I am currently doing a part-time Master's degree in Physiotherapy at the University of Witwaterstrand. For my studies I am completing research in cerebral palsy, closely looking at the factors that affect gait in children with spastic diplegia. I would like to invite your child to participate in this study.

Your child will participate in a once-off assessment at school in the presence of their physiotherapist. The assessment will take approximately one hour to complete. The following assessments will be done:

- Video gait analysis: this will be done with a camera and it will enable me to see how your child walks. I will ask your child to walk a few metres with or without their assistive device and film them walking. These videos will always be kept confidential and will not be distributed to anyone. This will only take a few minutes as most of the analysis will be done after assessments.
- Muscle tone using the Modified Ashworth Scale: this will assess the resistance of your child's muscle to stretching. Your child will be asked to lie down and relax and I will assess the leg muscles tightness. This should take approximately 15 minutes. The child will notify the researcher if they feel any discomfort.
- Muscle strength using a handheld dynamometer: this will assess the strength of each muscle in the lower limb. The child will be asked to push against the equipment. The child will notify the researcher if they feel any discomfort.
- Lower limb sensation will be tested using the brief peripheral neuropathy screen and pin-prick test. A small vibration and pin prick will be applied to your child's leg and I will ask whether they can feel the sensation. The child will notify the researcher if they feel any discomfort.
- Medical history questionnaire: I will ask you to complete a questionnaire in order to gain information about your child's medical history, including the maternal history, medication and background. It will be written in the English language, but I will translate this to your home language if you have difficulty understanding it.
- Your child's learner profile will be used to assess medical history.

Information about your child will always be confidential and used only for research purposes. Your child's name or images will not be used in the study.

You have the right to withdraw from this study at any point in time. This assessment will not affect therapy and work at school.

If you are willing to allow your child to participate in this study, please sign the consent form attached. If your child is over the age of six years, he or she will be required to sign an assent form.

Please don't hesitate to contact me if you have any questions or concerns.

Thank you,

Rosie Hanley

Physiotherapist

0848539766

Supervisor: Joanne Potterton

Contact details: joanne.potterton@wits.ac.za

Human Research Ethics Committee

Chairperson: Professor Clement Penny

Number: 011 717 2301

Email: Clement.Penny@wits.ac.za

Appendix 7 Consent Form

Factors that affect gait pattern in children with spastic diplegia in a South African school setting

I _____ have read and understood the information sheet provided on this study.

I will / will not (please circle) give consent for my child _____ to participate in this study.

I give consent for Rosie Hanley to record the necessary information from my child's learner profile.

I understand that my child can withdraw at any time and understand the assessments that this study entails.

_____ _____

(Parent/Guardian Signature) Date

_____ _____

(Researcher Signature) Date

I also give consent for video filming of my child to be used for the purposes of this research.

_____ _____

(Parent/Guardian Signature) Date

_____ _____

(Researcher Signature) Date

Appendix 8 Assent Form (Children over the age of 6)

Factors that affect gait pattern in children with spastic diplegia in a South African school setting

I _____ will / will not (please circle your choice) take part in this study. I have read or been read the information sheet and understand what I need to do in this study. I understand I can stop at any point and if the tests cause discomfort or pain I will tell the researcher immediately.

_____ _____

(Child Signature) Date

_____ _____

(Researcher Signature) Date

I also agree to be video filmed for this study.

_____ _____

(Child Signature) Date

_____ _____

(Researcher Signature) Date

Appendix 9 The Patients' Rights Charter

THE PATIENTS' RIGHTS CHARTER

For many decades the vast majority of the South African population has experienced either a denial or violation of fundamental human rights, including rights to health care services. To ensure the realization of the right of access to health care services as guaranteed in the Constitution of the Republic of South Africa (Act No 108 of 1996), the Department of Health is committed to upholding, promoting and protecting this right and therefore proclaims this *PATIENTS' RIGHTS CHARTER* as a common standard for achieving the realization of this right.

This Charter is subject to the provisions of any law operating within the Republic of South Africa and to the financial means of the country.

A HEALTHY AND SAFE ENVIRONMENT

Everyone has the right to a healthy and safe environment that will ensure their physical and mental health or well-being, including adequate water supply, sanitation and waste disposal as well as protection from all forms of environmental danger, such as pollution, ecological degradation or infection.

PARTICIPATION IN DECISION-MAKING

Every citizen has the right to participate in the development of health policies and everyone has the right to participate in decision-making on matters affecting one's health

ACCESS TO HEALTHCARE

Everyone has the right of access to health care services that include:

i. receiving timely emergency care at any health care facility that is open regardless of one's ability to pay;
ii. treatment and rehabilitation that must be made known to the patient to enable the patient to understand such treatment or rehabilitation and the consequences thereof;
iii. provision for special needs in the case of newborn infants, children, pregnant women, the aged, disabled persons, patients in pain, person living with HIV or AIDS patients;
iv. counselling without discrimination, coercion or violence on matters such as reproductive health, cancer or HIV/AIDS;
v. palliative care that is affordable and effective in cases of incurable or terminal illness;
vi. a positive disposition displayed by health care providers that demonstrate courtesy, human dignity, patience, empathy and tolerance; and
vii. health information that includes the availability of health services and how best to use such services and such information shall be in the language understood by the patient.

KNOWLEDGE OF ONE'S HEALTH INSURANCE/MEDICAL AID SCHEME

A member of a health insurance or medical aid scheme is entitled to information about that insurance or medical aid scheme and to challenge, where necessary, the decisions of such health insurance or medical aid scheme relating to the member.

CHOICE OF HEALTH SERVICES

Everyone has the right to choose a particular health care provider for services or a particular health facility for treatment provided that such choice shall not be contrary to the ethical standards applicable to such health care providers or facilities, and the choice of facilities in line with prescribed service delivery guidelines.

BE TREATED BY A NAMED HEALTH CARE PROVIDER

Everyone has the right to know the person that is providing health care and therefore must be attended to by clearly identified health care providers.

CONFIDENTIALITY AND PRIVACY

Information concerning one's health, including information concerning treatment may only be disclosed with informed consent, except when required in terms of any law or an order of the court.

INFORMED CONSENT

Everyone has the right to be given full and accurate information about the nature of one's illnesses, diagnostic procedures, the proposed treatment and the costs involved, for one to make a decision that affects anyone of these elements.

REFUSAL OF TREATMENT

A person may refuse treatment and such refusal shall be verbal or in writing provided that such refusal does not endanger the health of others.

BE REFERRED FOR A SECOND OPINION

Everyone has the right to be referred for a second opinion on request to a health provider of one's choice.

CONTINUITY OF CARE

No one shall be abandoned by a health care professional worker or a health facility which initially took responsibility for one's health.

COMPLAIN ABOUT HEALTH SERVICES

Everyone has the right to complain about health care services and to have such complaints investigated and to receive a full response on such investigation.

EVERY PATIENT OR CLIENT HAS THE FOLLOWING RESPONSIBILITIES:

- Advise the health care providers on his or her wishes with regard to his or her death.
- Comply with the prescribed treatment or rehabilitation procedures.
- Enquire about the related costs of treatment and/or rehabilitation and to arrange for payment.
- Take care of health records in his or her possession.
- Take care of his or her health.
- Care for and protect the environment.
- Respect the rights of other patients and health providers.
- Utilise the health care system properly and not abuse it.
- Know his or her local health services and what they offer.
- Provide health care providers with the relevant and accurate information for diagnostic, treatment, rehabilitation or counselling purposes.

National Department of Health: Private Bag X828, Pretoria. 0001. Telephone: 012 395 8264/3
www.doh.gov.za

health
Department:
Health
REPUBLIC OF SOUTH AFRICA

Appendix 10 Parent Questionnaire

PARENT QUESTIONNAIRE

Child number:	
Age: (e.g. 6 years 5 months)	
Child diagnosis:	
Birth history:	Normal ☐ Caesarian ☐ Full term ☐ Preterm ☐ Weeks _____ Birth weight: _____ Mother health during pregnancy: _____ Mother health at birth: _____

Medical and surgical history:	Please state any hospital admissions, surgery or botox that your child has had. _____ _____ _____
Medication:	Please state all medication your child is taking. _____ _____ _____
Milestones:	Sit: _____Crawl: _____ Walking: _____
Family history:	Please state any family illnesses or conditions. _____ _____

Appendix 11 Data Collection Sheet

Child Number:		Gender:	
Height:		Weight:	
Assistive Device:		AFOS:	Y / N
Date:		Time:	

Muscle Tone	R	L
Adductor		
Hamstrings		
Gastrocs		
Soleus		
Quadriceps		

+ in BPNS Subjective	R	L
Vibration (seconds)		
Reflexes		
Pinprick (diminished areas)		

Muscle Strength	R		L	
Trunk Flexion				
Trunk Extension				
DF				
PF				
Knee Extension				
Knee Flexion				
Hip Flexion				
Hip Abduction				

Appendix 12 Muscle Tone Testing Procedure

Muscle Tone Testing Procedure

Gastrocnemius Muscle – The child will lie in supine position with hips in neutral and knees fully extended. The examiner places one hand on the knee to stabilise it and the other hand's thumb on the plantar surface of the foot with fingers wrapped around towards medial arch of foot. The examiner takes the ankle from full plantar flexion to full dorsiflexion.

Soleus Muscle – The child will lie in the supine position with hips and knees flexed to 45 degrees. The examiner places one hand on the knee to stabilise it and the other hand's thumb on the plantar surface of the foot with fingers wrapped around towards medial arch of the foot. The examiner takes the ankle from full plantar flexion to full dorsiflexion.

Hamstrings Muscle – The child will lie in the supine position with hips flexed to 45 degrees. The examiner places one hand on the knee and the other hand's thumb on the plantar surface of the foot with fingers wrapped around towards medial arch of foot. The examiner fully flexes and extends the knees in this position.

Hip Adductors Muscle – The child will lie in the supine position with hips and knees in neutral. The examiner places one hand at the lateral hip and the other hand at the ankle joint. The examiner moves the joint from full hip adduction to full hip abduction.

Quadriceps Muscle – The child will lie in the prone position with hips and knees in neutral. The examiner places one hand at the lateral hip and the other hand at the ankle joint. The examiner will move the knee from full extension to full flexion.

(Naik et al., 2018)

Appendix 13 Normal Joint Range of Movement

Joint	Movement	Full Range, Degrees
Hip	Flexion	120
	Hyperextension	10
	Abduction	45
	Adduction	0
Extended hip	Internal rotation	45
	External rotation	45
Knee	Flexion	150
	Extension	0
Ankle	Plantar flexion	50
	Dorsiflexion	20

(Abdel Ghany et al., 2016)

Appendix 14 Muscle Strength Testing Procedure with HHD

Trunk flexor strength – Child will be in the supine position. Hips flexed to 30 degrees and trunk supported in this 30 angle by a wedge cushion or adjustable plinth. A strap will be placed 10cm above lateral malleolus and over the anterior superior iliac spine to prevent pelvic rotation. The examiner will place the HDD on the sternum below the suprasternal notch. The child will cross their arms over the chest, with their fingers reaching to opposite acromion processes. The examiner will hold HHD perpendicular to the trunk. (De Blaiser et al., 2018)

Trunk extensor strength – Child will be in the prone position. Hips flexed to 30 degrees and trunk supported in this 30 angle by use of wedge or adjustable plinth. A strap will be placed 10cm above lateral malleolus and over the posterior superior iliac spine to prevent pelvic rotation. The HHD will be placed at the height of T4 by the examiner. The child will place the back of their hands on their forehead during the test. The examiner will hold the HHD perpendicular to the trunk. (De Blaiser et al., 2018)

Hip flexor strength – Child will be in seated position with both knees flexed off the plinth. The examiner will stabilize the pelvis with one hand and place the HHD with the other hand on the anterior thigh, 5cm proximal to the patella.

Hip abduction strength – The child will be in the supine position with both hips flexed to 45 degrees. The examiner will stabilise with one hand at the pelvis and use the other hand to hold the HHD at the lateral thigh 5cm proximal to the knee joint.

Knee flexion strength – The child will be in a seated position with both knees flexed to 90 degrees. The examiner will stabilise with one hand at the pelvis and use the other hand to hold the HHD at the posterior calf equidistant between ankle and knee joint.

Knee extension strength – The child will be in the seated position with both knees flexed to 90 degrees. The examiner will use one hand to stabilise at the pelvis and the other hand to hold the HHD equidistant between ankle and knee joint.

Ankle plantar flexor strength – The child will be in the supine position with hip and knees flexed to 90 degrees. Ankle will be in neutral position. The examiner will use one hand to stabilise the lower leg at the knee or pelvis and the other hand will hold the HHD at the plantar surface of the foot.

Ankle dorsi flexor strength – The child will be in the supine position with hip and knees flexed to 90 degrees. Ankle will be in the neutral position. The examiner will use one hand to stabilise the lower leg at the knee or pelvis and the other hand will hold the HHD at the dorsum of the foot. (Naik et al., 2018)

Appendix 15 Edinburgh Visual Gait Score

Stance					
	Flexion		Normal		Ext
Foot	2	1	0	1	
1. Initial contact			Heel contact	Flatfoot contact	
2. Heel lift	No forefoot contact	Delayed	Normal	Early	
3. Max ankle dorsiflexion	Excessive dorsiflxn (>40° df)	Increased dorsiflxn (26°–40° df)	Normal dorsiflxn (5°–25° df)	Reduced dors (10° pl	
4. Hindfoot varus/ valgus	Severe valgus	Mod valgus	Neutral/slight valgus	Mild	
5. Foot rotation	Marked extn >KPA (by >40°)	Mod ext >KPA (by 21°–40°)	SI more extn than KPA (by 0°–20		
Knee					
8. Knee progression angle	External, part knee cap visible	External, all knee cap visible	Ne		
9. Peak extn stance	Severe flexn (>25°)	Mod flexn (16°–25°			
Hip					
12. Peak extn stance	Severe flexn (>15°)	M			
Pelvis					
14. Obliquity at mid stance	Mark				
15. Rotation at mid stance					
Trunk					
16. Peak					
17. M					

Swing					
	Flexion		Normal		Extension
Foot	2	1	0	1	2
6. Clearance in swing		High steps	Full	Reduced	None
7. Max ankle dorsiflexion	Excessive dorsiflxn (>30° df)	Increased dorsiflxn (16°–30° df)	Normal dorsiflxn (15° df–5° pl)	Mod plantarflxn (6°–20° pl)	Marked plantarflxn (>20° pl)
Knee					
10. Terminal swing	Severe flexn (>30°)	Mod flexn (16°–30°)	Normal (5°–15° flxn)	Mod overextn (4° flx–10° xtn)	Severe hyperextn (>10° xtn)
11. Peak flexn swing	Severely increased (>85° flxn)	Mod increased (71°–85° flxn)	Normal (50°–70° flxn)	Mod reduced (35°–49° flxn)	Severely reduced (<35° flxn)
Hip					
13. Peak flexion swing	Marked increase (>60° flxn)	Increased flexn (46°–60° flxn)	Normal flexn (25°–45° flxn)	Reduced flexn (10°–24° flxn)	Severely reduced (<10° flxn)

(Read et al., 2003)

Appendix 16 Brief Peripheral Neuropathy Screening Tool

The Brief Peripheral Neuropathy Screening Tool

NEUROLOGICAL SCREEN

Symptom description:

1. Have you ever had odd/strange/painful feelings or discomfort in your feet?

Yes ☐ **No** ☐

2. Do you currently have odd/strange/painful feelings or discomfort in your feet?

Yes ☐ **No** ☐

If "No", go to Question 4, in the "Testing of signs" section on page

3. If you currently have odd/strange/painful feelings or discomfort in your feet, how well does each of the following words describe this feeling or discomfort? Please rate the severity of these symptoms using the scale (mild, moderate of severe pain):

Symptom	**Symptom presence** (tick one)			**If "YES", what is the intensity** (tick one)
	NO	**UNSURE**	**YES**	
a) Hot / burning *isiZulu: kuyashisa / kuyavutha* *Setswana: go molelo / go a fisa / go a asha* *Sesotho: ho a tjesa / ho ho tjang*				☐ Mild ☐ Moderate ☐ Severe
b) Cramping *isiZulu: inkwantshu / amacrampu* *Setswana: go bogatsu* *Sesotho: ho bahatsu*				☐ Mild ☐ Moderate ☐ Severe
c) Painful / sore / aching *isiZulu: kubuhlungu* *Setswana: go botlhoko* *Sesotho: ho botlhoko*				☐ Mild ☐ Moderate ☐ Severe
d) Itching *isiZulu: kuyaluma* *Setswana: go a baba* *Sesotho: ho a baba*				☐ Mild ☐ Moderate ☐ Severe
e) Numb / lack of feeling *isiZulu: kundikindiki* *Setswana: go a bogatsu* *Sesotho: bohatsu*				☐ Mild ☐ Moderate ☐ Severe
f) Cold / freezing *isiZulu: kuyabanda/ kuyiqwa* *Setswana: go maruru / go tsididi* *Sesotho: ho a bata*				☐ Mild ☐ Moderate ☐ Severe
g) Pins & needles / stabbing / pricking *isiZulu: kuyahlaba* *Setswana: mo go tlhabang* *Sesotho: hoo hlabang*				☐ Mild ☐ Moderate ☐ Severe

(Cherry et al., 2005)

4. The Vibration Test

The child will be in a seated position with feet supported. The examiner will explain the vibration instrument to the child and demonstrate the sensation on the right distal ulna head. The examiner will apply the vibration and remove it to make the child aware of the sensation and tell the child that they must tell them when the vibration or “buzzing” stops. The examiner will instruct the child to close their eyes. The test will then be performed on the child’s big toe. The child will notify when they feel the vibration has stopped.

5. Reflex Test

The child will be in a seated position with feet unsupported. The examiner will use one hand at the plantar surface under the base of the big toe to position the ankle to a 90 degree angle. The examiner will tap the Achilles tendon using a reflex hammer. The examiner will feel whether a tendon reflex is present. Ankle reflexes scoring is 0 = Absent, 1 = Present, 2 = Unable to assess. This reflex test was repeated up to three times if reflexes were delayed or absent.

6. Pin-prick Test

The child will be in a supine position with hips and knees in a neutral position with 20 degrees of hip abduction. A standard safety pin would be used for this test and the examiner will show the child that the pin will not harm them by demonstrating the procedure on their arm with their eyes open. The examiner will then test areas of the leg from the knee downward following the dermatomal pattern.

(Cherry et al., 2005)

Appendix 17 Turnitin Report

Factors that affect gait pattern in children with spastic diplegia in a South African school setting

ORIGINALITY REPORT

19%	13%	13%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	wiredspace.wits.ac.za Internet Source	4%
2	"Cerebral Palsy", Springer Science and Business Media LLC, 2020 Publication	2%
3	www.science.gov Internet Source	<1%
4	Langerak, Nelleke G, Jacques du Toit, Marlette Burger, Mark F Cotton, Priscilla E Springer, and Barbara Laughton. "Spastic diplegia in children with HIV encephalopathy: first description of gait and physical status", Developmental Medicine & Child Neurology, 2013. Publication	<1%
5	pure.bond.edu.au Internet Source	<1%
6	J. M. Rodda, H. K. Graham, L. Carson, M. P. Galea, R. Wolfe. "Sagittal gait patterns in spastic diplegia", The Journal of Bone and Joint Surgery. British volume, 2004 Publication	<1%
7	wvuscholar.wvu.edu:8881 Internet Source	<1%
8	Tasvi Naik, Joanne Potterton, Gregory Bodley Firth, Kerry S. Wilson, Carolyn R. Humphries.	<1%

	"A comparison of the clinical presentation of with HIV infected (HIVE) to uninfected (CP) children with spastic diplegia in South Africa", Vulnerable Children and Youth Studies, 2018 Publication	
9	eprints.brighton.ac.uk Internet Source	<1%
10	pdfs.semanticscholar.org Internet Source	<1%
11	www.mmec.montana.edu Internet Source	<1%
12	udspace.udel.edu Internet Source	<1%
13	minerva-access.unimelb.edu.au Internet Source	<1%
14	Alaric Aroojis, Bhushan Sagade, Suresh Chand. "Usability and Reliability of the Edinburgh Visual Gait Score in Children with Spastic Cerebral Palsy Using Smartphone Slow-Motion Video Technology and a Motion Analysis Application: A Pilot Study", Indian Journal of Orthopaedics, 2021 Publication	<1%
15	repository.unika.ac.id Internet Source	<1%
16	www.tandfonline.com Internet Source	<1%
17	Submitted to University of Kent at Canterbury Student Paper	<1%
18	Submitted to La Trobe University Student Paper	<1%
19	e-journal.uajy.ac.id Internet Source	

		<1%
20	uir.unisa.ac.za Internet Source	<1%
21	Remco P. H. Peters, Mette S. Van Ramshorst, Helen E. Struthers, James A. McIntyre. "Clinical assessment of peripheral neuropathy in HIV-infected children on antiretroviral therapy in rural South Africa", European Journal of Pediatrics, 2014 Publication	<1%
22	"American Academy for Cerebral Palsy & Developmental Medicine 2004", Developmental Medicine & Child Neurology, 09/2004 Publication	<1%
23	Submitted to Sim University Student Paper	<1%
24	Submitted to Lovely Professional University Student Paper	<1%
25	Submitted to University of Sydney Student Paper	<1%
26	link.springer.com Internet Source	<1%
27	repository.up.ac.za Internet Source	<1%
28	A. Waninge, R.A. Rook, A. Dijkhuizen, E. Gielen, C.P. van der Schans. "Feasibility, test–retest reliability, and interrater reliability of the Modified Ashworth Scale and Modified Tardieu Scale in persons with profound intellectual and multiple disabilities", Research in Developmental Disabilities, 2011	<1%

Publication

<1%

29 Jooyeon Ko, Ji-Hea Woo, Jin-Gang Her. "The Reliability and Concurrent Validity of the GMFCS for Children with Cerebral Palsy", Journal of Physical Therapy Science, 2011
Publication

<1%

30 Submitted to The Hong Kong Polytechnic University
Student Paper

<1%

31 M Gough. "Botulinum toxin and cerebral palsy: time for reflection?", Developmental Medicine & Child Neurology, 09/12/2005
Publication

<1%

32 del Pilar Duque Orozco, Maria, Oussama Abousamra, Chris Church, Nancy Lennon, John Henley, Kenneth J. Rogers, Julieanne P. Sees, Justin Connor, and Freeman Miller. "Reliability and validity of Edinburgh visual gait score as an evaluation tool for children with cerebral palsy", Gait & Posture, 2016.
Publication

<1%

33 "World Congress of Pediatric Gastroenterology, Hepatology and Nutrition", Journal of Pediatric Gastroenterology & Nutrition, 2016
Publication

<1%

34 Mellanie Geijen, Eugene Rameckers, Marlous Schnackers, Carolien Bastiaenen, Andrew Gordon, Lucianne Speth, Rob Smeets. "Reproducibility of Task-Oriented Bimanual and Unimanual Strength Measurement in Children with Unilateral Cerebral Palsy", Physical & Occupational Therapy In Pediatrics, 2018
Publication

35	Submitted to University of Derby Student Paper	<1%
36	Submitted to Shenandoah University Student Paper	<1%
37	tp.amegroups.com Internet Source	<1%
38	www.transbiomedicine.com Internet Source	<1%
39	Heather S. Read, M. Elizabeth Hazlewood, Susan J. Hillman, Robin J. Prescott, James E. Robb. "Edinburgh Visual Gait Score for Use in Cerebral Palsy", Journal of Pediatric Orthopaedics, 2003 Publication	<1%
40	docplayer.net Internet Source	<1%
41	online.boneandjoint.org.uk Internet Source	<1%
42	thesis.miuc.ac.ke Internet Source	<1%
43	www.ncbi.nlm.nih.gov Internet Source	<1%
44	Cathleen E Buckon. "Comparison of three ankle–foot orthosis configurations for children with spastic diplegia", Developmental Medicine & Child Neurology, 09/2004 Publication	<1%
45	Ross, S.A.. "Relationships Between Spasticity, Strength, Gait, and the GMFM-66 in Persons With Spastic Diplegia Cerebral Palsy", Archives of Physical Medicine and Rehabilitation, 200709 Publication	<1%

46	atikatyagita.wordpress.com Internet Source	<1%
47	pjiap.org Internet Source	<1%
48	repository.out.ac.tz Internet Source	<1%
49	toubkal.imist.ma Internet Source	<1%
50	Robert J Palisano, Steven E Hanna, Peter L Rosenbaum, Dianne J Russell et al. "Validation of a Model of Gross Motor Function for Children With Cerebral Palsy", Physical Therapy, 2000 Publication	<1%
51	Siconolfi-Morris, Gina Cecilia. "Use of a video game based balance training intervention on the balance and function of children with developmental disabilities.", Proquest, 2014. Publication	<1%
52	ir.mu.ac.ke:8080 Internet Source	<1%
53	www.scribd.com Internet Source	<1%
54	"Abstracts", Developmental Medicine & Child Neurology, 03/2010 Publication	<1%
55	"Cerebral Palsy", Springer Science and Business Media LLC, 2018 Publication	<1%
56	"Orthotic management of cerebral palsy", Developmental Medicine & Child Neurology, 2007 Publication	<1%

57	Submitted to Institute of Graduate Studies, UiTM Student Paper	<1%
58	Joseph F. Norman. "Comparison of the Energy Expenditure Index and Oxygen Consumption Index During Self-Paced Walking in Children with Spastic Diplegia Cerebral Palsy and Children Without Physical Disabilities", Pediatric Physical Therapy, 2004 Publication	<1%
59	Tasvi Naik, Joanne Potterton. "A comparison of the clinical presentation of HIV infected children with spastic diplegia to HIV uninfected children with spastic diplegia in a South African setting", European Journal of Physiotherapy, 2017 Publication	<1%
60	Submitted to University College London Student Paper	<1%
61	Submitted to University of Bradford Student Paper	<1%
62	Submitted to University of Strathclyde Student Paper	<1%
63	ir-library.egerton.ac.ke Internet Source	<1%
64	www.pubfacts.com Internet Source	<1%
65	Submitted to California State University, Fresno Student Paper	<1%
66	Submitted to Flinders University Student Paper	<1%

67	Horwood, Linda. "Sleep, Behaviour and Health-Related Quality of Life in Preschool-And School-Aged Children with Cerebral Palsy.", McGill University (Canada), 2020 Publication	<1%
68	Robert, Maxime. "The Role of Feedback on Cognitive Motor Learning in Children with Cerebral Palsy.", McGill University (Canada), 2021 Publication	<1%
69	Submitted to University of Wales Institute, Cardiff Student Paper	<1%
70	Verda Tuzer, Suheyla Dogan Bulut, Bahar Bastug, Gülseren Kayalar, Erol Göka, Emrem Beştepe. "Causal attributions and alexithymia in female patients with fibromyalgia or chronic low back pain", Nordic Journal of Psychiatry, 2010 Publication	<1%
71	epubs.scu.edu.au Internet Source	<1%
72	pprp.info Internet Source	<1%
73	"Knee Surgery for Children with Cerebral Palsy", Operative Techniques Pediatric Orthopaedic Surgery, 2011. Publication	<1%
74	Submitted to AUT University Student Paper	<1%
75	Neurosurgery for Spasticity, 2014. Publication	<1%
76	Submitted to Queen's University of Belfast Student Paper	

		<1%
77	Submitted to University of Edinburgh Student Paper	<1%
78	Submitted to University of San Francisco Student Paper	<1%
79	Submitted to University of Wales central institutions Student Paper	<1%
80	Submitted to University of Witwatersrand Student Paper	<1%
81	Zarkou, Anastasia. "Somatosensory Deficits Affect Balance and Motor Function in Children with Cerebral Palsy: Stochastic Resonance Stimulation can Modulate Somatosensation to Enhance Balance.", University of Delaware, 2017 Publication	<1%
82	dspace.nehu.ac.in Internet Source	<1%
83	media.mycrowdwisdom.com.s3.us-east-1.amazonaws.com Internet Source	<1%
84	researchers.mq.edu.au Internet Source	<1%
85	www.ftrdergisi.com Internet Source	<1%
86	Jie Zhang, Peng Xu, Feng Liu. "One-child policy and childhood obesity", China Economic Review, 2016 Publication	<1%

87	Lee Barks, Peggy Shaw. "Wheelchair Positioning and Breathing in Children with Cerebral Palsy: Study Methods and Lessons Learned", Rehabilitation Nursing, 2011 Publication	<1%
88	Submitted to Monash University Student Paper	<1%
89	Submitted to Oklahoma State University Student Paper	<1%
90	Submitted to University of Brighton Student Paper	<1%
91	centenary.dspacedirect.org Internet Source	<1%
92	etd.vcu.edu Internet Source	<1%
93	Hall, Melissa. "Examining the Relationship Between Family Stress and Family Cohesion on Sibling Relationship and Well-Being.", Capella University, 2020 Publication	<1%
94	Submitted to Kingston University Student Paper	<1%
95	Lidbeck, Cecilia. "Standing in Children with Bilateral Spastic Cerebral Palsy: Aspects of Muscle Strength, Vision and Motor Function.", Karolinska Institutet (Sweden), 2021 Publication	<1%
96	Linda Reus, Leo A. van Vlimmeren, J. Bart Staal, Anjo J.W.M. Janssen et al. "Objective evaluation of muscle strength in infants with hypotonia and muscle weakness", Research in Developmental Disabilities, 2013 Publication	<1%

97	Muayad Kadhim, Freeman Miller. "Crouch gait changes after planovalgus foot deformity correction in ambulatory children with cerebral palsy", Gait & Posture, 2014 Publication	<1%
98	WWW.MDPI.COM Internet Source	<1%
99	amsdottorato.unibo.it Internet Source	<1%
100	assets.researchsquare.com Internet Source	<1%
101	etheses.dur.ac.uk Internet Source	<1%
102	hdl.handle.net Internet Source	<1%
103	"American Academy for Cerebral Palsy & Developmental Medicine 2002", Developmental Medicine & Child Neurology, 08/2002 Publication	<1%
104	BMCpregnancychildbirth.biomedcentral.com Internet Source	<1%
105	Bar-Haim, S., M.D. Al-Jarrah, I. Nammourah, and N. Harries. "Mechanical efficiency and balance in adolescents and young adults with cerebral palsy", Gait & Posture, 2013. Publication	<1%
106	Brett Lullo, Nicole Mueske, Carmel Diamant, Alexander Van Speybroeck, Deirdre Ryan, Tishya Wren. "Predictors of Walking Activity in Children and Adolescents With Myelomeningocele", Archives of Physical Medicine and Rehabilitation, 2020	<1%

Publication

<1%

107 Conway, Mikayla Diane. "Neurodevelopmental Treatment for Children with Hemiplegic Cerebral Palsy: Clinical Guidelines for Occupational Therapists.", Boston University, 2020
Publication

<1%

108 Kincaid, Patrick S.. "Implications of Hispanics Using mHealth Applications to Self-Manage Diabetes: A Quantitative, Cross-Sectional Analysis.", Northcentral University, 2020
Publication

<1%

109 Pallant, Julie. "SPSS Survival Manual: A Step by Step Guide to Data Analysis using IBM SPSS", SPSS Survival Manual: A Step by Step Guide to Data Analysis using IBM SPSS, 2020
Publication

<1%

110 Raj Sharma, Jyoti Sharma, Vikas Bharadwaj. "EVIDENCE BASED REVIEW OF PHYSIOTHERAPY MANAGEMENT OF CEREBRAL PALSY PATIENTS", International Journal of Physiotherapy and Research, 2018
Publication

<1%

111 Univendspace.univen.ac.za
Internet Source

<1%

112 Submitted to University of College Cork
Student Paper

<1%

113 Submitted to University of Leeds
Student Paper

<1%

114 dehesa.unex.es
Internet Source

<1%

115 ejes.eu
Internet Source

116	jccm.ro Internet Source	<1%
117	pearl.plymouth.ac.uk Internet Source	<1%
118	repositorio.ufmg.br Internet Source	<1%
119	scholar.sun.ac.za Internet Source	<1%
120	www.gaitincerebralpalsy.net Internet Source	<1%
121	www.unicef.org Internet Source	<1%
122	"Textbook of Obstetrics and Gynaecology", Springer Nature, 2019 Publication	<1%
123	Eilander, Jansje (Ans) H. C.. "Micronutrients, Omega-3 Fatty Acids and Cognitive Performance in Indian Schoolchildren.", Wageningen University and Research, 2021 Publication	<1%
124	Hata, Tiffany. "Does Whole-Body Vibration (WBV) Have the Same Effect in Children and Adults on Walking Endurance and Timed Up and Go (TUG) Scores in Individuals with Cerebral Palsy: a Meta-Analysis.", California State University, Fresno, 2021 Publication	<1%
125	Lowing, Kristina. "Goal-Directed Therapy for Children with Cerebral Palsy", Karolinska Institutet (Sweden), 2021 Publication	<1%
126	N. Y. Mapoure, M. N. Budzi, S. A. F. B. Eloumou, A. Malongue, C. Okalla, H. N. Luma.	<1%

"Neurological manifestations in chronic hepatitis C patients receiving care in a reference hospital in sub-Saharan Africa: A cross-sectional study", PLOS ONE, 2018
Publication

127	Olaf Verschuren, Marjolijn Ketelaar, Tim Takken, Marco van Brussel, Paul J. M. Helders, Jan Willem Gorter. "Reliability of hand-held dynamometry and functional strength tests for the lower extremity in children with Cerebral Palsy", Disability and Rehabilitation, 2009 Publication	<1%
128	Patrice K. Nicholas, Inge B. Corless, Linda A. Evans. "Peripheral Neuropathy in HIV: An Analysis of Evidence-based Approaches", Journal of the Association of Nurses in AIDS Care, 2014 Publication	<1%
129	S. Morishita, A. Tsubaki, J.B. Fu, Y. Mitobe, H. Onishi, T. Tsuji. "Cancer survivors exhibit a different relationship between muscle strength and health-related quality of life/fatigue compared to healthy subjects", European Journal of Cancer Care, 2018 Publication	<1%
130	brage.bibsys.no Internet Source	<1%
131	de Carbonel, Claudette E. "Differentiation and job satisfaction: Does the Differentiation of Self Inventory (DSI-R) predict job satisfaction as measured in the Job Satisfaction Survey (JSS)?", Proquest, 20111109 Publication	<1%
132	espace.curtin.edu.au Internet Source	

		<1%
133	mjselt.com Internet Source	<1%
134	nectar.northampton.ac.uk Internet Source	<1%
135	novaprd-lb.newcastle.edu.au Internet Source	<1%
136	open.uct.ac.za Internet Source	<1%
137	publications.aston.ac.uk Internet Source	<1%
138	trap.ncirl.ie Internet Source	<1%
139	ujcontent.uj.ac.za Internet Source	<1%
140	www.ahu.on.ca Internet Source	<1%
141	www.docstoc.com Internet Source	<1%
142	www.sportengeneeskunde.nl Internet Source	<1%
143	www.udel.edu Internet Source	<1%
144	"American Academy for Cerebral Palsy & Developmental Medicine 2001", Developmental Medicine & Child Neurology, 08/29/2001 Publication	<1%
145	Anastasia Zarkou, Samuel C. K. Lee, Laura A. Prosser, John J. Jeka. "Foot and Ankle	<1%

	Somatosensory Deficits Affect Balance and Motor Function in Children With Cerebral Palsy", Frontiers in Human Neuroscience, 2020 Publication	
146	Gutierrez, Gabrielle. "Perinatal Risk Factors for Cerebral Palsy in Twin Gestations", Michigan State University Publication	<1%
147	John F. McLaughlin. "Lower extremity sensory function in children with cerebral palsy", Pediatric Rehabilitation, 1/1/2005 Publication	<1%
148	Ong, A.M.L.. "Reliability and validity of the Edinburgh Visual Gait Score for cerebral palsy when used by inexperienced observers", Gait & Posture, 200808 Publication	<1%
149	Opheim, Arve. "Walking in Adults with Spastic Cerebral Palsy - The Relation to Pain, Fatigue, Gait and Balance", Karolinska Institutet (Sweden), 2021 Publication	<1%
150	Pickering, Amy Janel. "Water Access, Hand Hygiene, and Child Health in Sub-Saharan Africa.", Stanford University, 2020 Publication	<1%
151	Tedroff, Kristina. "Children with Spastic Cerebral Palsy: Aspects of Muscle Activity and Botulinum Toxin a Treatment", Karolinska Institutet (Sweden), 2021 Publication	<1%
152	David Karpul, Sarah McIntyre, André van Schaik, Paul P. Breen, Jeannine M. Heckmann. "Vibrotactile sensitivity of patients with HIV-	<1%

related sensory neuropathy: An exploratory study", Brain and Behavior, 2019
Publication

153 Hugo Pasini Neto, Luanda André Collange Grecco, Thaluanna CL Christovão, Luiz Alfredo Braun et al. "Effect of posture-control insoles on function in children with cerebral palsy: Randomized controlled clinical trial", BMC Musculoskeletal Disorders, 2012 <1%
Publication

154 Jeffrey L. Young, Jill Rodda, Paulo Selber, Erich Rutz, H. Kerr Graham. "Management of the Knee in Spastic Diplegia: What is the Dose?", Orthopedic Clinics of North America, 2010 <1%
Publication

155 P. A. Burtner, M. H. Woollacott, G. L. Craft, M. N. Roncesvalles. "The capacity to adapt to changing balance threats: A comparison of children with cerebral palsy and typically developing children", Developmental Neurorehabilitation, 2009 <1%
Publication

156 Thoms, Jennifer Catherine. "Children with Cerebral Palsy: Parents' Satisfaction of Speech and Language Therapy in Early Intervention", Nova Southeastern University, 2021 <1%
Publication

157 kclpure.kcl.ac.uk <1%
Internet Source

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

Turnitin report Rosemary Hanley

Please note that I have checked Ms Hanley's full plagiarism report. Although the final figure is high at 19% I am satisfied that this is made up of numerous common phrases and terms being identified rather than any significant pieces of work being copied.



Prof Joanne Potterton (Supervisor)