A PILOT STUDY TO DETERMINE THE EFFECT OF WEIGHT BEARING EXERCISES AND WHOLE BODY VIBRATION ON GROSS MOTOR FUNCTION AND SPASTICITY IN CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

The aim of this study was to determine the effects of an eight-week weight bearing exercise program coupled with whole body vibration (WBV) on gross motor function, functional mobility and spasticity in hemiplegic type cerebral palsied school going children. The experimental group was compared to a control group undergoing the same exercise program. The control group excluded WBV training. Fifteen children participated in the study nine females and six males. There were eight children with right hemiplegia and seven with left hemiplegia; all children had gross motor classification (GMFCS) of Level 1. Significant improvements were seen in both groups for gross motor function. There was no difference in the amount of change seen between the two groups. A decline was noticed in the functional mobility assessment. The findings of this study demonstrated that both the children in the control and the experimental groups showed significant improvements in the GMFM scores after a weight bearing exercise program. The children in the experimental group who received WBV while exercising showed significant improvement from baseline to completion of the study compared to the group that did weight bearing exercise alone; better carry over effect in this group from WBV. Time up and down stairs (TUDS) and modified ashworth scale (MAS) scores showed less convincing results and need further investigation. Further research is required to determine the most effective and efficient way of managing children with cerebral palsy in a resource poor area.

DECLARATION

I, Amy Honour declare that this research report is my own work. It is being submitted for the degree of Master of Science in Physiotherapy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

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On this ___________ day of ___________ 2014.

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LIST OF ABBREVIATIONS

ABD	ABDUCTORS
ADD	ADDUCTORS
CP	CEREBRAL PALSY
DF	DORSIFLEXION
GMFCS	GROSS MOTOR FUNCTION CLASSIFICATION SYSTEM
GMFM	GROSS MOTOR FUNCTION MEASURE
KE	KNEE EXTENSORS
KF	KNEE FLEXORS
MAS	MODIFIED ASHWORTH SCALE
MS	MULTIPLE SCLEROSIS
NDT	NEURODEVELOPMENTAL THERAPY
PF	PLANTAR FLEXION
QOL	QUALITY OF LIFE
SCI	SPINAL CORD INJURY
TUDS	TIME UP AND DOWN STAIRS
WBV	WHOLE BODY VIBRATION

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Cerebral palsy (CP) is a term used to describe a group of non-progressive, but changing, disorders of motor function (Rosenbaum, 2003). These disorders result from injury to the central nervous system during its development in-utero, during birth or in early childhood (Koman et al., 2004; Rosenbaum, 2003; Morris, 2007). As a result neural connections are disrupted during their development and therefore contribute to impaired motor strength and coordination (Aisen et al., 2011). CP may be diagnosed as early as 12 months of age when the child is not attaining certain developmental milestones.

Types of cerebral palsy are classified firstly according to the main pattern of involvement and secondly according to quality and distribution of tone. Hemiplegia is described as unilateral impairment of the arm and leg on the same side. Diplegia involves the lower limbs with possible mild involvement of the arms. Quadriplegia is described as impairment of both arms and legs, also involving the trunk (Rosenbaum, 2003; Koman et al., 2004).

Spasticity is defined as an increase in muscle tone, with a velocity dependant resistance to passive stretch, hyperactive reflexes and weakness of the affected muscle; these being due to damage of the inhibiting pathways causing hyperactive spinal reflexes (Goldstein, 2001). Tone is defined as a resistance to a passive stretch and a state of readiness of the muscle for movement or activity (Clopton et al., 2005). The non-progressive nature of CP is complicated by secondary impairments that arise, as muscle length and nervous system maturation are not matched with physical growth and strength. Even though CP is a non-progressive disorder, as the child matures they may appear to endure further physical limitations due to growth of muscles and nervous system maturation (Mayston, 2001; Koman et al., 2004; Mockford & Caulton, 2010).

One aim of physiotherapy is to improve gross motor function by decreasing the incidences of secondary deformities. This is achieved by stretching muscles that are at risk of shortening (those that are affected by an increase in tone). The stretching helps to maintain the normal range of movement of that joint by maintaining muscle length (Wu et al., 2011). Strengthening the weaker muscles helps to improve gross motor function (Koman et al., 2004). Weight bearing activities are used to promote activation of antigravity muscles and assist in decreasing tone and improving strength. Static weight bearing is used as a prolonged stretch to reduce spasticity (Pin, 2007). Reducing the degree of spasticity allows the child to use their muscles more effectively and therefore gain strength (Koman et al., 2004). Bobath practice of neurodevelopmental therapy aims to reduce the spasticity to facilitate normal movement patterns (Mockford & Caulton, 2010).

Whole body vibration (WBV) is a new alternative way of exercising using a vibrating plate. The plate (Power Plate ®) vibrates in three directions: up and down, forward and backwards and left to right (Hopson et al., 2007). Muscle spindles are stimulated as a result of the movement of the plate causing a lengthening of the muscle fibres and in response producing a stretch reflex contraction. As a result of the acceleration there is also an increase in force, which increases the load of the muscle at work on the plate (Hopson et al., 2007).

Previous studies in able-bodied adults and children have shown that using WBV training has led to an improvement of strength, stability, balance and functional mobility (Madou & Cronin, 2008; Runge et al., 2000). An increase in dynamic range of movement in the hamstrings when stretching with WBV has also been reported and this increase was greater than that compared to conventional stretching methods (Cronin et al., 2007). In research done with children with CP it has been found to improve gross motor function, increase walking speed and reduce muscle spasticity (Ahlborg et al., 2006; Stark et al., 2010; Noma et al., 2009; Unger et al., 2013). WBV training allows shorter training duration to receive the same effect as long training sessions due to the increased load on the muscles and the activation of the tonic vibration reflex.

Problem statement:

High therapy demands for children with CP pose a need for a form of therapy with fast, effective and reliable results. The use of WBV as a form of therapy in this population in South Africa has not been well researched. To the authors knowledge only one other study has been conducted in South Africa in a similar setting.

Research Question:

What is the effect of an eight-week lower limb weight bearing exercise program coupled with WBV on the gross motor function, functional mobility and spasticity of children with hemiplegic cerebral palsy compared with lower limb weight bearing exercises without WBV?

Aim:

The aim of this study was to compare the effect of an eight-week lower limb weight bearing exercise program coupled with WBV on the gross motor function, functional mobility and spasticity in children with hemiplegic cerebral palsy to a control group receiving lower limb weight bearing exercises without WBV.

Objectives:

To Determine:

1. the level of gross motor function of participants using the GMFM
2. the degree of spasticity of participants using the MAS
3. the level of functional mobility of participants using TUDS
4. the effect of WBV and exercise on spasticity using the MAS
5. the effect of weight bearing exercises on spasticity using the MAS
6. the effects of WBV and exercise on gross motor function using the GMFM
7. the effects of weight bearing exercise on gross motor function using the GMFM
8. the effect of WBV and exercise on functional mobility using TUDS
9. the effect of weight bearing exercises on functional mobility using TUDS

Significance of the Study

The effect of WBV training on strength, mobility and function is unknown. To date there are limited studies available on the effects of whole body vibration training on gross motor function, spasticity and functional mobility in children with cerebral palsy in South Africa. This research may introduce a new form of therapy for children with cerebral palsy as well as providing rehabilitation centres with a less human resource intensive approach to management. Further research may be promoted if favourable results from this study are found.

CHAPTER 2: LITERATURE REVIEW

This literature review will provide a background of CP focusing on hemiplegia. A review of current literatures pertaining to CP, therapy techniques, functional mobility, WBV gross motor function measure (GMFM) and other tools used in the study will be made.

Searches were made through the following databases: ScienceDirect, Medline, Cochrane Collaboration, CINAHL and PubMed. The following keywords were used: cerebral palsy, vibration training, whole body vibration and spasticity. Only articles published in English were reviewed.

2.1 EPIDEMIOLOGY:

In South Africa, statistics regarding the number of individuals living with cerebral palsy are not readily available. Previous census assessments have not stated type of disability, however 736 deaths were reported in 2007 due to cerebral palsy (Statistics SA, 2010). The worldwide incidence is said to be 2.4 for every 1000 children between the ages of three and ten (Koman et al., 2004; Rosenbaum, 2003) and 2-3 per 1000 births (Morris, 2007). These statistics relate to developed populations but may not be applicable to the developing South African population. The incidence of CP is not declining in developed countries due to the increase in the number of premature births, advancement in our medical care and facilities enabling babies to survive insults due to prematurity (Mayston, 2001; Eunson, 2012).

2.2 PATHOLOGY AND PRESENTATION:

Children with CP can be classified according to motor abnormalities impairments, anatomical distribution according to physical presentation and neuro-imaging findings, cause of injury and time of onset. Motor abnormailities include type of tone and functional motor limitations. Impairments include musculoskeletal, sensory, communication and cognitive function (Rosenbaum et al., 2007).

2.2.1 CAUSES

CP can be caused by a number of insults such as complications of prematurity, low birth weight, birth asphyxia, hypoxia, epilepsy, central nervous system infections and trauma (Shevell et al., 2011; Eunson, 2012). Socioeconomic status is also a risk factor for CP (Eunson, 2012).

CP due to birth asphyxia can result in a number of different presentations depending on the severity of hypoxia, hemorrhage, ischemia or mechanical damage to the brain (Koman et al., 2004). In the full term neonate the grey matter is more vulnerable than the white matter and marked asphyxia will damage the grey matter (Flodmark, 2007). Mild hypoxia leading to ischemia in the watershed area of the brain usually leads to cortical infarcts. The infarcts are commonly seen in the branches of the middle cerebral artery (MCA). The MCA supplies the primary motor cortex of the cerebrum, the area responsible for gross motor and fine motor movements of the body. Damage to this area generally results in hemiplegia and is more common on the left than the right.

Children who are born premature may develop periventricular leukomalacia (Shevell et al., 2011) due to the vulnerability of the white matter during week 26-34 of gestation (Koman et al., 2004). A mild bleed can lead to spastic diplegia with low truncal tone, visual and perceptual problems (Mayston, 2001). A more severe bleed extending sub-cortically can cause spastic quadriplegia with more severe visual, perceptual as well as cognitive problems (Mayston, 2001). Any insult occurring between weeks 38-40 can cause dystonia as this is the time when the basal ganglia is most at risk due to its rapid development (Koman et al., 2004).

2.2.2 MOTOR IMPAIRMENTS

Motor impairments are classified into hemiplegia, diplegia and quadriplegia. Some terms also accepted include bilateral or unilateral, symmetrical or asymmetrical involvement (Eunson, 2012). Hemiplegia is regarded as a motor impairment of arm and leg on the same side, whereas in diplegia both legs are affected with the arms showing minimal or no involvement, and in quadriplegia both arms and legs are equally involved (Rosenbaum, 2003). It is however not acceptable to only classify a child with CP as quadriplegic, hemiplegic or diplegic as within these classifications the presentation can be diverse, therefore the following movement impairments need to be taken into account. A diagnosis should be made in terms of tone and function. Tone should be assessed in terms of quality and distribution.

2.2.3 MOVEMENT IMPAIRMENTS

Movement impairments seen in CP are dyskinetic (dystonic or athetoid), ataxic and spastic (Gorter et al., 2009; Eunson, 2012). Tone can either be increased (hypertonic), decreased (hypotonic) or fluctuating between the two. Dyskinetic CP is characterized by involuntary and uncontrolled movements often involving primitive reflex patterns. Muscle tone in these individuals fluctuates with each subgroup having predominately high or low tone. The dystonic subgroup presents with abnormal postures and easily aggravated hypertonia. The athetoid subgroup characteristically has hyperkinesia with predominately hypotonia (Cans et al., 2007). Dyskinetic CP generally is associated with damage located in the basal ganglia, speech is sometimes affected and more often than not cognition is spared (Bax et al., 2007). Ataxia is characterized by hypotonia. This is as a result of cerebellar damage resulting in uncoordinated, ungraded muscle movements of abnormal force and rhythm (Cans et al., 2007).

2.2.4 SPASTICITY

Spasticity is defined as a velocity dependent resistance to a muscle stretch (Cheney, 1997; Bovend'Eerdt et al., 2008; Gorter et al., 2009). It is one of the primary impairments noted in CP (Ross & Engsberg, 2007). In CP damage to the cerebrum results in a decreased inhibition from the upper motor neuron corticospinal tracts (Cheney, 1997; Nardone & Schieppati, 2005) to the reflex arch of the corresponding limb. The lateral section of these tracts mediate reflex activity by inhibiting muscle spindles (Cheney, 1997). Unwanted reflexes result when these tracts are damaged. Muscle spindles are sensory receptors that act within the muscle to detect a change in the length of muscle fibers. Without the correct functioning of these tracts the stretch reflexes of the involved muscles will be hyperactive (Goldstein, 2001; Gorter et al., 2009). Therefore any stretch on that particular muscle, even during movement, will result in the activation of spinal reflex action and contraction of that muscle; this is termed hyperactive reflexes. As a result of spasticity, the muscle loses ability to maintain endurance and selective control and strength of the muscle is compromised (Goldstein, 2001).

The typical pattern of tone presented in a hemiplegic distribution is that of predominant upper limb flexion and lower limb extension. The arm will be held in shoulder internal rotation, elbow flexion, wrist flexion and finger flexion. The lower limb will be held in hip internal rotation, knee extension and ankle plantar flexion.

2.3 DIAGNOSIS:

Diagnosis of CP is usually made within the first few years of life. Caregivers will often report to the doctor that the child is not performing as per the norms of child development (Rosenbaum, 2003). In the event that there is no defining incident where the insult to the brain is noted, such as with a motor vehicle accident causing obvious head injury, it is important then to note prenatal and birth history (Koman et al., 2004). The injury to the brain may have occurred during the birth process due to a lack of oxygen for example. Diagnosis can be made via MRI or CT scans which will indicate areas of damage to the cortex or other structures (Koman et al., 2004; Flodmark, 2007). Neurologists, physiotherapists and occupational therapists, making up part of the multi disciplinary team (MDT), are able to provide a diagnosis by administering a number of physical tests to assess the extent and location of neural damage. These tests mainly assess the adequacy of the cortex to control gross and fine motor movements. The tests applicable to this study will be explained in the assessment tools section of this literature review.

2.4 CLASSIFICATION:

2.4.1 THE GROSS MOTOR CLASSIFICATION SYSTEM

The Gross Motor Classification System (GMFCS) was developed by Palisano and colleagues to classify children with CP into five levels according to their motor abilities. These levels are described according to age groups: below two years, two to four years, four to six years and six to 12 years. Children falling under level one are generally independent and functional in activities but lack the balance and coordination when compared to their able bodied peers. At level two, children are able to negotiate their environment with assistance from handrails when using stairs and assistive devices provide stability on uneven terrain or amongst large groups of people. Long distance walking may be challenging and could require the use of a wheelchair. Children at level three use an assistive device for most ambulation inside and out. They are able to self propel in a wheelchair over short distances; climbing stairs is only possible with assistance. In level four, children are either in powered wheelchairs or devices that need supervision; they may be able to walk for short distances with assistance from a device and an assistant. Children at level five are limited in their control of functional movement; they need assistance in all areas of daily living and may lack postural control against gravity. (Campbell et al., 2012; Rosenbaum, 2003; Gray et al., 2010).

2.4.2 THE INTERNATIONAL CLASSIFICATION OF FUNCTIONING

The International classification of functioning (ICF) is a conceptual framework set out to record comprehensive details of an individual's disability. It was revised in 2007 and now covers impairments encountered in children and youth: The International Classification of Functioning – Child and Youth (ICF-CY). The ICF-CY is divided into five structures including: impairments in body structure and functioning, activity limitation, participation restriction and environmental factors pertaining to the child. Therefore it looks at the child as a whole and is not just focused purely on the disability. Its emphasis, however, is on function and disability and has been designed for use across disciplines in a universal language (World Health Organisation, 2007).

2.5 SECONDARY IMPAIRMENTS:

Decreased cortical control from the motor cortex via the corticospinal tracts results in reduced voluntary and selective motor activity (Mockford & Caulton, 2010; Mayston, 2001; Dallmeijer et al., 2011). Children with hemiplegia are generally more impaired in their distal upper limb than the lower limb (Damiano & Abel, 1998). Since the corticospinal tracts are responsible for fine motor movements in the hand, manipulation of objects will be difficult (Vandermeeren et al., 2003). Postural control of the trunk is a challenge for these children (Mayston, 2001; Prosser et al., 2010) and distal muscle groups take over the stabilizing role resulting in ineffective movement and fatigue (Prosser et al., 2010). With continued use of the incorrect muscle groups abnormal patterns of movement develop (Mockford & Caulton, 2010).

2.5.1 MUSCLE WEAKNESS

Muscle weakness in hemiplegics is well documented (Hombergen et al., 2012; Eek & Beckung, 2008; Wiley & Damiano, 1998; Ross & Engsberg, 2007; Damiano & Abel, 1998; Dallmeijer et al., 2011) and spasticity is a known cause of weakness in the affected muscle group (Ross & Engsberg, 2007). The antagonist to the spastic muscle has been found to be significantly weaker for both hamstrings and quadriceps (Damiano et al., 2001).

Typical patterns of weakness are seen in the hip extensors on both dominant and non-dominant sides in these children, as well as weakness in both the ankle plantar flexors and dorsiflexors. This weakness could also be a result of a decrease in neuronal activation, insufficient motor unit recruitment and coordination between muscle fibers (Eek & Beckung, 2008; Ostensjo et al., 2004; Mockford & Caulton, 2010). Weakness of these muscle groups contributes to decreased force production and selective atrophy (Patikas et al., 2006). Strength is directly correlated to gross motor function in this population (Ross & Engsberg, 2007; Damiano & Abel, 1998; Eek & Beckung, 2008) but the relation to spasticity and function is debatable (Ross & Engsberg, 2007). Maintaining overall muscle strength is therefore important to keep up with gross motor milestones (Dallmeijer et al., 2011).

2.5.2 GROSS MOTOR FUNCTION

Gross motor function is the ability to use large muscle groups to control mass movement of the body such as walking or jumping. Motor learning is the ability to use experience in movement to obtain and maintain skilled purposeful action (Ustad et al., 2009). Children with CP are limited in their exposure to movement due to associated impairments and therefore their motor learning is impeded. The result is poor attainment or delayed gross motor milestones and fine motor skills, especially when compared to their peers (Mockford & Caulton, 2010; Ustad et al., 2009). Sensory feedback may also be impaired (Mockford & Caulton, 2010).

Functional mobility or functional movement is movement with purpose (Campbell et al., 2012) and is often limited or decreased in children with CP due to their associated impairments and lack of attainment of milestones. During walking in the child with hemiplegia the step length and heel strike of the affected side are decreased which affects functional mobility (O'Reilly et al., 2009).

2.5.3 POSTURAL CONTROL

Postural control is the ability to control the body within its environment even when an external stimulus causes displacement (Shumway-Cook et al., 2003; Mayston, 2001). It is an important component to function in day-to-day life (Zadnikar & Kastrin, 2011). Postural control can be divided into two levels; firstly, the overall direction in which the body is displaced causes the muscles to react and maintain the upright posture. Secondly, fine motor reactions are recruited to fine-tune this movement smoothly (Zadnikar & Kastrin, 2011). Reactions to correct these displacements are known as equilibrium and righting reactions.

Decreased reciprocal inhibition affecting co-contraction of muscles (Mayston, 2001; Mockford & Caulton, 2010) as well as incoordination (Prosser et al., 2010) of muscles makes selective activity difficult. This also leads to subluxations of joints due to the increased force of one muscle group that is unopposed by the reciprocal group. In hemiplegics this is generally seen in the hip joint (Martinsson & Himmelmann, 2011).

Associated reactions, generally flexion of the elbow or extension of the lower limb, occur in the affected limb when there is increased effort on the unaffected side in the hemiplegic child; this reaction is involuntary and often interferes with activity (Chiu et al., 2011).

2.5.4 ORTHOPEDIC COMPLICATIONS

Due to a decrease in muscle activity on the hemiplegic side of the body, some children may present with underdeveloped bone structures on that side. This causes the affected side to be smaller and shorter compared to the unaffected side and gives children an asymmetrical appearance (Bax et al., 2007; Damiano & Abel, 1998). If untreated this may cause other deformities in the spine such as scoliosis.

Contractures develop in children with CP due to decreased movement causing stiffness in the muscle fibers (Martinsson & Himmelmann, 2011). This stiffness and reduced activity leads to loss of sarcomeres (Mockford & Caulton, 2010; Ostensjo et al., 2004) and therefore overall length of the muscle fiber (Dietz & Sinkjaer, 2007). If contractures continue to be untreated they may cause bony changes around the affected joint (Pin, 2007).

2.6 PHYSIOTHERAPY AIMS

The main aim of physiotherapy is to improve gross motor function by decreasing the incidence of secondary deformities. This is achieved by maintaining muscle range of movement through stretching muscles that are at risk of shortening (those that are affected by an increase in tone). The stretching helps to maintain the normal range of movement of that joint by maintaining muscle length (Wu, et al., 2011). Strengthening the weaker muscles helps to improve gross motor function (Koman, et al., 2004). Weight bearing activities are used to promote activation of antigravity muscles and assist in decreasing tone and improving strength. Static weight bearing is used as a prolonged stretch to reduce spasticity in the lower limbs (Pin, 2007). Reducing the degree of spasticity allows the child to use their muscles more effectively and therefore gain strength (Koman, et al., 2004).

When a muscle is strengthened there are neural changes that occur within to improve coordination between muscle fibers, inhibit antagonists and activate prime movers (Bruton, 2002). These neural changes occur within the first four weeks of training in a normally functioning muscle.

Muscle strength is needed in any typically developing child to complete any gross motor task no matter how simple. Without muscle strength, activities of daily living become difficult and a muscle will begin to atrophy. This atrophy, due to disuse, is generally first seen in the quadriceps and gastrocnemius muscles (Moreau et al., 2010).

Children with CP vary in their pattern of muscle weakness depending on their classification. Much research has gone into strength training as a physiotherapy technique in this area. Research to date has revealed that strength training in individuals with CP does not have negative effects on spasticity or associated reactions (Anderson et al., 2003) but does contribute to improved gross motor functioning, (Damiano & Abel, 1998; Lee et al., 2008; Ross & Engsberg, 2007) especially walking ability (Eek & Beckung, 2008; Thompson et al., 2011) and stair mobility (Ferland et al., 2011).

Although Lee et al. (2008) had a relatively small sample size (17); their results are significant to show that a five-week experiment strength training (including weights and weight bearing positions with functional activity) is more beneficial when compared with neurodevelopmental therapy (NDT). At a six week follow up strength training had most retained strength in the lower limbs.

Eek & Beckung (2008) compared muscle strength profiles of 50 children with CP diplegia across three levels of the GMFCS to evaluate whether higher levels of GMFCS correlated with higher strength profiles on the GMFM. The sample size of this study allows a good indication of reliable results. Therefore concluding that increased muscle strength related to improved functioning.
Similarly Ferland et al. (2011) tested the relation of strength profiles using isometric muscle strength tests, in GMFCS level 1 & 2 in 50 children with CP, comparing it to functional mobility using the one-minute walk tests and TUDS.

2.6.1 WEIGHT BEARING

Weight bearing is defined as supporting the weight of your body; this can be achieved through the upper or lower limbs. Standing is regarded as weight bearing through the lower limbs and can be achieved using a standing frame with a child who is unable to stand independently. Upper limbs can be exposed to weight bearing directly through the hands or forearms in various positions (Pin, 2007). Weight bearing in a child with CP is important as it promotes normal development of bones and muscles (Martinsson & Himmelmann, 2011), promotes activation of antigravity muscles and assists in decreasing spasticity and improving strength by influencing the proprioceptors. Static weight bearing is used as a prolonged stretch to reduce risks of contractures (Pin, 2007). There is also a possibility that weight bearing can have positive effects on bone density (Pin, 2007).

2.6.2 STRETCHING

The literature surrounding stretching in children with CP is controversial (Wiart et al., 2008; Pin et al., 2006; Effgen & McEwen, 2008; Katalinic et al., 2010). Pin et al. (2006) found, in a review done on studies of children with CP below the age of 18, evidence to support the hypothesis that sustained stretching may assist in improving ROM. In a well-conducted systematic review by Katalinic et al. (2010) it was found there is no evidence to support stretching for prevention of contractures regardless of the duration. Research in this area remains inconclusive and further research is warranted (Effgen & McEwen, 2008).

The thought process behind stretching is that of increasing the number of sarcomeres in the length of the muscle fibre, therefore increasing the length of the muscle. This has proven true in animal studies (Katalinic et al., 2010). In children with CP, there are three ways in which a stretch on a muscle can be performed. Firstly, passively, whereby the therapist stretches the muscle/limb; secondly, active stretching, where the child actively engages in a position or activity that stretches the muscle group: and finally, positioning, whereby the child is positioned in such a way that the structures are held in a stretch, such as standing frames (Wiart et al., 2008).

Passive stretching may assist in reducing the likelihood of contractures by maintaining the available range of movement while not necessarily affecting spasticity (Pin et al., 2006). Stretching for longer durations, however, has led to improvements in range and spasticity in these children. Active stretching is seen to be more functional and less uncomfortable for the child and is the preferred method (Wiart et al., 2008).

2.6.3 BALANCE (POSTURAL CONTROL) TRAINING

Balance is defined as a person's ability to control their body postures when an outside force displaces the body (Pollock et al., 2000). These are referred to as balance reactions or postural control. This ability to control the bodies posture after external displacement is essential for normal functioning in society (Pollock et al., 2000). For example walking through busy crowds or on uneven streets.

Children with CP struggle to maintain their posture when displaced due to their associated impairments, especially spasticity but also including contractures and muscle weakness (Shumway-Cook et al., 2003; Mayston, 2001).

Balance training makes up part of physiotherapy rehabilitation with these children to enable them to transfer this strength into every day activities. This training can be achieved a number of ways; using moving platforms such as balance boards (Shumway-Cook et al., 2003), walking on uneven surfaces, activities in postures with a small base of support such as one legged standing. Therapy in this domain uses practice and repetition (Shumway-Cook et al., 2003) to build muscle memory and strength. It can be progressed by introducing other factors that further challenge balance such as carrying objects, fast turns and stop-start activities. Children with hemiplegia have shown to increase their Gross Motor Function Measure (GMFM) scores after balance training (Shumway-Cook et al., 2003).

2.7 QUALITY OF LIFE

Quality of life (QoL) is defined as a person’s holistic (physical emotional and social) wellbeing (Livingston et al., 2007; Davis et al., 2010; Shelly et al., 2008).

Individuals with a disability are generally at a disadvantage physically and therefore their overall physical fitness is limited due to decreased activity (Hombergen et al., 2012). Physical fitness is needed to maintain a state of wellbeing and prevent deconditioning (loss of strength and endurance) (Hombergen et al., 2012; Verschuren et al., 2012). Physical wellbeing is directly related to gross motor function (Livingston et al., 2007). As CP is a movement disorder, these individuals are at a risk of deconditioning due to impaired and ineffective movement, thus resulting in difficulties in activities of daily living and functional mobility (Hombergen et al., 2012; Verschuren et al., 2012) contributing to other health problems such as obesity and depression (Maher et al., 2010;

Capio et al., 2012). School-going children with CP are less active than their abled bodied peers (Van Wely et al., 2012).

Although it would be assumed that a lower GMFCS level should be related to lower QoL, the opposite is true. Despite the fact that children with CP may present with challenges in function and ADLs, which correlates to the physical aspect of QoL, they perceive their QoL to be high (Shelly et al., 2008) or similar to typically developing children (Majnemer et al., 2007; Dickinson et al., 2007). However offering them the opportunity for exercise may enable them to improve their functioning and ADLs therefore preventing other health care problems in the future that relate to decreased functioning.

2.8 ASSESSMENTS TOOLS:

There are a number of assessment tools available to therapists to assess function, mobility and spasticity. This section will describe those tools that are applicable to this study.

2.8.1 GROSS MOTOR FUNCTION MEASURE

The Gross Motor Function Measure (GMFM) assesses the level of the participants' gross motor function systematically. The GMFM - 88 is a standardised tool used to measure the gross motor function of children with cerebral palsy over time. It has 88 different tasks assessing the gross motor function grouped into five sections: lying and rolling (seventeen tasks); sitting (twenty tasks); crawling and kneeling (fourteen tasks); standing (thirteen tasks); and walking, running and jumping (twenty four tasks) (Avery et al., 2003). It enables the examiner to have a clear understanding of the participant's possible areas of weakness. Scoring is outlined as follows: 0 (does not initiate), 1 (initiates), 2 (partially completes) and 3 (completes). The scores are added together and the final score is represented as a percentage; any small change over time can therefore be noted. The GMFM-88 has good reliability (ICC= 0.99) and validity for children with CP (Palisano et al., 1997; Russell et al., 2000; Avery et al., 2003) and is a commonly used tool in research of this nature (Ahlborg et al., 2006; Eek & Beckung, 2008).

2.8.2 THE MODIFIED ASHWORTH SCALE

The Modified Ashworth Scale (MAS) is a measure of spasticity in the upper and lower limbs and is a six point scale from 0 to 4 measuring the degree of spasticity. 0, being no increase in muscle tone; 1, shows a slight increase in tone with a catch and release; 1+, indicates a slight increase in tone with a catch and minimal resistance throughout range; 2, more marked increase in tone throughout range; 3, passive movement difficult due to increase in tone, and 4 being, affected limb rigid (Yam & Leung, 2006). The subject is placed in supine with the muscle to be tested relaxed; the therapist rapidly stretches the muscle; for example, flexes the knee to test quadriceps. It is a subjective test but it has good intrarater reliability (ICC > 0.75) for hamstrings (Clopton et al., 2005; Barlow, 2008). The MAS has been used previously in research involving CP as well as other neurological conditions where spasticity is present (Mehrholz et al., 2005; Caliandro et al., 2012; Schyns et al., 2009; Murillo et al., 2011).

2.8.3 TIMED UP AND DOWN STAIRS

Timed up and down stairs (TUDS) assesses the level of functional mobility that a child possesses. A participant is required to ascend and descend a set of fourteen stairs at their own pace and is timed from start to finish. The time taken to do this is recorded from the word ‘Go’ until both feet have stepped off of the bottom step. The participant is able to use an assistive device or hold on to the rail if necessary during the test. Ascending and descending a flight of stairs needs adequate dynamic balance, strength and coordination, the typically developing child is able to average 0.52 seconds/step (Brien & Sveistrup, 2011). This test stemmed from the timed up and go test used in elderly clients, whereby they are tested from sitting in a chair and asked to stand up, walk 6 meters turn around and return to the chair. The TUDS was developed for a more active group of disabled individuals but both tests measure functional mobility. It has adequate reliability (ICC = 0.94) and validity for use in CP (Zaino et al., 2004; Ferland et al., 2011; Gorter et al., 2009). It has been previously used to assess the effect of ankle foot orthoses (AFO) in children with hemiplegic type CP on improved functioning and weight bearing (O'Reilly et al., 2009) as well as the impact of exercise on function and endurance (Gorter et al., 2009) and more recently virtual reality programs (Brien & Sveistrup, 2011; Jelsma et al., 2013). When comparing results, a shorter time taken to complete the test shows an improvement in functional mobility (Gorter et al., 2009).

2.9 WHOLE BODY VIBRATION (WBV)

Whole body vibration (WBV) is an alternative way of exercising using a vibrating plate. The plate of the device transmits the vibration and can do so in two ways. Synchronous vibration where by the plate moves vertically or side alternating vibration where by the left and right sides of the plate move up and down, the same as a seesaw motion (Rauch et al., 2010). The vibration is transmitted through the plate to the body as long as the body is in contact with the plate. There are a number of vibration plates available for exercising. For the purpose of this paper the focus will be on the Power Plate®, which is a synchronous vibration.

2.9.1 POWER PLATE ®

The plate (Power Plate®) uses a synchronous vibration and vibrates in three directions: up and down, forward and backwards and left to right (Hopson et al., 2007). This movement in the above three planes causes an increase in acceleration and therefore a gravitational force (*g*) of 1.76*g* (based on sinusoidal vibration platform) when set at 30Hz (Crewther et al., 2004). As a result of the increase in force production the load of the muscle at work on the plate increases

(Hopson et al., 2007), that in turn helps to improve muscle strength, balance (Cochrane et al., 2008) and flexibility (Gerodimos et al., 2010; Cronin et al., 2007).

The frequency of the Power Plate® ranges from 30Hz to 50Hz with an amplitude of high 4mm and low 2mm. Duration intervals can be set at 30 seconds, 45 seconds and 60 seconds.

A frequency of 20Hz induces muscle relaxation (Rittweger et al., 2003). Flexibility improves within a range of frequencies (Gerodimos et al., 2010), however it has been found that range of movement of a muscle improves most at around 30Hz (Cronin et al., 2007). Balance improvements were seen with frequencies around 30Hz with an amplitude of 3mm (Madou & Cronin, 2008). In a functional mobility test (timed up and go) the biggest improvements were seen at frequencies close to 30Hz (Madou & Cronin, 2008).

A few definitions need to be laid down in order to understand the proposed effect of WBV on muscles during exercise. Muscle spindles are sensory receptors that act within the muscle to detect a change in the length of muscle fibers. These receptors are an important component of the stretch reflex cycle. If stimulated by a rapid stretch of the muscle they will initiate contraction of that muscle. (Goldstein, 2001; Gorter et al., 2009)

The Golgi tendon organ is also a sensory receptor found within the muscle fibers that senses a change in the muscles tension. It acts by causing a relaxation of the antagonist muscle to a contracted muscle (Gerodimos et al., 2010; Cronin et al., 2007). For example, if a person wants to flex their elbow, the biceps will contract causing tension in the opposing triceps muscle group. The golgi tendon organ is then stimulated within the triceps and results in relaxation of the muscle.

The tonic vibration reflex is activated when a muscle contracts and is exposed to vibration, this will result in a sustained contraction of that muscle, in essence a continued stretch reflex (Ritzmann et al., 2011; Cochrane et al., 2008; Cronin et al., 2004; Hopson et al., 2007).

Due to the movement of the plate at a rapid speed, in a sense vibrating, muscles are subjected to a quick stretch and therefore muscle spindles are stimulated (Ritzmann et al., 2011; Knikou, 2010), in response producing a stretch reflex contraction (Cochrane et al., 2008). This contraction causes the golgi tendon organ to produce a relaxation effect of the antagonist, reciprocal inhibition (Cronin et al., 2004; Nordlund & Thorstensson, 2007). At the same time the contracted muscle continues to contract via the tonic vibration reflex.

It has been noticed that with WBV exposure, the representation area of the cortex for gross motor function is activated. Neural plasticity, the brains ability to reorganise (Ustad et al., 2009), may be stimulated by sensory stimulation (Forner-Cordero et al., 2008). Therefore opening an area for WBV to assist in treatment of CP and neurological conditions. There is also an increase in motor unit recruitment as a result of muscle spindle activation (Cronin et al., 2007).

Side effects noticed immediately after using WBV are said to be erythema (Rittweger et al., 2003), increased blood flow (Cochrane et al., 2008) increased muscle temperature (Cronin et al., 2004; Cronin et al., 2007). The increase in blood flow also causes itchiness (Crewther et al., 2004). These side effects subside after a few minutes of stopping the vibration and are not harmful to the body.

2.9.2 ACTIONS POST WHOLE BODY VIBRATION

Research to date on WBV is controversial as to the exact action on the reflex pathways post vibration. Some research points to the increased excitability of the arch and therefore increased responsiveness post treatment (Rittweger et al., 2003), others point to the over excitability of the arch producing a dulling effect on the stretch reflex (Ritzmann et al., 2011; Nordlund & Thorstensson, 2007). It could be said that the exercises or postures used and duration of vibration training is therefore crucial as to the effects you are looking for (Madou & Cronin, 2008).

Even though WBV training has been said to activate the stretch reflex arch, which is hyperactive in the CP child, it can be used to activate the antagonist to the spastic muscle to induce relaxation in that muscle. It is thought that WBV has an overall suppressive effect on the stretch reflex post training due to a depletion of neurotransmitters in the presynaptic terminals, this effect however lasts approximately 5 -10 minutes (Ritzmann et al., 2011; Nordlund & Thorstensson, 2007; Nardone & Schieppati, 2005).

Previous studies have shown that using WBV training in the elderly has led to an improvement of balance (reducing falls) and functional mobility (Madou & Cronin, 2008; Bogaerts et al., 2007) with a large focus on improving the quality of life in these individuals (Runge et al., 2000). Strength, stability and gait in patients with neurological conditions (Madou & Cronin, 2008) also improved after a WBV program.

Madou & Cronin (2008) conducted a systematic review between 1997 and 2007 of WBV effects on elderly balance, functional performance, strength and gait. This high level of evidence shows positive effects on the above when training with WBV.

Bogaerts et al. (2007) conducted a 12 month randomised control trial with three groups (fitness, WBV and control group) to determine the effects of postural control in healthy older adults. Falls frequency was assessed and it was found to be reduced in the WBV group more so than the fitness group.

In a study done on healthy athletic males it was found that there was an increase in dynamic range of movement in the hamstrings when stretching with WBV and this increase was greater than that compared to conventional stretching methods (Cronin et al., 2007). Another study in healthy males Stewart et al. (2009) focused on the effects of different vibration times on knee extensor strength, it was found that a shortened duration improved strength (two minutes) and longer durations (four to six minutes) decreased strength. This could be due to the stimulation of the muscle spindles initially causing excitation and recruitment of inactive muscle fibres and later over activity of the neurones causing a depression on the reflex arch and muscles. This again emphasises the importance of selecting the correct parameters for exercise depending on the desired results.

Rittweger et al. (2003) found an improved recruitment of large motor units post WBV training with squatting exercises in healthy young adults. It was also found that there was an increase in stretch reflex amplitude immediately after the vibration training, which faded after approximately 20 seconds. This could be due to increased neuromotor excitability and a change in central motor control patterns. This excitability of the reflex arch is not what is desired in a spastic muscle as the reflexes are already increased; however there is a possibility that when the effect fades it may decrease excitability and therefore decrease the overall spasticity of that muscle. A change in central motor control however is a positive effect for individuals with CP.

Isolated vibrations to individual lower limb muscles causes postural responses in the body. For example stimulating the tibialis anterior muscle of the lower leg on one side of the body causes the body to tilt forwards and towards the stimulated leg. And the opposite happens when stimulating the gastrocnemius muscle, the body tilts backwards and away from the stimulated leg (Polonyova & Hlavacka, 2001). From this understanding it would seem that by applying vibrations to the lower limbs would influence a balance reaction. This would be a useful therapeutic tool for individuals needing balance training such as in CP. It could be especially useful in hemiplegic CP when increased weight bearing is desired on the affected side, if the vibration could be localised to stimulate movement towards the affected limb, this will aide in improving strength as well as balance. Postural control has also been studied in healthy athletes and orthopaedic conditions and the results were favourable towards WBV (Ebersbach et al., 2008).

Previous studies in children with CP have focused on the effect of WBV on bone mineral density (BMD) (Ruck et al., 2010). The reasoning is due to the fact that children with CP are less active than their able bodied peers and therefore risk fractures due to decreased loading on the bones to influence BMD. Contradictory to the thought, BMD has not been seen to improve after WBV (Ruck et al., 2010) despite the fact that the increase in acceleration causes an increase in mass of the body in contact with the plate, therefore loading the bones. Improved function in these studies has not been the main focus and research is limited but emerging.

Significant improvements in walking speed of children with cerebral palsy exposed to an eight-week as well as a six-month trial of WBV have been documented (Lee & Chon, 2013; Ruck et al., 2010).

Incorporating WBV into therapy had positive effects on gross motor functioning with cerebral palsied adults and children (Ahlborg et al., 2006; Stark et al., 2010).

Ahlborg et al. (2006) compared 14 adults with dipelgic CP in a randomised control trial to determine the effectiveness of WBV training as opposed to resistance training. Each group was tested for spasticity using the Ashworth scale, walking ability using the six-minute walk test; balance using timed up and go test and gross motor performance using the GMFM. Subjects received eight weeks of intervention with three sessions per week. Both groups started each session with the same warm up and finished with the same stretches. The experiment group received six minutes of WBV in static standing in 50° of hip and knee flexion. Frequency was set between 25-40Hz depending on the participant. The control group performed resistance training leg press exercises with three sets of 10-15 repetitions with two minutes rest in between. Results found an improvement in the GMFM.

Stark et al. (2010) looked at a new concept in physiotherapy called ‘on your feet’ where by children receive a combination of therapies (conventional physiotherapy, WBV, resistance training, weight supported treadmill training and hydrotherapy) daily for a period of six months. This is an intensive type of therapy and WBV forms part of it. The WBV used was a side-alternating device and all parameters were set according to the child’s specific needs and goals. Frequency ranged from 5-25Hz but time frames were set for all children at: daily three sets of three minutes WBV with three minutes rest.

In a study done in South Africa on children with spastic CP, it was found that by targeting the trunk postural muscles in WBV exercises significantly improved their posture as well as functional mobility (Unger et al., 2013). A randomised cross over design was used in a sample of 27 children with spastic type CP (hemiplegic and diplegic). A 2D postural analysis was done; thickness of the abdominal muscles was tested using ultrasound as well as a 1-minute walk test was performed. Number of sit-ups completed in one minute was also tested as a measure of strength. Exercises targeted abdominal muscles and were done for four weeks before cross over. Week one consisted of two sessions, week two three sessions, week three and four had four and five sessions. Exercises were started at 45 seconds per exercise and increased to 60 seconds per exercise.

Other studies have looked at the effect of vibration on spasticity and it was seen that applying a vibration directly to the muscle belly of the elbow extensors in hemiplegic stroke patients produced a significant decrease in spasticity immediately and up to 30 minutes after treatment (Noma et al., 2009; Forner-Cordero et al., 2008). Knee extensor spasticity was decreased with WBV training in adults with CP (Ahlborg et al., 2006). In a more recent study it was reported by the participants that their legs felt loose and it was easier to walk (Unger et al., 2013) after four weeks of WBV, even though this study did not measure the effects of spasticity the fact that it was reported by the children is an interesting factor to consider.

In a study conducted on adults with spinal cord injuries (SCI) it was found that a frequency of 50Hz vibration applied directly to the muscle belly of the rectus femoris produced a significant reduction of spasticity and clonus in these individuals. This decrease in spasticity led to an improvement in range of passive motion (Murillo et al., 2011). Increased walking speed was also noted after a four week WBV study with lower level incomplete SCI patients (Ness & Field-Fote, 2009).

Schyns et al. (2009) looked at the effects of WBV training on tone and functional performance in individuals with multiple sclerosis (MS). Although MS is different from CP it was found that the WBV had positive effects on the individuals spasms and although not significant due to sample size, their functional performance also improved.

WBV training allows an individual to exercise without added weights and devices. Shorter treatment times can be used and have the same effect as training for longer durations. This is beneficial to the CP population as often therapy sessions can be long, tiresome and numerous. However for training with WBV to be beneficial it is said that exercises must be consistent for at least eight weeks (Mikhael et al., 2010).

2.10 CONCLUSION

Due to the increasing number of children born with cerebral palsy in South Africa, there is an increasing strain on our health care system to treat these children at a primary level. More focus is needed to treat these children more effectively and efficiently. Starting early intervention and promoting wellbeing in these children will help to prevent deformities which lead to further complications and more need for hospitalization as well as high demand on school based therapists. There is a wide range of evidence to support that WBV has positive effects on gross motor function, functional mobility and spasticity, not only in CP but other disabilities as well. However more research needs to be conducted with children and adults with CP. Research within South Africa especially needs to be conducted in this area. Most studies on CP have had small sample sizes and a short duration of total exposure to WBV therefore limiting the effects of the results. With the wide range of devices used it becomes difficult to pinpoint whether the effects can be generalised to all machines or specific types of vibration devices.

CHAPTER 3: METHODS

This chapter will discuss the study location, procedure, participants, instrumentation and ethical considerations.

3.1 STUDY DESIGN

The study was a randomized control trial, pilot study.

3.2 ETHICAL CONSIDERATIONS

Permission to conduct the study was obtained from the local department of education as well as the principal of the school (Appendix V:). Ethical clearance was obtained from the Ethics committee of the University of the Witwatersrand on submission of the protocol (Appendix V:). Information sheets (Appendix I:) were handed to caregivers explaining the procedure and side effects; these were also explained in their mother tongue. Caregivers signed consent forms (Appendix III:) and assent forms (Appendix IV:) were obtained from the participants. Video footage was taken for assessment purposes only and was only available to the authors. All participants were given a study number so all assessments remained anonymous.

3.3 LOCATION

Harding Special School is a school for the physically disabled it is situated in the southern most part of Kwa-Zulu Natal, South Africa. It is in a rural town and is attended by children from the Kwa-Zulu Natal as well as the Eastern Cape provinces. The school currently educates 150 children with mixed disabilities including cerebral palsy, muscular dystrophy, spina bifida and includes those with learning disabilities. Approximately 90% of the children are hostel boarders, only going home during the holidays. Classes are run from grade one through to grade seven with three intermediate classes. Skills programs are also offered for those scholars who are non-academic.

3.4 PARTICIPANTS

Participants were selected from Harding Special School in Kwa-Zulu Natal as a sample of convenience. All participants were of African descent. Those who met the inclusion criteria were invited to participate in the study. A Sample size calculation was not done due to a limited access to a high number of children.

3.5 INCLUSION CRITERIA

- Children with hemiplegic cerebral palsy
- Children between the ages of six and eighteen years of age
- Ability to ambulate and climb stairs

3.6 EXCLUSION CRITERIA

- Any child undergoing orthopedic surgery or spasticity altering procedures twelve months before or during the study trial period.
- Any child with any other condition or associated co-morbidity affecting gross motor performance.

3.7 PROCEDURE

Seventeen children met the inclusion criteria and were invited to participate in the study. Once the participants had been identified the caregivers were contacted and asked to meet in the physiotherapy department at the school with their child. A meeting was held with the participants and their caregivers, the study was explained to them in their home language via a translator who has background knowledge in physiotherapy. An information sheet was handed to each parent and consent forms were signed. The participants were also asked to sign a separate assent form to indicate that they understood and were happy to participate. Some caregivers agreed that their child may participate but on the condition that no videos would be taken of them, this was noted on their consent forms and the request was adhered to. Participants understood that they could withdraw from the study at any time and continue with their usual physiotherapy regime. Of the 17 selected participants two were excluded due to caregivers not signing consent forms or due to refusal of their child to participate.

The participants were then allocated random numbers using Microsoft Excel. These numbers became their study numbers to ensure confidentiality throughout the study. These numbers were then sorted chronologically. The group was then split into two, the top eight in group one and the rest in group two. This ensured randomization of the groups.

The participants were assessed at baseline for gross motor function using the GMFM-88 outcome measure; spasticity was assessed using the Modified Ashworth scale for spasticity. Time up and down stairs was also assessed to assess the child's level of functional mobility. All assessments were done by the researcher. All participants were assessed with out shoes for their GMFM assessment, the implications of removing orthotic boots were considered but the nature of the boots (for these participants) did not alter results of testing.

To keep the study as reliable as possible a video was taken during the assessment of a few randomly selected children (providing consent was given for that child to be videoed) and was sent to the supervisor. All initial scores and assessment sheets were filed and not referred back to until data collection at the end of the study.

Each group began the same weight-bearing program consisting of seven different exercises with three of those being repeated on the left and right sides to make a total of ten exercises (Appendix VI:); group one did the exercises with WBV (using a Power Plate®) and group two did exercises only without WBV. The Power Plate® settings were set at: 60 seconds, 35Hz and a low amplitude. These settings best activate the postural muscles (Hopson et al., 2007). Children were barefoot for all exercises regardless of group.

Exercises were static exercises in positions that either stretched lower limb muscles or targeted balance. The exercises were chosen by the researcher. If the child needed to hold on to prevent falling, this was allowed initially but they were encouraged to try and improve their balance and let go later on. Each position was held for sixty seconds and then they moved on to the next position. Group one receiving the WBV on the Power Plate®, time was programmed into the Power Plate®. Group two receiving no WBV (Power Plate® switched off), time was kept using the clock next to the Power Plate®, by the assistant. If assistance was needed to attain a position the researcher assisted this but the children were encouraged to maintain it by themselves. All exercises were supervised by the researcher or the assistant who has had training on the use of the Power Plate® as well as training in physiotherapy. The assistant was a physiotherapy assistant, currently working at the school, with training and experience in using the Power Plate®. Her role was to assist with time keeping and recording during assessments and treatment sessions. Where necessary she would assist with the treatment sessions.

3.7.1 INTERVENTION:

Exercise 1. Hamstring stretch: children were instructed to stand on the Power Plate® facing away from the column with feet apart (wide enough to fit a hand between the feet). They were encouraged to keep their knees straight while bending over to reach their toes. A therapy block was placed in front of them if they needed to put their hands on for balance. A reminder was given to keep their knees as straight as possible.

Exercise 2. Calf stretch: children were instructed to stand with one foot on the plate and the other foot in front of them on the gym step. They held onto the handlebars of the Power Plate® with their left hand for balance. The front knee was slightly bent whilst the back leg was straight. They were reminded to keep looking forwards (there was a mirror in front of them) and not to twist their hips. Most of the children needed assistance in keeping their back heel flat on the plate. The same exercise was repeated on the other side. Children chose which leg to start with.

Exercise 3. Half kneeling balance: children were instructed to get onto their knees and then lift one leg, to place their foot in front of them. It was ensured that knees and hips were at 90 degrees of flexion. Children were instructed to look forwards at themselves in the mirror. They were reminded not to let their knee fall inwards and to keep their legs up straight. Both legs were in contact with the plate (knee on one side, foot on the other). They were allowed to hold onto the handlebars for balance in the beginning but were encouraged to balance on their own. The same exercise was repeated on the other side. Children chose which leg to start with.

Exercise 4. Static Squat: with both feet on the plate, children were asked to bend their knees and keep their back straight. Their position was assisted initially but then they had to maintain it for the duration of the exercise. Both hands were holding onto the bars for support. They were encouraged to look at the mirror to maintain their posture.

Exercise 5. Bridge: children were asked to lie on their backs with their head and shoulders on a wedge which was placed on the gym step at the side of the Power Plate®. They were instructed to bend their knees and keep their feet on the plate, arms had to be crossed over their chests. Once they had obtained the correct position they were instructed to lift their buttocks and hold them up for the allocated time.

Exercise 6. Four point kneeling: children were instructed to get onto their hands and knees on the Power Plate®. Their position was checked by the therapist to ensure that hands were under shoulders and knees under hips. They were encouraged to keep their back straight and not to move their hands or knees. They were reminded to look ahead at themselves in the mirror.

Exercise 7. Four point kneeling with leg extension: children were instructed to get onto their hands and knees on the Power Plate®. Their position was check by the therapist to ensure that hands were under shoulders and knees under hips. They were encouraged to keep their back straight and not to move their hands or knees. Once they had obtained the correct position they were asked to straighten one leg and to hold it up. They were reminded to look ahead at themselves in the mirror, keep their leg straight and not to let their toes touch the ground. The same exercise was repeated on the other side. Children chose which leg to start with.

The exercises were done three times a week; Monday, Wednesday and Friday and continued for eight weeks. These sessions were in place of regular physiotherapy sessions.

All participants were re-assessed for gross motor function (GMFM), spasticity (MAS) and functional mobility (TUDS) after the eight-week period. The children went home for the holidays; on returning to school the following term (one week later) they were reassessed as before to assess for sustainability of any functional gains.

All participants were informed that regardless of their allocated group they would be allowed to exercise with the Power Plate ® once the study was completed. This was adhered to and all participants requested continuation of Power Plate ® at study completion.

All assessments were done by the researcher who was the only therapist working in the Harding area.

3.8 INSTRUMENTATION

- The Gross Motor Function Measure (GMFM) assesses the level of the participants' gross motor function systematically. The GMFM - 88 is a standardised tool used to measure the gross motor function of children with cerebral palsy over time. It has 88 different tasks assessing the gross motor function grouped into five sections: lying and rolling (seventeen tasks); sitting (twenty tasks); crawling and kneeling (fourteen tasks); standing (thirteen tasks); and walking, running and jumping (twenty four tasks) (Avery et al., 2003). It enables the examiner to have a clear understanding of the participant's possible areas of weakness. Scoring is outlined as follows: 0 (does not initiate), 1 (initiates), 2 (partially completes) and 3 (completes). The scores are added together and the final score is represented as a percentage; any small change over time can therefore be noted. The GMFM-88 has good reliability and validity for children with CP (Russell et al., 2000; Avery et al., 2003) and is a commonly used tool in research of this nature (Ahlborg et al., 2006; Eek & Beckung, 2008). It was decided to use the GMFM as it gives an outline of gross motor functional change over time and small differences can be noticed due to the sensitivity of the scoring system. Its comprehensive assessment through the dimensions of gross motor domains makes it easy to follow and administer. Extra equipment is not needed, what is found in a standard physiotherapy gym is sufficient, and therefore makes assessment in poor resourced areas possible. The GMFM was assessed with the child in the physiotherapy department of the school; equipment used was uniform for all the participants throughout the study. Both the researcher and the assistant were present for the assessments and all other distractions were minimized.

- The Modified Ashworth Scale measures the spasticity in the upper and lower limbs and is a six point scale from 0 to 4 measuring the degree of spasticity. 0, being no increase in muscle tone; 1, shows a slight increase in tone with a catch and release; 1+, indicates a slight increase in tone with a catch and minimal resistance throughout range; 2, more marked increase in tone throughout range; 3, passive movement difficult due to increase in tone, and 4, being affected limb rigid (Yam & Leung, 2006). The subject is placed in supine with the muscle to be tested relaxed; the therapist rapidly stretches the muscle; for example, bends the knee to test quadriceps. It is a subjective test but it has good reliability for hamstrings (Clopton et al., 2005; Barlow, 2008). The MAS has been used previously in research involving CP as well as other neurological conditions where spasticity is present (Mehrholz et al., 2005; Caliandro et al., 2012; Schyns et al., 2009; Murillo et al., 2011). It was chosen for this study as the MAS has also been used in similar studies (Ahlborg et al., 2006; Nardone & Schieppati, 2005; Noma et al., 2009). Participants were assessed in lying on a mat in the physiotherapy department of the school. Muscles tested were: hamstrings, quadriceps, ankle plantar flexors, ankle dorisflexors, hip abductors and hip adductors.

- Timed up and down stairs (TUDS) assesses the level of functional mobility that a child possesses. A participant is required to ascend and descend a set of fourteen stairs at their own pace and is timed from start to finish. The time taken to do this is recorded from the word ‘Go’ until both feet have stepped off of the bottom step. The participant is able to use an assistive device or hold on to the rail if necessary during the test. Ascending and descending a flight of stairs needs adequate dynamic balance, strength and coordination, the typically developing child is able to average 0.52 seconds/step (Brien & Sveistrup, 2011). This test stemmed from the timed up and go test used in elderly clients, whereby they are tested from sitting in a chair and asked to stand up, walk six meters turn around and return to the chair. The TUDS was developed for a more active group of disabled individuals but both tests measure functional mobility. It has adequate reliability and validity for use in CP (Zaino et al., 2004; Ferland et al., 2011; Gorter et al., 2009). It has been previously used to asses the effect of ankle foot orthoses (AFO) in children with hemiplegic type CP on improved functioning and weight bearing (O'Reilly et al., 2009) as well as impact of exercise on function and endurance (Gorter et al., 2009) and more recently virtual reality programs (Brien & Sveistrup, 2011). This test was chosen due to the fact that it is a quick test to administer and does not require extra equipment; it can therefore be administered in a resource poor setting. When comparing results, shorter time taken to complete the test shows an improvement in functional mobility (Gorter et al., 2009).

The TUDS was assessed at the local education department who had a set of fourteen stairs with a rail down the center. The participants were taken there on the same day by bus at each testing interval. Videos were recorded of each participants test and times were taken with a stopwatch and recorded on a score sheet.

The results of the study will be presented in the following chapter

CHAPTER 4: RESULTS

This chapter will present the results and discuss the findings obtained from the data collected in this study. The data collected was analysed with SPSS version 21.0. The results will present the data in the form of descriptive statistics in the form of graphs, cross tabulations and measures of central tendencies and variations. Inferential techniques include the use of various testing procedures and correlations which are interpreted using the p-values ($p<0.05$).

Fifteen children participated in the study nine female (60%) and six male (40%). All participants completed the full intervention. The children’s demographics will be presented first followed by their assessment results.

4.1 DEMOGRAPHICS

The range of ages tested was eight to 18 years (SD=2,6; mean=12). All participants were matched for race. There were eight right hemiplegic and seven left hemiplegic children (Table 4.1). All children had GMFCS classification of Level 1.

Table 4.1 Diagnosis by Gender

Gender	*Left Hemiplegic*	*Right Hemiplegic*
Male	5	1
Female	2	7
Total	7	8

Eight children participated in the experimental group (Group 1) with male to female ratio being equal (4:4). Seven children participated in the control group (Group 2) with the ratio of male to female 2:5.

Table 4.2 Demographics: Group 1

Study Number	*Gender*	*Age*	*Affected Side*	*Assistive Device*
133	F	18	Right	None
188	M	12	Left	None
211	M	14	Left	None
559	F	9	Left	Orthotic Boots
570	F	9	Right	None
578	M	10	Left	None
588	F	12	Right	None
619	M	11	Right	None

In Group 1, there were equal numbers of left and right hemiplegic children (4:4). Three females were right hemiplegics and one was a left hemiplegic. Three males were left hemiplegics and one was a right hemiplegic. One female wore orthotic boots. No other assistive devices were used (Table 4.2)

Table 4.3 Demographics: Group 2

Study Number	*Gender*	*Age*	*Affected Side*	*Assistive Device*
744	F	14	Right	Orthotic Boots
764	F	14	Left	None
797	M	9	Left	None
803	M	8	Left	Orthotic Boots
911	F	12	Right	None
935	F	12	Right	None
946	F	14	Right	None

In Group 2 there were four right hemiplegic and three left hemiplegic children. Four females were right hemiplegics and one was a left hemiplegic. The two males in the group were both left hemiplegics. Two children wore orthotic boots (one female, one male). There were no other assistive devices used. (Table 4.3)

4.2 GROSS MOTOR FUNCTION MEASURE (GMFM)

An assumption of normality has been met. The null hypothesis that the average for all time periods is the same was rejected. The main effect of change over time was statistically significant. It is noted that the measure of association for this analysis (using the Partial Eta-Squared) is 0.62, which indicates that approximately 62% of the total variance in the dependent variable is accounted for by the variance in the independent variable. The linear component of time is more plausible as an effect. Its significance value is <0.05, and it is also the most basic component of the simplest within-subjects effect. The rejection of the equality of the (combined) means is also shown at the end by comparisons using paired t-tests. Scores between the two groups at test one were not significantly different ($p=0.89$) (Table 4.6).

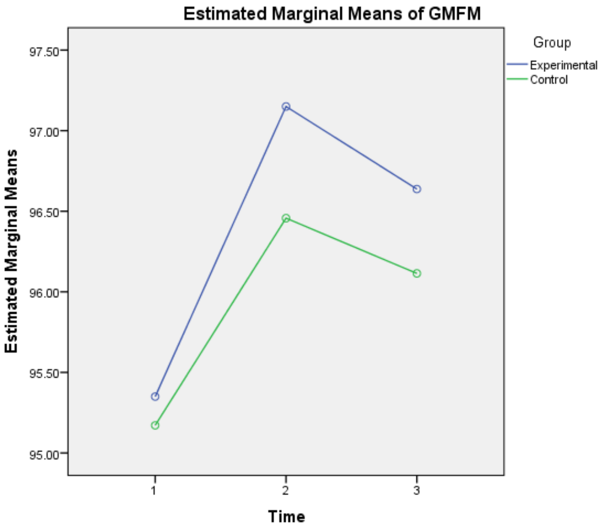


Figure 4.1 Comparison of means of GMFM over time

Figure 4.1 compares the means of GMFM values for each group over the three time periods tested. The figure indicates that the control group values are less than the experimental group for each time period. Both groups increased at time two but the experimental group increased more than the control group. The significance of the differences is tested below.

Table 4.4 GMFM Experimental Group

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Total 1 - Total 2	-1.80	1.08	0.38	-2.71	-0.89	-4.70	7	0.00
Pair 2	Total 1 - Total 3	-1.29	1.03	0.36	-2.15	-0.43	-3.54	7	0.01
Pair 3	Total 2 - Total 3	0.51	0.70	0.25	-0.07	1.10	2.07	7	0.08

Table 4.4 shows the paired samples and compares the results of the GMFM totals of the experimental group at three time frames to see if there is a significant difference between the results using paired t-tests. Total one represents baseline measurements, total two was measured at completion of intervention and total three was measured on completion of the study. The highlighted pairs indicate that the difference in the mean values is significant between total one and total two (p=0.00) and total one and total three (p=0.01). Significant differences were found between baseline measurement and completion of intervention, but no significance between completion of intervention and re-test at completion of study. The directions are given by the mean values in the table above.

Table 4.5 GMFM Control Group

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Total 1 - Total 2	-1.29	0.86	0.32	-2.08	-0.49	-3.96	6	0.01
Pair 2	Total 1 - Total 3	-0.94	1.12	0.42	-1.98	0.10	-2.22	6	0.07
Pair 3	Total 2 - Total 3	0.34	0.84	0.31	-0.43	1.12	1.09	6	0.32

Table 4.5 shows the paired samples and compares the results of the GMFM totals of the control group at three time frames to see if there is a significant difference between the results. The highlighted pairs indicate that the difference in the mean values is significant between total one and total two (p=0.01) and not significant between total one and total three (p=0.07). Between baseline measurement and post intervention testing there was a significant increase but on retesting on study completion the results were not significant. The directions are given by the mean values in the table above.

Table 4.6 ANOVA Test to compare the means between groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Total 1	Between Groups	0.12	1	0.12	0.02	0.89
	Within Groups	70.81	13	5.45		
	Total	70.93	14			
Total 2	Between Groups	1.79	1	1.79	0.41	0.53
	Within Groups	56.52	13	4.35		
	Total	58.31	14			
Total 3	Between Groups	1.02	1	1.02	0.19	0.67
	Within Groups	69.53	13	5.35		
	Total	70.55	14			

When comparing the experimental group to the control group totals over the three time periods it was found that since none of the p-values are less than 0.05, it implies that the mean values between the two groups are not significantly different. Therefore no group improved more significantly than the other.

Both groups had a significant difference between baseline and post intervention (total one and total two) individually. But when comparing the groups to each other the difference between the improvement in experiment group and control group is not significant (p=0.53). However the experimental group had significant differences between baseline and completion of the study where as the control group only had significant changes between baseline and post intervention and not carried over to the completion of the study.

The table below looks at the differences for the combined totals of GMFM, irrespective of groups.

Table 4.7 Combined experimental and control GMFM totals over time

Paired Samples Test

GMFM Totals (combined control and experimental group)		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Total 1 - Total 2	-1.56	0.99	0.25	-2.11	-1.01	-6.12	14	0.00
Pair 2	Total 1 - Total 3	-1.13	1.05	0.27	-1.71	-0.55	-4.16	14	0.00
Pair 3	Total 2 - Total 3	0.43	0.74	0.19	0.02	0.84	2.26	14	0.04

The highlighted values imply that there is a significant difference in the mean values over time (combined groups) as illustrated earlier. The most significant difference is noticed between the baseline and post intervention testing (p=0.00). Confirming the difference overall was significant.

4.3 MODIFIED ASHWORTH SCALE (MAS)

From Table 4.8 the mean scores for MAS over the three test periods can be seen.

The experimental group remained constant in plantarflexor spasticity. Dorsiflexor and quadriceps spasticity decreased from 1 in test one to 0 in tests two and three. Hamstrings spasticity remained constant for the first two test periods and then increased in test three; as did Hip flexor and Hip abductor spasticity. Hip adductor spasticity remained constant over all three periods.

The control group decreased plantarflexor spasticity from 3 in test one to 1 in test three. Dorsiflexor spasticity remained constant at 0 over all three test periods, as did the quadriceps spasticity at 1. Hamstring spasticity remained constant at test one and two and increased at test three to 2, hip abductor spasticity followed a similar pattern and increased at test three to 1. Hip flexor spasticity decreased from test one but increased again at test three. Hip adductor spasticity decreased from test one to 0 and remained constant at test three.

The only value of significance between the control and experimental groups is for quadriceps spasticity at test three (p=0.00)

Table 4.8 Mean Ashworth Scale scores for the different muscle groups.

	Test Period	Plantar-flexors	Dorsi-flexors	Ham-strings	Quad-riceps	Hip Flexors	Abductors	Adductors
Experimental	1	2	1	1	1	1	0	0
Control	1	3	0	1	1	2	0	1
Experimental	2	2	0	1	0	1	0	0
Control	2	2	0	1	1	1	0	0
Experimental	3	2	0	2	0	2	1	0
Control	3	1	0	2	1	2	1	0

Prior to comparing the two group means for the various muscles, normality tests were performed. Comparisons of the values with significant departure from normality were tested using the Mann-Whitney U-test.

Table 4.9 ANOVA results comparing the means for the two groups over three test periods for each muscle group with normal distributions.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Plantar-	Between Groups	5.67	1	5.67	3.55	0.08

flexors1*	Within Groups	20.73	13	1.60		
	Total	26.40	14			
Hamstrings*	Between Groups	0.12	1	0.20	0.22	0.65
	Within Groups	7.21	13	0.56		
	Total	7.33	14			
Quadriceps*	Between Groups	1.63	1	1.63	1.59	0.23
	Within Groups	13.30	13	1.02		
	Total	14.93	14			
Hip Flexors1*	Between Groups	0.39	1	0.39	0.26	0.62
	Within Groups	19.21	13	1.48		
	Total	19.60	14			
Hip Abductors1*	Between Groups	0.00	1	0.00	0.00	0.00
	Within Groups	0.00	13	0.00		
	Total	0.00	14			
Plantar-flexors2*	Between Groups	0.00	1	0.00	0.00	0.97
	Within Groups	11.73	13	0.90		
	Total	11.73	14			
Dorsi-Flexors2*	Between Groups	0.00	1	0.00	0.00	0.00
	Within Groups	0.00	13	0.00		
	Total	0.00	14			
Hamstrings2*	Between Groups	0.01	1	0.01	0.01	0.94
	Within Groups	21.59	13	1.66		
	Total	21.60	14			
Hip Flexors2*	Between Groups	0.34	1	0.34	0.31	0.59
	Within Groups	14.59	13	1.12		
	Total	14.93	14			
Plantar-Flexors3*	Between Groups	0.39	1	0.39	0.54	0.47
	Within Groups	9.21	13	0.71		
	Total	9.60	14			
Dorsi-Flexors3*	Between Groups	0.00	1	0.00	0.00	0.00
	Within Groups	0.00	13	0.00		
	Total	0.00	14			
Hamstrings3*	Between Groups	0.01	1	0.01	0.00	0.95
	Within Groups	14.93	13	1.15		
	Total	14.93	14			
Quadriceps3*	Between Groups	2.86	1	2.86	12.93	0.00
	Within Groups	2.88	13	0.22		
	Total	5.73	14			
Hip Flexors3*	Between Groups	0.12	1	0.12	0.10	0.75
	Within Groups	15.21	13	1.17		
	Total	15.33	14			
Abductors3*	Between Groups	0.01	1	0.01	0.01	0.91
	Within Groups	11.59	13	0.89		
	Total	11.60	14			

*1=baseline test, 2=post intervention test, 3=completion of study test

The only significant result was for quadriceps spasticity 3 (measurements taken at study completion) as the p-value (0.00) was less than the level of significance of

0.05. Therefore the Experimental Group score (0) is less than the Control Group (1). Statistically, this difference is significant as a lower score is an improvement.

Table 4.10 Results showing MAS distributions that were not normal.

Test Statistics[a]

	Dorsi-flexors1	Hip Adductors1	Quad-riceps2	Hip Abductors2	Hip Adductors2	Hip Adductors3
Mann-Whitney U	22.50	18.50	19.00	27.50	27.00	24.50
Wilcoxon W	50.50	54.50	55.00	63.50	55.00	52.50
Z	-0.82	-1.42	-1.23	-0.10	-0.14	-0.94
Asymp. Sig. (2-tailed)	0.41	0.16	0.22	0.92	0.89	0.35
Exact Sig. [2*(1-tailed Sig.)]	0.54[b]	0.28[b]	0.34[b]	0.96[b]	0.96[b]	0.69[b]

a. Grouping Variable: Group

b. Not corrected for ties.

When looking at the values that were not normally distributed it is also seen that since none of the p-values are less than the level of significance of 0,05, it implies that the scores in the control group were not significantly different from those in the experimental group.

4.4 TIME UP AND DOWN STAIRS (TUDS)

The analysis below is the comparison of the control and experimental groups over time.

The data was first tested for normality using the Kolmogorov – Smirnov Test for normality and the distribution was normal.

The figure below presents the mean times for the two groups.

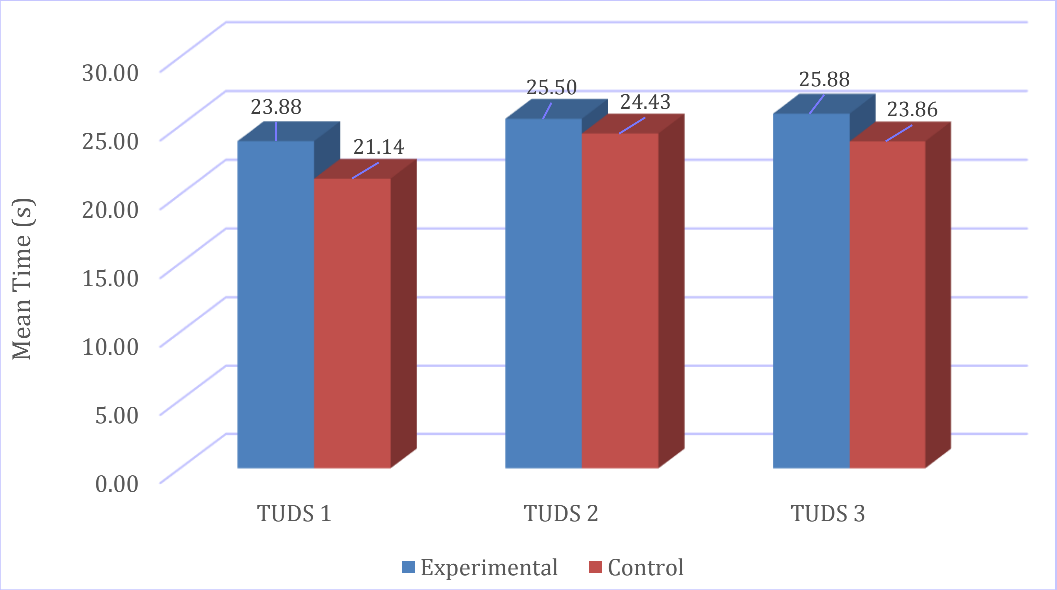


Figure 4.2 TUDS over time

It is noted that the Control group times are lower than those for the Experimental group for each time period. The control group decreasing in time from time 2 to time 3, whereas the experimental group increased post intervention.

The ANOVA test below compares the means and determines whether the differences are significant. The times were first compared to each other within the groups.

The results are presented below.

Table 4.11 Experimental Group ANOVA TUDS

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	TUDS 1 - TUDS 2	-1.63	6.39	2.26	-6.97	3.72	-0.72	7	0.50
Pair 2	TUDS 1 - TUDS 3	-2.00	6.02	2.13	-7.04	3.04	-0.94	7	0.38
Pair 3	TUDS 2 - TUDS 3	-0.38	7.11	2.51	-6.32	5.57	-0.15	7	0.89

None of the p-values are significant. The experimental group did not improve. That means that there is no significant difference in the times within the experimental group.

Table 4.12 Control Group ANOVA TUDS

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	TUDS 1 - TUDS 2	-3.29	5.77	2.18	-8.62	2.05	-1.51	6	0.18
Pair 2	TUDS 1 - TUDS 3	-2.71	3.20	1.21	-5.67	0.24	-2.24	6	0.07

Pair 3	TUDS 2 - TUDS 3	0.57	5.22	1.97	-4.26	5.40	0.29	6	0.78

The pattern is similar for the control group with no significant improvements being seen over time.

The ANOVA table below presents the comparative results for the time periods between the two groups.

Table 4.13 Experimental vs Control

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
TUDS 1	Between Groups	27.87	1	27.87	0.47	0.50
	Within Groups	767.73	13	59.06		
	Total	795.60	14			
TUDS 2	Between Groups	4.29	1	4.29	0.04	0.84
	Within Groups	1381.71	13	106.29		
	Total	1386.00	14			
TUDS 3	Between Groups	15.20	1	15.20	0.14	0.71
	Within Groups	1381.73	13	106.29		
	Total	1396.93	14			

None of the p-values are significant. Therefore when comparing the groups no group improved more significantly than the other.

CHAPTER 5: DISCUSSION

This chapter will discuss the results and compare the findings between the groups. Reference will be made to previous studies of a similar nature. Limitations as well as recommendations for future studies will be discussed.

5.1 STUDY DESIGN

This study compared the effects of two exercise programs using the same exercises but with slightly different principles regarding muscle activation. The experimental group participated in an eight-week weight bearing exercise program coupled with WBV, whilst the control group did the same exercises without WBV. This design is similar to Ahlborg et al. (2006) where adults with CP participated in eight weeks of either WBV training or resistance training.

5.2 DEMOGRAPHICS

There was a relatively even distribution of side affected with seven left hemiplegics and eight right hemiplegics. There were more females overall (9:6) which is not representative of the general hemiplegic population (1:1,7). The groups were evenly distributed according to affected side. Group 1 having equal numbers and

Group 2 had one more right hemiplegic than left hemiplegics. One child in Group 1 wore orthotic boots with a supporting iron for foot correction and two children in Group 2 wore the same boots, one with a raise on one side to correct a leg length discrepancy and the other just wore the boots. All three children's boots remained the same through out the study and none were worn during exercising.

One child was eighteen years old; all other children were between eight and fourteen. This was due to the fact that the study needed to include as many participants as possible and numbers at the site were limited. Stark et al. (2010) included participants up to the age of 24 years, as their study had a large sample size they were able to divide results above and below age ten. Ruck et al. (2010) included children six to twelve years of age, similar to Unger et al. (2013) who had children from six to thirteen years of age.

5.3 GROSS MOTOR FUNCTION MEASURE (GMFM)

There was no significant difference between the two groups at the baseline measurement (p=0.89). Overall the mean control group scores were lower when compared to experimental group for all three test periods. However the difference between the groups was not significant at test two (p=0.53) or test three (p=0.67).

When looking at the experimental group alone it was found that the most significant difference was seen between test one and test two (baseline to post intervention) (p=0.00). This difference shows that the WBV training had a positive influence on the GMFM. However the control group scores also improved significantly (p=0.01) between test one and test two. When combining the experimental and control group scores it was found that there was a significant increase in scores over all three time periods (total 1 – total 2 p=0.00; total 1 – total 3 p=0.00; total 2 – total 3 p=0.40) (Table 4.6). These finding suggest that the exercises had a positive impact on the GMFM of both groups and the improvement cannot be isolated to the WBV training. Although not significant, the results for the experiment group were still higher than the control group (Figure 4.1) and more so after the WBV training program. These findings are in keeping with Ahlborg et al. (2006) where they found their experimental group increased significantly but their control group receiving resistance training did not. Stark et al. (2010) also found in their study significant increases in GMFM post intervention. Their intervention included other therapeutic techniques so the result cannot be isolated purely to WBV.

For this study scores between baseline and study completion for the experimental group remained significant (p=0.01) whereas the control groups scores did not (p=0.68). This shows there was a carry over of function gained that remained for two weeks post intervention with WBV training in the experimental group. Unger et al. (2013) found in their study that the participants maintained their strength in the abdominals four weeks post intervention but this did not translate into maintained functional mobility.

5.4 MODIFIED ASHWORTH SCALE (MAS)

When looking at the trend it was seen that WBV training had a positive influence on the spasticity of the lower limbs in this population sample.

The DF and KE spasticity decreased between baseline and post intervention in the experimental group. PF spasticity remained constant over all while KF spasticity remained constant for the first two test periods then increased by one point. However this increase was not significant.

These findings are similar to those of Ahlborg et al. (2006), where a significant decrease in knee extensors was seen. Murillo et al. (2011) found significant decrease in MAS scores in the lower limbs during vibration in SCI patients.

In the control group the PF spasticity decreased by one point between base line and intervention and decreased further after two weeks post intervention. DF and KE spasticity remained constant over the time periods tested. This suggests that the exercises had a positive influence on the PF spasticity but did not influence any other muscle groups. These figures however are not significant. PF spasticity is one of the functionally limiting factors of CP, the increase in spasticity in this muscle group causes increased plantarflexion of the ankle and therefore reducing the surface area of the foot in contact with the ground. By reducing the spasticity in this muscle would help the foot to assume a better position for weight bearing therefore allowing more control. This could be the reason for the increased scores on the GMFM.

Mean KE spasticity reduced significantly (p=0.00) after intervention over both groups.

Despite the above findings the testing procedure of the MAS was difficult in this population due to a lack of understanding of the participants. This could have influenced the results and masked actual changes in spasticity.

5.5 TIME UP AND DOWN STAIRS (TUDS)

At baseline measurement the mean TUDS between the experimental and control groups was not significantly different (p=0.50) suggesting that the groups had similar levels of functional ability as assessed by the TUDS.

When comparing the mean times of the experimental group over the three time periods there was an increase from 23.88 seconds to 25.50 seconds from baseline testing to testing post experiment. At the third test the mean value had increased again slightly to 25.88 seconds. This shows that there was a negative effect on functional mobility from use of the WVB training and is contradictory to what was expected. Had there been an influence on functional mobility the times would have decreased. Times only increased for three children in this group but the difference was so large that it affected the overall mean of the group. The reason for this increase in time is unclear. The weather could have played a part, as it was colder at test two and three compared to baseline testing which would affect spasticity (Goldstein, 2001). These figures are not significant (p=0.50). The three children whose times increased still had improvements in GMFM scores so we know they improved in function.

The control group followed a similar pattern. At baseline testing the mean time was 21.14 seconds, which increased to 24.23 seconds post experiment. This time however also dropped two weeks post training to 23.86 seconds. As with the experiment group three children's scores increased while the others decreased, these though were large enough to affect the whole group. Again the GMFM scores of these three children improved between the three testing periods. The change seen here however is not clinically significant for this population and it was hopped that the improvement in time would have been more.

It is interesting to note though that both groups followed the same pattern. These findings are similar to those from Jelsma et al. (2013) where half of their samples scores deteriorated and the other half improved, overall the improvements were not significant. Their scores for each child vary considerably before, during and after intervention however.

A possible hypothesis is that the exercises prescribed in this study didn't target specific muscle groups needed for stair climbing. Ferland et al. (2011) found a relationship between hip flexor isometric muscle strength and ankle plantarflexor concentric muscle strength and TUDS. These two muscle groups provide 90% of the forward power needed to ascend the stairs in typically developing children, which could be possible that the same is true for children with CP (Ferland et al., 2011). These muscle groups were not exercised specifically in this study. On looking at the MAS results the hip flexor scores increased from time 1 to time 3 in the experimental group. Whereas the control group decreased from time 1 to time

2 and then increased again at time 3. There could be a possibility that the hip flexor spasticity influenced the TUDS scores.

Although Unger et al. (2013) did not use TUDS, they tested functional mobility with the 1-minute walk test and found an improvement after four weeks of trunk targeted WBV. This suggests that functional mobility should improve if the correct muscles are targeted.

TUDS is an assessment recording performance over time and does not give any information of quality of movement; therefore any improvements in movement quality cannot be recorded and accounted for. It is possible that quality of movement could have been influenced by WBV and this test was not suitable for this study. Based on these findings as well as Jelsma et al. (2013) it could be said that perhaps a 1-minute walk test used by Unger et al. (2013) would have been more appropriate.

Although every effort was taken to eliminate bias in this study it must be taken into account in the outcome of the results. The researcher administered the testing and intervention and knew the participants prior to the study.

5.6 LIMITATIONS

This study had a few limitations that were unavoidable. Firstly the sample size was one of convenience and was therefore small. Due to the rural location of the school and the specificity of the equipment it was not feasible to include another site to increase the sample size.

Due to the nature of this study it could not be seen if the functional gains were from vibration alone, of if the exercises need to be combined with vibration to be effective.

The researcher administered the assessments as well as the treatments; however every effort was taken to ensure reliability of the study by issuing study numbers and only calculating results on completion of the intervention. There was no other physiotherapist working at Harding Special School, or in the area who could assist with either the treatments or assessments. The research assistant was a physiotherapy assistant and was therefore not able to conduct treatment or assessment without supervision.

During the assessment of the Modified Ashworth for spasticity it was noticed by the researcher that the participants did not understand what was needed of them and could not fully relax their limbs for the test to be adequately administered. This may have affected the results as the test needed to be passive. The effect of testing all muscle groups in the lower limb for spasticity and the influence of the tests of the surrounding muscles was also not taken into consideration during the study.

5.7 IMPLICATIONS

This study has shown that a weight bearing exercise program results in marked increases in GMFM. Therefore exercise programs should be included in the treatment protocols of school going children with CP. Where resources are limited, group exercise activities can be introduced using the same principles making therapy cost effective.

The addition of the Power Plate® had no ill effects on function, spasticity or health of the child and the carry over was longer. This shows that it can be safely incorporated into school based therapy programs.

Exercising with the Power Plate® allows the child to exercise and strengthen muscles with no added weights or items of restriction.

5.8 RECOMMENDATIONS FOR FUTURE RESEARCH

Due to the difficulty of assessing spasticity in this population it is recommended for further researchers in this field to focus more on the functional mobility, balance and possibly range of movement and muscle strength. Alternative methods of assessing spasticity could also be used. Alternatively one muscle group could be identified to target, for example plantarflexors, and only these must be tested.

In the TUDS assessment, scores could be taken three times per testing period per child and the average of those scores used per child. These tests could either be administered over a number of days or with sufficient rest periods in between to allow for recovery and to eliminate fatigue. This should give a more holistic picture of the child’s functional mobility. Factors such as weather, effort and motivation should be accounted for.

An alternative assessment of functional mobility such as the 1-minute walk test should be considered instead of the TUDS for a more reliable reflection of the child’s functional mobility.

Further research could include other types of CP to see if similar trends apply with the use of WBV, or if one type of CP benefits more than another. Upper limb function could also be researched using similar exercise protocols that focus on upper limb strength.

A third control group could be added which receives vibration with standing alone and no exercise to further compare results.

CHAPTER 6: CONCLUSION

The aim of this experimental study was to compare the effect of an eight-week lower limb weight bearing exercise program coupled with whole body vibration on the gross motor function, functional mobility and spasticity in children with hemiplegic cerebral palsy to a control group receiving lower limb weight bearing exercises without whole body vibration.

The main findings of this study demonstrated that both the children in the control and the experimental groups showed significant improvements in the GMFM scores after the exercise program.

The children in the experimental group who received WBV while exercising showed significantly greater improvement in gross motor function from baseline to completion of the study compared to the group that did exercise alone. This demonstrated a better carry over effect in this group receiving WBV. Functional mobility (TUDS) and spasticity (MAS) scores showed less convincing results and need further investigation.

In conclusion this study confirms that the role of exercise is very important in the management of children with cerebral palsy and that the use of WBV may be a useful adjunct in the treatment of these children. Further research is required to determine the most effective and efficient way of managing children with cerebral palsy in a resource poor area.

APPENDIX I: PARENT INFORMATION SHEET

A pilot study to determine the effect of weight bearing exercises and whole body vibration on gross motor function and spasticity in children with cerebral palsy.

Dear Parent/Caregiver

My name is Amy Honour, I am the physiotherapist at Harding Special School. I am doing research on the effects that exercising on a Power Plate ® ® (a machine that vibrates and causes muscle contraction) has on a child with cerebral palsy. I want to see if it helps to decrease the spasticity of a muscle (tightness in the muscles), and to see whether it helps to improve the strength and function in these children.

Your child has been selected for this study as they have hemiplegic type cerebral palsy.

I would like to invite your child to take part in this study and request your permission to allow your child to do so. By signing the consent form below you agree to let your child participate in the study.

What is a Power Plate ® ?:

A Power Plate ® is an exercise machine that is used to stimulate a muscle contraction in the muscles that are in contact with the plate. It works by vibrating and causes a quick stretch on the muscles which then causes a contraction of that muscle. It can also be used to stretch muscles.

What is involved?:

At the beginning of the study your child will be assessed for the following:
1.Their gross motor functioning (how well they are able to perform specific tasks such as standing on one leg for 10 seconds).
2. The time it takes them to walk up and down a flight of stairs.
3. The amount of tightness in their leg muscles (spasticity)

After being assessed they will be put into a group (either 1 or 2). Group 1 will start with doing a set of 8 exercises using the Power Plate ® and continue with these exercises for 8 weeks. At the same time group 2 will be doing the same exercises but without the Power Plate ® . They will be assessed again, by this time it will be school holidays and the learners will return home. On returning to school the following term they will be assessed a third time. During one of the assessments your child may be videoed, the video will be sent to my supervisor Carolyn Humphries to check that the assessment has been carried out correctly. Once the study has been completed the video will be destroyed. Your child will remain anonymous at all times.

Risks of the study:

Your child may experience fatigue (get tired) after either one of the treatment sessions.
There are no risks of the Power Plate ® causing harm to your child, it has been tested in children and there are no adverse side effects. However your child may experience itching in the legs while exercising on the Power Plate ® , this is due to an increase in blood flow to the legs. This is not harmful and will disappear approximately 5 minutes after stopping the Power Plate ® .

Participation:

Please understand that participation in the study is voluntary and if your child wishes not to take part, his or her decision will be taken into account. Also if your child wishes to stop the study during the 8 weeks they are entitled to do so. If opting not to take part in the study or dropping out during the study your child will still receive physiotherapy as before.

If positive results are found from the study your child may continue with the Power Plate ® exercises.

Confidentiality:

All information about your child will be kept confidential. Please be aware that your child may be videoed during an assessment which will be sent to the supervisor for viewing. No other person will have access to these videos. On completion of the study all videos will be destroyed.

Thank you for taking the time to read this information. If you have any further questions or concerns please contact me at the school in person or phone on: 039 4331143 or 0729823599.

Thank you,

Amy Honour
(Physiotherapist)

APPENDIX II: CHILD INFORMATION SHEET

My name is Amy Honour, I am the physiotherapist here at Harding Special School. I would like to ask you if you would like to be part of a study. I would like to see how the Power Plate ® (a machine that vibrates and causes muscles to get stronger) can help you. I want to see if it helps the tightness of a muscle, and to see whether it helps to make you stronger.

In the beginning I will see how well you can do some tests, they show me how well you can walk up and down stairs, get from sitting to standing and balancing on one leg and a few others.

Then you will be put into a group, one group will do exercises with the Power Plate ® and the other group will do the same exercises but with out the Power Plate ® . After doing the exercises for 8 weeks I will test you again for the same things we did in the beginning. You can then go home for the holidays and when you come back to school I will test you again. You might have to be videoed while doing some of the tests but the only people who can see the video are myself and Mrs Humphries (she is helping me with my study and will check that I am doing the right tests) she wont know your name and after I have finished my study it will be destroyed.

When doing the exercises on the Power Plate ® you might feel tired and your legs might get a little bit itchy but it wont hurt you.

If you don't want to do the exercises or if you start them and after a few days or weeks don't want to carry on then you can stop and go back to your normal physiotherapy.

If you want to take part in the study then you need to sign an assent form to say that you understand and want to do it.

If you have any questions you can ask me any time. You can speak to me in the physiotherapy department or call me on 072 982 3599.

Thank you,
Amy Honour
(Physiotherapist)

APPENDIX III: CONSENT FORM

The effect of weight bearing exercises and whole body vibration on gross motor function and spasticity in children with cerebral palsy.

I ___________________have read the above information sheet and agree to let my child _________________ partake in the above-mentioned study. I understand the procedure and that the study will not harm my child. I also understand and agree that my child may be videoed for assessment purposes.

____
(Parent signature)

Date:

____
(Researcher)

APPENDIX IV: ASSENT FORM

The effect of weight bearing exercises and whole body vibration on gross motor function and spasticity in children with cerebral palsy.

I ___________________have read the above information sheet and want to partake in the study. I understand the procedure and that the study will not harm me and my questions have been answered. I understand that if I want to stop at any time I can and I can continue with my normal physiotherapy.

____
(Child signature)

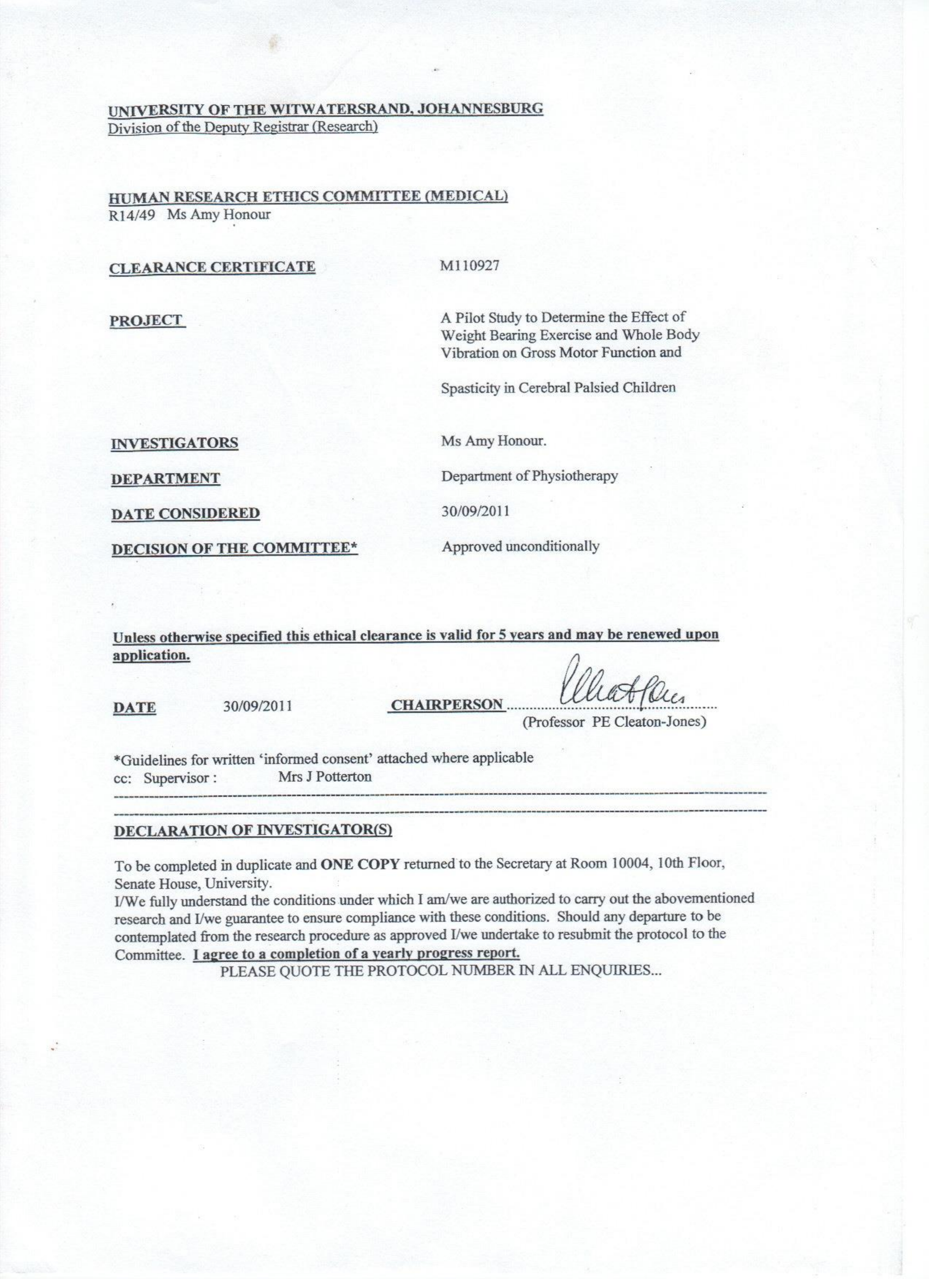
Date:

____
(Researcher)

If you have any further questions please contact me at any time on:
072 982 3599
(039)433 1143

Also you are welcome to come and speak to me in person at the physiotherapy department.

APPENDIX V: ETHICAL CLEARANCE



UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Ms Amy Honour

CLEARANCE CERTIFICATE	M110927
PROJECT	A Pilot Study to Determine the Effect of Weight Bearing Exercise and Whole Body Vibration on Gross Motor Function and Spasticity in Cerebral Palsied Children
INVESTIGATORS	Ms Amy Honour.
DEPARTMENT	Department of Physiotherapy
DATE CONSIDERED	30/09/2011
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

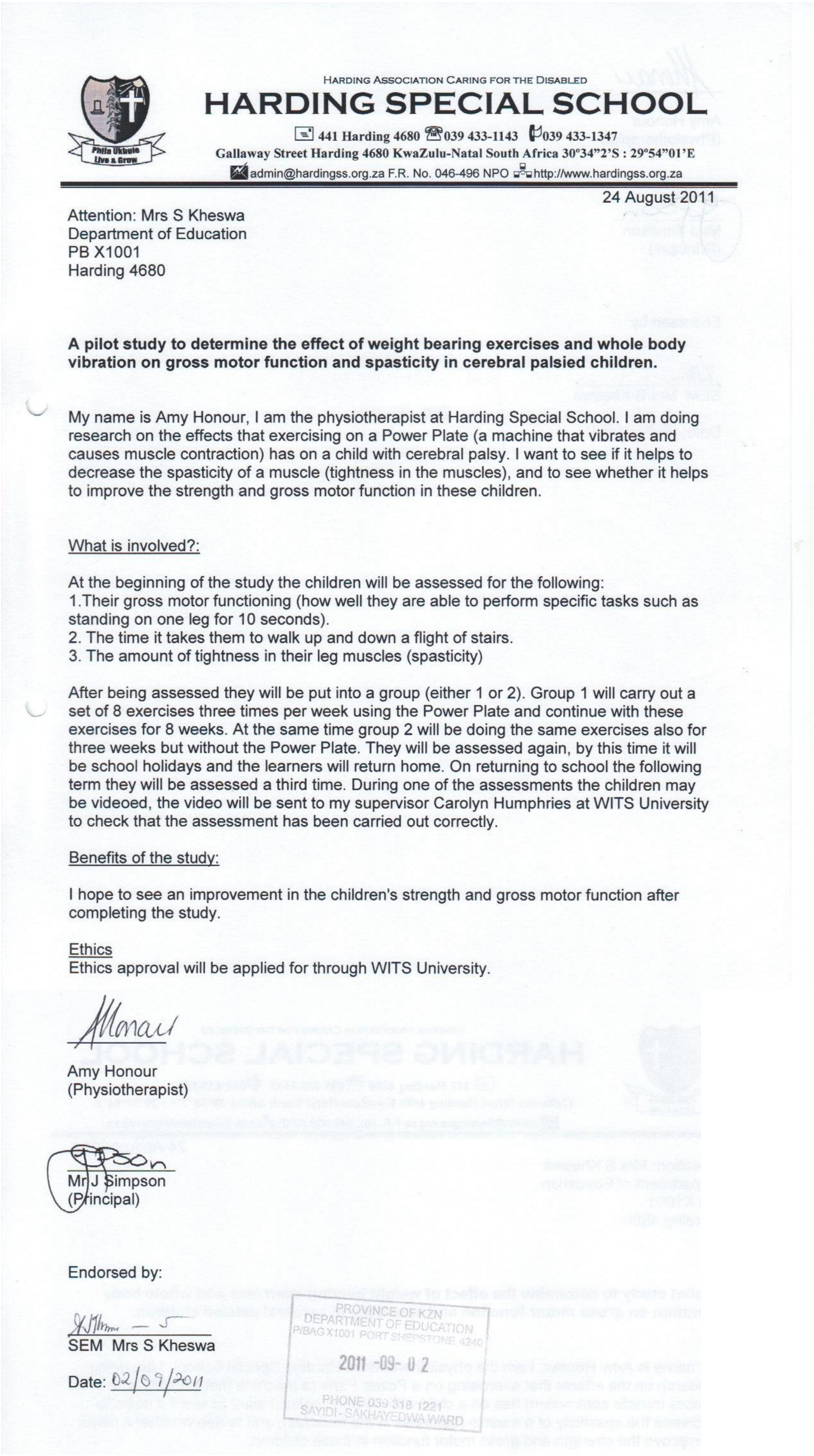
DATE 30/09/2011 **CHAIRPERSON** ....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Mrs J Potterton

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...



HARDING ASSOCIATION CARING FOR THE DISABLED
HARDING SPECIAL SCHOOL
441 Harding 4680 ☎ 039 433-1143 ℻ 039 433-1347
Gallaway Street Harding 4680 KwaZulu-Natal South Africa 30°34"2'S : 29°54"01'E
admin@hardingss.org.za F.R. No. 046-496 NPO http://www.hardingss.org.za

24 August 2011

Attention: Mrs S Kheswa
Department of Education
PB X1001
Harding 4680

A pilot study to determine the effect of weight bearing exercises and whole body vibration on gross motor function and spasticity in cerebral palsied children.

My name is Amy Honour, I am the physiotherapist at Harding Special School. I am doing research on the effects that exercising on a Power Plate (a machine that vibrates and causes muscle contraction) has on a child with cerebral palsy. I want to see if it helps to decrease the spasticity of a muscle (tightness in the muscles), and to see whether it helps to improve the strength and gross motor function in these children.

What is involved?:

At the beginning of the study the children will be assessed for the following:
1.Their gross motor functioning (how well they are able to perform specific tasks such as standing on one leg for 10 seconds).
2. The time it takes them to walk up and down a flight of stairs.
3. The amount of tightness in their leg muscles (spasticity)

After being assessed they will be put into a group (either 1 or 2). Group 1 will carry out a set of 8 exercises three times per week using the Power Plate and continue with these exercises for 8 weeks. At the same time group 2 will be doing the same exercises also for three weeks but without the Power Plate. They will be assessed again, by this time it will be school holidays and the learners will return home. On returning to school the following term they will be assessed a third time. During one of the assessments the children may be videoed, the video will be sent to my supervisor Carolyn Humphries at WITS University to check that the assessment has been carried out correctly.

Benefits of the study:

I hope to see an improvement in the children's strength and gross motor function after completing the study.

Ethics
Ethics approval will be applied for through WITS University.

AHonour
Amy Honour
(Physiotherapist)

Mr J Simpson
(Principal)

Endorsed by:

SEM Mrs S Kheswa

Date: 02/09/2011

PROVINCE OF KZN
DEPARTMENT OF EDUCATION
P/BAG X1001 PORT SHEPSTONE 4240
2011 -09- 02
PHONE 039 318 1221
SAYIDI - SAKHAYEDWA WARD

APPENDIX VI: EXERCISES

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