

THE IMPACT OF AN EIGHT-WEEK PROGRESSIVE RESISTED EXERCISE PROGRAM IN ADOLESCENTS WITH SPASTIC CEREBRAL PALSY

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APRIL 2004

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature:

Date:

ABSTRACT

Muscle weakness is a problem for many young people with spastic cerebral palsy (CP). Many studies have reported that selective strength-training programs can improve muscle strength. However, most of these studies are of single group design and do not adequately control for confounding variables.

Objective:

To determine the impact of a comprehensive strength training program targeting multiple muscle groups on adolescents with CP, using basic inexpensive free weights and resistance devices.

Method:

A randomised clinical trial evaluated the effects of an eight-week strength-training program on 31 independently ambulant adolescents with spastic CP, with or without walking aids, from Eros School (19 males, 12 females; mean age 16 years 1 month; range 13 – 18 years). The Kin-Com dynamometer, 3-D gait analysis, the Economy of Movement test and a questionnaire was used to evaluate selected muscle strength, the degree of crouch gait, free walking velocity and stride length, energy consumption during walking and perceptions of body image and functional competence. Twenty one subjects took part in the strength-training program and were compared with 10 control subjects. Results were analysed using repeated measures ANOVA and bootstrap analysis.

Results:

Compared with the control, significant improvement in the degree of crouch as measured by the sum of the ankle, knee and hip angles at midstance ($p=0.05$) and perceptions of body image ($p=0.01$) were noted for the experimental group. Significant trends were also noted for isometric knee extension muscle strength at 30° as well as for hip abduction at 10° and 20° . Walking efficiency, -velocity and stride length remained unchanged as well as perceptions of functional ability.

Conclusion:

A strength-training program targeting multiple muscle groups including upper and lower limbs as well as the trunk, can lead to changes in muscle strength and improve the degree of crouch gait with improved perception of body image. Successful participation in such a program at school may motivate children with CP to continue with home-based basic strength training. Strength training alone did not decrease oxygen consumption during walking and inclusion of aerobic exercise is recommended.

ABSTRAK

Spierswakheid is 'n probleem vir baie jong mense met serebrale verlamming (SV). Navorsing het getoon dat selektiewe versterkende oefenprogramme selektiewe spiere kan versterk, maar die meeste studies bestaan uit 'n enkel groep met onvoldoende beheer oor verstrengelde veranderlikes.

Doel:

Om die impak van 'n omvattende versterkende oefenprogram met basiese, goedkoop gewigte en weerstandsapparaat wat vele spiergroepe teiken, op adolessente met spastiese SV te evalueer.

Metodologie:

Die effekte van 'n agt weke lang versterkende oefenprogram is op 31 onafhanklik mobiel adolessente met spastiese SV, met of sonder loophulpmiddel, van Eros Skool deur middel van 'n ewekansige kliniese proef geëvalueer (19 manlike, 12 vroulike deelnemers; gemiddelde ouderdom 16 jaar 1 maand; omvang 13 – 18 jaar). Die Kin-Com dinamometer, "3-D gait analysis", die "Economy of Movement" toets en 'n vraelys is gebruik om geselekteerde spiersterkte, die hoeveelheid knie fleksie gesien in die onderste ledemaat tydens loop, loopspoed en treelengte, energieverbruik tydens loop asook persepsies van liggaamsbeeld en funksionele vermoë te evalueer. Een en twintig het in die versterkende oefenprogram deelgeneem en is met 10 kontrole deelnemers vergelyk. Resultate is met behulp van herhaalde metings "ANOVA" en "bootstrap analysis" geanaliseer.

Resultate:

In vergelyking met die kontrole groep, het die eksperimentele groep betekenisvolle verbetering getoon in die hoeveelheid fleksie gesien in die onderste ledemaat ($p=0.05$) soos bereken deur die som van die enkel-, knie- en heuphoek in midstaan fase tydens loop, asook in liggaamspersepsie ($p=0.01$). Beduidenisvolle tendense is ook gesien by die eksperimentele groep vir isometriese knie ekstensie spiersterkte by 30° asook vir heup abduksie by 10° en 20° . Energieverbruik tydens loop asook loopspoed en treelengte was onveranderd asook persepsie van funksionele vermoë.

Gevolgtrekking:

'n Versterkende oefenprogram wat verskeie spiergroepe teiken, insluitende die onderste en boonste ledemate asook die romp, kan lei tot 'n verbetering in spiersterkte, minder fleksie in die onderste ledemate tydens loop asook 'n verbetering in liggaamspersepsie. Suksesvolle deelname aan so 'n program op skool, mag kinders dalk motiveer om 'n basiese versterkende oefenprogram tuis voort te sit. Versterkende oefening alleen het geen vermindering in suurstofverbruik tydens loop veroorsaak en die insluit van aerobiese oefening word aanbeveel.

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ADDENDA

A: INFORMATION AND INFORMED CONSENT DOCUMENT

(English and Afrikaans)

B: DECLARATION BY THE CHILD (English and Afrikaans)

**C: QUESTIONNAIRE: PERCEPTIONS OF PHYSICAL APPEARANCE AND
FUNCTIONAL COMPETENCE (English and Afrikaans)**

D: SUBJECT'S PARTICIPATION RECORD

E: LETTER OF CONSENT FROM THE DEPARTMENT OF EDUCATION

CHAPTER 1

INTRODUCTION

Cerebral palsy (CP) is one of the neurological conditions most frequently encountered by pediatric physiotherapists (Olney and Wright, 2000). It is a complex condition with huge variation in clinical presentation and management options. The training background of the physiotherapist, the availability of services and facilities, the financial resources and the needs and beliefs of the child and his family are diverse and complicate decision-making regarding intervention and management strategies.

1.1 DEFINITION AND CHARACTERISTICS OF CP

Cerebral palsy is caused by a non-progressive defect or lesion in single or multiple locations in the immature brain that results predominantly in a motor dysfunction. The primary physical impairments that occur due to this pathophysiological damage include insufficient force generation (muscle weakness), spasticity, abnormal range of movement and exaggerated or hyperactive reflexes (Kwagel, 2000). These lead to decreased selective control of muscle activity, poor regulation of posture and body movement and decreased ability to learn selective movements. Sensory deficits such as mental retardation or learning disabilities, speech, auditory and vision impairments as well as seizures may also occur (Olney and Wright, 2000).

Clinical observation has shown that secondary impairments of the musculo-skeletal system occurs due to poor motor control and include orthopaedic complications such as malalignments in the skeletal system, joint dislocations, leg-length discrepancy and progressive musculo-tendon contractures, pain and arthritis. This is supported by Gajdosik and Cicerello (2001) in their literature review of the musculo-skeletal system in adolescents and adults with CP. The functional problems and challenges experienced by persons with CP due to these impairments may include difficulty with walking, running, negotiating steps, navigating safely over uneven terrain, propelling wheelchairs and performing activities of daily living (ADL). Furthermore, Gajdosik and Cicerello (2001) stated that community acceptance is poor world-wide and many persons with CP tend to

become isolated. These authors also stated also stated that unemployment and discrimination against people with disabilities is high.

1.2 MANAGEMENT OF CHILDREN WITH CP

The management of children with this complex diagnosis involves a multi-disciplinary team approach. Depending on the needs of the child this team usually consists of one or more specialist medical practitioners, rehabilitation therapists such as physiotherapists, speech therapists and occupational therapists, psychologists, nurses and caregivers.

Physiotherapists focus on facilitation of postural control, promoting more normal movement patterns and facilitating independence. Occupational therapists address integration, spatial and perceptual difficulties that affect reading, writing and learning. In the older child occupational therapists are involved with prevocational testing and training. Speech therapists manage hearing and communication impairments, speech, language and feeding difficulties. Psychologists deal with problems ranging from poor self-image to serious behaviour problems. They are responsible for psychometric testing, guidance counselling, psychotherapy and psychometric testing. Orthopaedic surgery is often indicated to lengthen muscles and improve postural alignment. Neurosurgical interventions such as selective dorsal rhizotomies, intracathetal Baclofen pumps and Botulinum toxin injections may be indicated to reduce spasticity.

Assistive devices such as orthotics, walking aids, head pointers and specialised computer equipment are used to optimise posture and function. Additional structural adaptations to accommodate wheelchairs such as ramps, wider doors and adapted bathrooms in both the person's home, at school as well as in public buildings and amenities may be needed. Aides to assist with activities of daily living (ADL) may also be necessary.

It is unknown how many of the children with disabilities, including CP attend school in South Africa (Education WHITE PAPER 6, 2001). There are special schools which cater for these children's special needs. A school nurse and doctor provide medical care. Usually physiotherapy, occupational therapy and speech therapy services are available as well as remedial teaching for those with learning problems. Classes tend to be small to

allow for more individual attention. School timetables accommodate these therapy and remedial sessions. Several other strategies are in place to make allowances for and accommodate these children's special needs, for example a scribe is provided for the child who is unable to write, or who types too slowly. Specialist medical clinics (neurology and orthopaedic clinics) are held at the schools regularly and are usually serviced by doctors from the nearest academic or government hospitals.

1.2.1 Special schools versus mainstream schooling

In 1994, the Salamanca Declaration was adopted at the World Conference on Special Needs Education in Spain (The Salamanca Declaration, 1994). This declaration is a statement on principles, policy and practice in special needs education and states that "...those with special education needs must have access to regular schools which should accommodate them within a child-centered pedagogy capable of meeting these needs..." (p1). Internationally the trend has been to mainstream children with CP and provide all the assistance they require within the mainstream school (Effgen, 2000). Therapy and other rehabilitation services are provided for by community based therapists who visit the schools regularly on a consultancy basis and provide treatment either at home or at the nearest medical centre (Murphy *et al*, 1995). However, children who are mentally challenged and are therefore unable to cope with the demands of an academic syllabus do still attend special training centres where less emphasis is placed on academic work and more on developing trade and life skills.

In South Africa, contrary to the international trend, the Education WHITE PAPER 6 (2001), a guideline for special needs education which forms part of the National Education Policy Act, states in the forward by the Professor K Asmal¹, that special schools "...will be strengthened rather than abolished." (p3), According to this document only 20% of learners with disabilities are being accommodated in about 380 special schools. The government's intention is to equip special schools with expertise which will then serve as a resource centre and support service for all children and adults with physical as well as other disabilities. Minimally physically disabled learners

¹ Professor Kader Asmal, Minister of Education

who are capable of coping with the current academic syllabus are encouraged to attend mainstream schools.

Since 2000 the enrolment profile has changed slightly with more children with learning disabilities being admitted to special schools which previously only accommodated children with physical disabilities. Many of these children however, exhibit subtle underlying motor difficulties (Miyahara, 1994) and could benefit from occupational therapy and physiotherapy. The redistribution and rationalisation of Government funding has resulted in posts for therapists at the special schools being reduced. Eros School in Athlone for example, is a school situated in a lower socio-economic neighbourhood and caters for learners from pre-school to grade 12. It enrolled 300 learners in 2003. Approximately 80% of these learners are physically disabled and require individual physiotherapy (PT). According to the school's records, the posts for therapists have dropped from 25 (of which ten are PT posts) in 1996 to 13 (six PT posts) therapists in 2003. Physiotherapy at this school is now targeted at the younger, growing child and the older high school learners are no longer considered to be a treatment priority.

1.2.2 Transition to adulthood

Although CP is a non-progressive neurological disorder (Olney and Wright, 2000), further secondary complications occur as children enter adolescence. This is often due to increased body weight and adipose tissue without similar increases in muscle strength. These complications may result in pain as well as in spinal and joint deformities and degenerative arthritis in weight bearing joints, which may lead to increasing activity limitations. Although prediction of lifetime functional outcomes in CP is uncertain, studies that have investigated functional abilities in adult CPs have reported a progressive decline in function, particularly in ambulatory ability (Murphy *et al*, 1995; Johnson *et al*, 1997; Andersson and Mattsson, 2001).

Once CP children have left Eros school at 19 or 20 years of age, almost none of them have the socio-economic means to obtain physiotherapy services. Those who do contribute to a medical aid are limited to approximately six to eight physiotherapy or occupational therapy sessions per year (Metropolitan Health Plan, 2004; Discovery

Health Plan, 2003). Day Hospitals and Community Health Centres have very limited facilities, physical space and experienced therapists to offer treatment to this group (Merryweather², 2002). This decline in access to rehabilitation services once these children have left the domain of paediatric and school services appears to be an international problem. Two surveys conducted in the United Kingdom, one by Stevenson *et al* (1997) and another by Fiorentino *et al* (1998), confirm this observation particularly for children with CP, unless they had a "...statement of special education need" (Fiorentino *et al*, 1998, p 308). Therefore only the more severely disabled child is likely to be followed up by adult medical services. A survey by Murphy *et al* (1995) in the United States of America found medical rehabilitation care for adults with CP "...at best to be inconsistent" (p 1082).

Empowering people with disabilities entails facilitating them to take on more responsibility for their own rehabilitation and maintenance of function. Much research in the field of CP is aimed at investigating interventions to optimise therapy and reducing the incidence and severity of secondary impairments. Some of these interventions may be implemented and conducted by adolescent children and adults with CP in their own homes and communities. A survey conducted in Norway, where 46% of the respondents were adults with CP found that those who continued with physical activity were able to significantly prevent deterioration (Jahnsen *et al*, 2003) in function.

1.2.3 Physiotherapy management of CP

There are many approaches to the treatment and rehabilitation of children with CP. According to De Groot *et al* (2000) these include the following neurophysiological approaches:

- neurodevelopmental therapy (NDT) developed by Bobath, which places emphasis mainly on interventions that normalise postural control and include reflex inhibition and facilitation techniques;
- the Vojta Concept which uses reflexology to normalise posture control; and

² Geoff Merryweather. CEO – Western Cape Cerebral Palsy Association

- the Doman-Delacato Method which is an intensive 14 hour rigid therapy regime involving parents and many volunteers and involves passive movements or patterning performed by up to five individuals in the child's home environment.

Other approaches to the treatment and rehabilitation of children with CP include:

- the Peto method, a form of conductive education which aims to activate the resting capacity of the brain by integrating all forms of therapy given by one individual, the conductor. The child has to initiate all activity itself instead of waiting passively for the therapist or caregiver; and
- the mechanical approach by Phelps, which involves performing movement patterns passively by the therapist.

Neurodevelopmental therapy is probably the most widely used form of therapy and therapists trained in NDT aim to achieve independent function by identifying missing components of normal movement and addressing the problems these create. One such component is muscle weakness. Clinical observations indicate that muscle weakness co-exists with spasticity in children with CP. There is debate in the literature however regarding the contribution of weakness to the motor dysfunction. Damiano *et al* (1995a) states that muscle weakness is a concurrent problem and not a primary cause for the motor dysfunction seen in children with spastic CP, whereas Rose and McGill (1998) have stated that the predominant impairment in CP is muscle weakness and not spasticity. Albeit that the identification and measurement of spasticity remains controversial, Ross and Engsborg (2002) also found muscle weakness to be a consistent finding when evaluating children with CP and that spasticity was not always present in all individuals with CP. Brown *et al* (1991) in their study with hemiplegic children also found weakness to be a predominant finding that can occur without spasticity.

1.3 STRENGTH TRAINING IN CP

According to Bobath (1980), traditional strengthening exercises should be discouraged because excessive effort could increase co-contraction, spasticity and associated reactions. In 1980, Lance defined spasticity as

“a motor disorder characterised by a velocity-dependant increase in tonic stretch reflexes (‘muscle tone’) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex, as one component of upper motor neuron syndrome.” (p7)

However, theoretical concepts have evolved since the 80’s which better explain analysis of spasticity, movement and motor control. Young (1994) has expanded on this definition of spasticity to include more detail regarding the pathophysiology of the enhanced stretch reflex. There are several mechanisms involved, including pyramidal tracts and descending inhibitory pathway mechanisms as well as spinal segmental mechanisms. These result in hypertonia (increased tone), clonus, clasp-knife phenomena, flexor and extensor spasms, cocontraction and flexor withdrawal reflexes. Hypertonia results in biomechanical changes such as reduced range and speed of movement. These secondary soft tissue changes contribute significantly to the clinical picture. Sheean (1998) states that these mechanisms should be seen independently and respond differently to treatment.

Muscle strengthening techniques are routinely prescribed for orthopaedic disorders in order to build muscle strength and increase range of movement, increase force production or improve muscle imbalance around a joint. Increased strength however, is not beneficial to the individual unless it translates into improved function or is able to prevent secondary complications. Damiano and Abel (1996; 1998) have shown that following selective strength training improvements were recorded by gait analysis (GA). These changes also correlated with changes in function as measured by the Gross Motor Function Measure (GMFM). Studies have also shown that gains in strength and improvement in gait do occur in muscles with increased tone following isotonic and isokinetic strength training programs and without apparent increase in spasticity (Damiano *et al*, 1995a; MacPhail and Kramer, 1995; Darrah *et al*, 1997; Damiano and Abel, 1998). Furthermore, Fowler *et al* (2001) showed that a single session of exercise with maximum effort does not increase spasticity. Yet, despite these findings, the perception is that many therapists remain reluctant to use progressive resisted exercises as part of their management of these children (Fowler *et al*, 2001; Damiano *et al*, 2002), even though others in the physical education community and biokineticists have promoted strength training in CP and other neuromuscular diseases (Bar-Or, 1976; McCubbin and Shasby, 1985)

Studies into the effect of strength training in children with CP have primarily focussed on strength training of selected muscles in the lower limb only (Damiano *et al*, 2002; Dodd *et al*, 2002). Gait analysis has been used to assess changes in function following strength training. However, according to the principle of specificity (McArdle *et al*, 1996) and due to the crucial role of the trunk muscles as stabilisers in normal gait (Kendal and McCreary, 1993), it could be suggested that inclusion of trunk muscles, which are predominantly weak in these children (Olney and Wright, 2000), may result in further improved function. Strengthening exercises in the studies by Damiano *et al* (1995b) and MacPhail and Kramer (1995) did not include the trunk and or the upper limbs.

The effect of an individually designed comprehensive strength training program, also targeting the upper limb and trunk muscles, has not yet been investigated in children with CP. However a recent study by Andersson *et al* (2003) in adults with CP has shown that such a training program does result in improvements in muscle strength, walking velocity and gross motor function.

Another aspect that has been poorly documented in the above studies is the impact that strength training has on self-image and perception of physical appearance and perceived functional competence. A study by Darrah *et al* (1999) noted a dramatic change in perceptions of physical appearance in the adolescent CP following participation in a community fitness program. Feeling better about ones' personal appearance has important implications for personal growth and competence (Laszlo and Bairstow, 1985). Additional benefits that may result from improved self-image and confidence are compliance and motivation to continue with basic strengthening exercises.

Comprehensive weight training using basic equipment could be an effective means to promote well-being as well as a suitable therapeutic self-help option to maintain muscle strength and functional ability in people with CP. The following chapter will provide a review of the literature regarding the classification of cerebral palsy, the physiology of the spastic muscle, the physiology of resistance or weight training and the principles and implications for implementation in this population. The use of outcome measures to determine change in muscle strength, function and walking efficiency as well as self-perception will also be discussed. An overview of the current research done in the field of strength training in cerebral palsy is included.

CHAPTER 2

LITERATURE REVIEW

An internet search using MEDLINE, PubMed, CINAHL, Cochrane, PEDro and Science Direct databases produced vast amounts of literature pertaining to cerebral palsy, including incidence and classification, impairments and secondary complications, functional status and the management of children with cerebral palsy (CP). More recent articles are beginning to investigate participation at community and social level as well as investigating the adult CP population. The field of sport research, particularly relating to strength training, is enormous and therefore background information and critical analysis of the literature relating to strength training in the CP population has been included.

2.1 DEFINITION AND CLASSIFICATION OF CEREBRAL PALSY

Cerebral palsy, also defined as cerebral motor dysfunction, is a non-specific term given to a whole collection of signs and symptoms caused by a lesion or lesions to any part or parts of the immature brain.

Cerebral palsy is generally classified according to the area of body exhibiting impairment. One classification (Bobath and Bobath, 1982) includes diplegia, involving primarily the lower limbs and hemiplegia involving upper and lower limb on one side of the body. These are the most common forms accounting for approximately 75%. Other forms include quadriplegia, involving all four limbs, monoplegia involving one limb and triplegia involving three limbs (Olney and Wright, 2000).

Another classification, used in association with the above is based on the most obvious movement abnormality and describes spastic, dyskinetic and ataxic types (Olney and Wright, 2000). With spasticity, muscles are perceived as stiff especially during attempted movement. The dyskinetic type or athetosis, varying muscle tone in the extremities or trunk result in involuntary movement patterns. Ataxia is characterised by incoordination of movement. Hypotonia or decreased resting muscle tone results in decreased ability to

generate voluntary muscle force. Mixed symptoms can also occur (Olney and Wright, 2000)

Diagnosing CP is complicated and the accuracy is weak before the age of five (Kitchen *et al*, 1987) as the clinical outcome or prognosis is considered to be dependant on many factors. These include the handling by caregivers, early therapeutic intervention, nutrition and socio-economic circumstances as well as level of intelligence of the child (Long and Cintas, 1995; Bartlett and Palisano, 2000). Diagnosing the older child sometimes leads to debate among professionals especially with mixed diagnostic types of CP and when subtle signs of involvement in supposedly unaffected limbs are observed (Olney and Wright, 2000). Hemiplegics might display subtle signs of increased tone in the unaffected side and the diplegic may show some upper limb involvement. This may be directly related to the lesion or due to lack of development through lack of movement experience. The therapeutic approach and management of these children should thus not be dependent on their diagnosis but rather on a thorough description of all the signs and symptoms observed.

The degree of severity varies greatly amongst persons with CP. Generally the designations mild, moderate and severe are used to clinically distinguish severity in motor dysfunction. The Gross Motor Disability Classification System (Palisano *et al* 1997) for example is a five-level, age-categorised system used for children with CP. Using knee angle at heel strike during gait has also been used to classify severity by Damiano *et al* (1995a, 1995b) and Hoffinger *et al* (1993). This classification however is limited to the severity of crouch during walking and is not indicative of functional disability. The use of different severity classification systems makes comparison between research studies difficult and limits the generalisability to the CP population. Most of the classification systems used do not represent participation at community and social level. Although not a classification system for CP alone, a more appropriate system advocated by the World Health Organisation may be the International Classification of Functioning, Disability and Health (ICF) (WHO, 2001). The ICF does not classify people but describes the situation of each person within an array of health or health related domains, within the context of environmental and personal factors.

2.2 ETIOLOGY

The causes of the damage are multiple and the mechanism of insult to the brain is not always understood. The literature suggests that the majority of cases of CP in full term infants are due to prenatal or unknown causes (Styer-Acevedo, 1994; Olney and Wright, 2000). Prenatal, perinatal and postnatal factors have been associated with CP. Prenatal factors include maternal malnutrition and infections such as rubella, exposure to radiation and drug ingestion. Perinatal factors include neonatal asphyxia, intracranial haemorrhage, which is common among premature infants, hyper-bilirubinemia and other blood incompatibilities and postnatal factors include physical abuse and trauma to the head (Olney and Wright, 2000).

2.3 PREVALENCE OF CP

According to the Western Cape Cerebral Palsy Association (WCCPA), the incidence of CP in South Africa is unknown. However a prevalence of 2.5 per 1000 live births is still accepted as being the international norm (Merryweather, 2002).

Olney and Wright (2000) have stated that the incidence of CP in developing countries is higher than in developed countries. Although in First World countries the improved survival rate of low birth weight infants was thought to have increased the incidence of children with neurodevelopmental impairments, a cohort study by O'Shea *et al* (1998) in the United States of America showed no increase in the prevalence of CP. These researchers studied 2076 infants with birth weights of 500 – 1500g between 1982 and 1994. Aylward (2002) stated in his review of cognitive and neurophysiological outcomes in preterm infants that although the incidence of major disabilities including CP has remained unchanged with improved survival in these infants, there is an increase in the prevalence of low severity dysfunction including learning disabilities (LD) and attention deficit and hyperactivity disorder (ADHD). However Miyahara (1994) suggested that children with LD and ADHD have subtle underlying motor dysfunction.

2.4 CLINICAL PRESENTATION

Children with cerebral palsy present with a wide variety of impairments including physical and sensory deficits. Primary impairments include spasticity, decreased force generation, abnormal hypo- or hyperextensibility of muscles and hyperactive reflexes. Secondary impairments include malalignment, early degenerative osteoarthritis, contractures and pain. Occurrence and severity of these impairments as well as environmental and socio-economic factors influence clinical appearance and prognosis of CP. Functional limitations and disabilities including reduced speed and accuracy of execution of movement in minimally affected individuals to total dependency in severely affected individuals exist (Olney and Wright, 2000).

For the purpose of the present study only the physical impairments of spasticity and muscle weakness and the impact of these on function and activity will be discussed in more detail. A brief discussion of the sensory impairments is also given.

2.4.1 Physical impairments

The cerebral lesion results in spasticity, hyperactive reflexes and decreased force generation. Ross and Engsborg (2002) hypothesised that no relationship exists between spasticity and strength within a single muscle or at opposing muscle groups in individuals with CP. They measured the strength of the ankle plantarflexors and dorsiflexors as well as the knee flexors and extensors, with a KinCom isokinetic dynamometer immediately following the passive spasticity test, which was conducted at 10°, 30°, 60°, 90° and 120°/s. They found no correlation between spasticity and muscle strength within either the same group or at opposing muscle groups and concluded that a spastic muscle is not a strong muscle and that spasticity does not cause weakness in the opposing muscle group. However, these researchers did not conduct electromyography (EMG) to assess muscle activity during passive movement. The researchers found no muscle imbalances in the flexors and extensors at the knee or consistent imbalances at the ankle. They did find though that individuals with spastic diplegia were more involved distally, displaying greater spasticity and less strength in muscles around the ankle as compared with the muscles around the knee.

Wiley and Damiano (1998) conducted a descriptive study in children with spastic CP and normal controls to determine lower extremity strength profiles using handheld dynamometers. They found that children with diplegia are weaker in all the muscles tested than their age matched peers, as were the children with hemiplegia. Weakness also existed in the uninvolved side of hemiplegics. Weakness was more pronounced distally in both groups and hip flexors and ankle plantar flexors tended to be relatively stronger than their antagonists, resulting in muscle imbalance across those joints. These findings confirm similar results found by Brown *et al* (1991) in their investigation of the neurophysiology of lower limb function in hemiplegic children.

Increased tone in the muscles offers resistance to passive stretching resulting in reduced range of movement. However, muscles may also become hyperextensible or over-lengthened due to repeated mechanical stretch with resultant decreased force-generating capability. Secondary impairments resulting from the above may include contracture formation, subluxation and dislocation as well as bony and alignment abnormalities such as femoral neck anteversion and femoral and tibial torsion. Pain and early degenerative changes due to abnormal compression forces in weight bearing joints exacerbate these secondary complications (Long and Cintas, 1995).

2.4.2 Functional and activity limitations

The primary and secondary impairments outlined above, impact mainly on gait and gross motor function of the individual.

2.4.2.1 GAIT

Not all children with CP are able to learn to walk, however all children with unilateral hemiplegia can be expected to walk (Brown *et al*, 1991). Most diplegics are able to walk but sometimes require assistive devices such as crutches and backward or forward walkers (Steinwender *et al*, 2001). Ambulant children with spastic diplegia or hemiplegia each have their own typical pattern of gait:

Spastic diplegic gait: these children usually display an asymmetric crouch gait, where the hips and knees are generally flexed and have reduced range of movement (ROM) with resultant decreased power generation in the hip extensors. The ankles may show a variety of deformities such as equinus or calcaneus, with very poor plantar- and dorsiflexion power. The hips are often internally rotated and give the impression of being adducted as can be observed during scissoring gait (Steinwender *et al*, 2001). Gait analysis by Johnson *et al* (1997) in a longitudinal study of 18 subjects with spastic diplegia, between four and 14 years old showed slower free and fast walking velocities and cadence, shortened stride length, increased double support and decreased single support, compared to their normal peers. They also reported that ambulatory ability tends to worsen over time in spastic cerebral palsy.

Spastic hemiplegic gait: according to Steinwender *et al* (2001) these children usually display poor hip extension in the involved lower limb and the knee remains slightly flexed or tends to snap into extension or hyperextension. Clinical observation has shown that the foot often has a persistent equinus. The most obvious abnormality on observation is lateral rotation of the leg and circumduction at the hip with loss of knee extension in the swing phase. Trendellenburg, a lateral tilt of the pelvis due to weak hip abductors may be observed with weight bearing on the involved side. The foot rarely shows good heel strike. Gait analysis of the hemiplegic gait conducted by Brown *et al* (1991) showed more normal walking velocities and cadence compared with the diplegic gait. Double support time was often increased compared to their normal peers and step length on the involved side was usually reduced compared to the uninvolved side.

Malalignments in both groups are particularly evident around the knee joints and result in increased effort during weight bearing as well as upward and forward propulsion. According to Steinwender *et al* (2001), other than the semi-flexed knee, the following may also occur:

- jump knee, where the knee snaps into extension during the stance phase due to impaired motor control,

- stiff knee, seen where spasticity results in co-contraction of the agonist and antagonist as well as
- recurvatum knee, or hyperextended knee.

Positions of the foot also impact on weight bearing and forward propulsion during gait (Donatelli, 1996). Typical deformities that prohibit the muscles from achieving an effective length for generating plantar flexion and toe-off force, seen in children with spastic CP include:

- equinus foot, a plantar flexion deformity usually due to shortened tendon achilles (TA) and triceps surae and may be accompanied by excessive eversion or pronation (equinovalgus) or inversion or supination (equinovarus)
- calcaneous foot, a dorsiflexion deformity
- pes cavus or high medial foot arch
- pes valgus or rocker bottom foot
- and hallux valgus may also occur

Abnormal movement patterns seen in the lower extremities of both the hemiplegic and diplegic gait, result in compensatory abnormal movement in the trunk and upper limbs. Often excessive side flexion and reduced trunk rotation with corresponding decreased arm swing can be observed (Levitt, 1991). The anterior pelvic tilt seen in the diplegic gait as well as on the involved side of the hemiplegic gait, inhibits contraction of the abdominal stabilisers, may result in excessive rotation at the pelvis (Norkin and Levange, 1992) as well as exaggerated arm movements (Levitt, 1991).

2.4.2.2 GROSS MOTOR FUNCTION

Not only is gait affected by the physical impairments but limitations regarding activities of daily living such as feeding, toileting and dressing also occur in individuals with impaired motor control and decreased selective movement. Furthermore, the ability to use public transport, participate in normal play and sport are all affected by the above impairments (Rosenbaum *et al*, 1990).

According to the definitions in the ICF (WHO, 2001), the functional limitations experienced by persons with CP may limit their potential to participate as productive members of society. Accessibility barriers and discrimination which occur due to poor communication exacerbate the problem (Gajdosik and Cicerello, 2001). The functional limitations necessitate adaptations to the person's home, work and community environment (Olney and Wright, 2000) and include structural adaptations such as ramps, wider doors, lowering washbasins and installation of lifts or hoists to accommodate wheelchairs. Handrails, special seating adaptations, such as inserts and specialised communication devices may be indicated (Styer-Acevedo, 1994). The equipment and adaptations needed to promote independence and quality of life are expensive. Existing schools, shopping centres and the public transport systems are often reluctant or unable to accommodate these adaptations either due to the high costs involved or the structures are unable to accommodate the changes.

The South African Government has endorsed the principles adopted by the United Nations which call for "...extensive changes in the environment to accommodate the diverse needs of disabled persons in society..." and "...which shifts how we view disabled people" (p (i), foreword, White Paper on Integrated National Disability Strategy, 1997). The government has formed partnerships with organisations such as Disabled People South Africa (DPSA) who are advocating for the rights of the disabled by encouraging social interaction and participation in local and national awareness campaigns (DPSA, 2003).

2.4.3 Sensory deficits and learning difficulties

Approximately 25% of children with CP also experience speech and auditory impairments. Twenty five to 35% experience seizures and abnormalities of vision occur in about 40 -50% of children with CP. These figures are supported by Styer-Acevedo (1994).

Learning difficulties may result from integration and spatial orientation problems which result from decreased movement experiences. These sensory deficits may further lead to limited and poor communication skills and comprehension ability as well as writing

and reading difficulties (Kranowitz, 1998). The implication of these deficits and resulting problems may have a profound impact on the intellectual classification or diagnosing of these children. Furthermore communication and comprehension ability may complicate and affect research within this population.

Olney and Wright (2000) maintain that 75% of children with CP experience mental retardation or learning difficulties apart from the impaired control of movement and coordination of voluntary muscles. Frampton *et al* (1998) investigated the prevalence of specific learning difficulties in 149 children with hemiplegia. A specific learning difficulty was defined as “the failure to achieve academic progress in reading, spelling and mathematics despite conventional instruction, adequate intelligence and sociocultural opportunity” (p 42). Fifty three of those children had Intelligence Quotient (IQ) scores below 70 and were not included in the analysis of this study. The authors found that children with hemiplegia whose cognitive abilities and predicted academic ability were within the average range, had significantly more specific learning difficulties than expected with 36% having at least one specific learning difficulty. The researchers also reported that the children with specific learning difficulties had more neurological impairments and a significantly higher rate of emotional and behavioural difficulties than a group of comparison children.

2.4.4 Effects of aging

Changes in body composition and physiological functioning normally occur across the lifespan (McArdle *et al*, 1996). Due to the nature and complexity of the impairments and secondary complications that occur in the CP population, these changes could be expected to be more severe (Gajdosik and Cicirello, 2001). Deterioration occurs as a CP child enters adolescence and is very often due to increased body weight and adipose tissue without similar increases in muscle strength. Another contributing factor might be that when adults with CP reach adulthood, they are often tired of physiotherapy and stop training (Andersson *et al*, 2003).

In an investigation by Murphy *et al* (1995), the researchers conducted a two hour interview and physical musculo-skeletal system examination on 101 adults with CP. They reported the incidence of certain symptoms and conditions, such as pain and

early arthritis in weight-bearing joints to be "...higher than one might expect" (p 1082), but did not do a comparative study with the normal population. Deterioration in function is supported by a survey using self-administered questionnaires conducted by Andersson and Mattsson (2001). The results showed that 51% of the respondents had reported that their walking ability had decreased during recent years and nine percent that they had stopped walking altogether due to a perceived reduction in muscle strength and balance control. Ando and Ueda (2000) in a three part survey conducted in Japan reported a 35% functional deterioration in 686 respondents. Of those 163 were physically examined and the researchers found the incidence of deterioration was the highest amongst individuals with involuntary movements. For the third part a cohort study from the 163 subjects examined, was conducted and included 122 subjects. Deterioration over a five year period was noted in eight of the subjects only. They concluded that although factors intrinsic to CP are often responsible for functional deterioration, environmental factors also need to be taken into account. The above studies were conducted in the USA, UK, Sweden and Japan. The researcher found no studies investigating functional status in adults with CP in South Africa.

2.5 MUSCLE WEAKNESS IN SPASTIC CP

Clinical observations of children with CP have shown muscle weakness to co-exist with spasticity. Brown *et al* (1991) demonstrated that weakness can occur without spasticity. They studied the neurophysiology of lower limb function in children with hemiplegia. However their findings should be interpreted with caution as their assessment of muscle tone was subjective and limited to passive rapid and slow stretch. They included the effect of body position in prone and supine with the head in a flexed and extended position. EMG verification however, would have increased reliability.

Interventions to reduce spasticity such as orthopaedic surgery, botox injections and selective dorsal rhizotomy, have further revealed underlying muscle weakness (Damiano *et al*, 1995a). The neurophysiologic and biomechanical basis for reduced force production is complex and there are several theories that could explain why these individuals are weak. These are discussed in the following paragraphs.

2.5.1 Structural adaptations

According to Rose *et al* (1994a) and Dietz and Berger (1995) histochemical analysis of muscles with spasticity show that they do undergo structural changes. These include variation in muscle size, ranging from relatively minor to very large, displaying both atrophy and hypertrophy. Change in fibre-type also occurs (see 2.3, p 19). Due to prolonged contraction of muscles with increased tone or spasticity, more fatigue-resistant type I fibres are required. This fibre-type I dominance due to atrophy of type II fibres leads to abnormally sustained postures with no dynamic postural responses and reduces the ability of these muscles to initiate phasic movement which requires more fast twitch or type II fibres (Irwin-Carruthers, 2001). Endomyseal fibrosis and fatty replacement have also been documented, hampering contractile and lengthening ability of the muscle.

Muscle tightness or contracture can prohibit a muscle from achieving an effective length for generating force (Dietz and Berger, 1995; Kwagel, 2000; Irwin-Curruthers, 2001). The structural unit of the muscle fibre is the myofibril, consisting of overlapping sarcomeres. During contraction actin filaments slide across myosin filaments and attach to the myosin heads, forming cross-bridges. If the muscle is overstretched, the actin has difficulty in sliding across. If the muscle is in the shortened position no further sliding is possible. In spasticity, where the muscle is held in the shortened position, the number of sarcomeres is reduced in an attempt to reproduce conditions in which the actin and myosin filaments can slide. Inability to activate the muscle prevents effective contraction. When the muscle is lengthened, the filaments no longer overlap and it is still impossible to activate the muscle. The lengthened antagonists of shortened muscles respond by increasing the number of sarcomeres in an attempt to achieve overlap. When normal length is restored in the agonist, there is too much overlap in the antagonist to allow a contraction resulting in muscle weakness.

2.5.2 Changes in motor unit firing rates and recruitment patterns

Motor unit firing rates as well as the variation of the interval of the motor-unit firing rate, have been found to be reduced in spastic muscle of adult chronic stroke patients (Gemperline *et al*, 1995). Motor units are recruited at lower force thresholds, fire less

rapidly and fail to increase their firing appropriately as the strength of contraction is increased. Kwagel (2000) refers to this as the “reduced output paresis” (p 327), which occurs due to decreased supraspinal drive. Gemperline *et al* (1995) suggest that there is greater reliance on recruitment rather than firing rate modulation to control force and that the inability to correctly modulate these rates may alter the precise match between the firing rates and the mechanical properties of the muscle-fibres. This reduces the efficiency of contraction and leads to fatigue, weakness and loss of dexterity in children with CP (Rose and McGill, 1998; Kwagel, 2000). For example, the required rapid increase in firing rates to achieve normal push-off in stance and toe-clearance in swing is diminished. Both plantarflexion and dorsiflexion are weakened and the premature onset of activation of the calf muscle before initial foot contact is thought to be a major contributor to the development of the equinus foot (Rose and McGill, 1998).

Electro-myography (EMG) on children with CP has also demonstrated that during sustained maximal contraction, motor unit recruitment and firing rate also steadily decrease (Rose and McGill, 1998). Even during sub-maximal contraction there was a decrease in individual motor-unit firing-rates, indicative of poor muscle endurance. Damiano *et al*, (1995b) found distortion in the length-tension relationship which was demonstrated by the reduced knee extension strength as the knee approached extension.

According to Kwagel (2000) muscle weakness in children with CP can also be explained by the theory of the “subtraction paralysis” (p 326) on the basis of the opposition of the antagonists during voluntary movement. In other words the development of co-contraction between the agonist and antagonist is regarded as being responsible for the reduced net force production in the agonist. This was confirmed by EMG studies. This co-contraction is thought to be caused by reduced selective supraspinal drive to the specific motor neuron pools resulting in both agonist and antagonist motor neuron pool co-activation.

2.5.3 Further contributing factors to muscle weakness

Over time muscle strength and tone imbalance lead to muscle weakness and atrophy as well as soft tissue contracture and eventual joint deformity (Dietz and Berger, 1996).

The lower level of activity observed in CP is also a potential contributor to weakness. Weakness in this population may be exacerbated by some of the procedures that children undergo to address certain impairments. Selective dorsal rhizotomy reveals weakness by reducing the antigravity support that may have been provided by spasticity (Guiliani, 1991). According to Damiano *et al* (2000) orthopaedic surgery such as tendon lengthening and transfers, has a temporary negative effect on force production. Botulinum toxin temporarily weakens injected muscles to reduce spasticity (Hallet, 2000) and intrathecal baclofen that acts on contracted muscles may have a negative effect on strength (Olney and Wright, 2000). Other common treatments such as the use of orthoses may cause weakness due to prolonged periods of immobility (Damiano *et al*, 2002).

2.6 PHYSIOLOGY OF STRENGTH TRAINING

Researchers Wiley and Damiano (1998) proposed that addressing the muscle imbalance that occurs in CP by strengthening the relatively weaker muscle may help to maintain adequate muscle length thereby reducing the formation of secondary impairments.

McArdle *et al* (1996) define muscle strength as “the maximum force or tension a muscle (or muscle groups) is able to generate when resistance is applied” (p 417). For normal muscles this ability is dependant on:

- the condition of muscle - which is predominantly determined by genetics, but also by appropriate nutrition, specific hormones (testosterone), physical activity and exercise as well as environmental factors
- fibre-type - fast-twitch (type IIa and IIb) are able to generate energy for powerful, rapid actions and slow-twitch (type I) are fatigue-resistant and suitable for prolonged activity
- length and shape of the muscle fibres - muscles with pennate or fan-shaped fibre arrangement can generate a lot more force than fusiform shaped muscles, where fibres run more parallel to one another
- anatomic lever arrangement of bone and muscle

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- neural factors and input - which include patterns of innervations, number of motor units firing and synchronisation of motor units firing

Resistance training can modify many of these factors whereas others appear to be training resistant. Studies reported by McArdle *et al* (1996) demonstrated that increased and improved neural facilitation probably accounts for the rapid and significant strength increases early in training. These are not necessarily associated with increase in muscle size and cross-sectional area. These neural adaptations may be the result of:

- more efficient neural recruitment patterns
- increased central nervous system activation
- improved synchronisation of motor units
- lowering of neural inhibitory reflexes
- inhibition of Golgi tendon organs

The later increase in muscle mass is primarily due to hypertrophy due to increased protein synthesis. According to McArdle *et al* (1996) there is debate in the literature whether muscle size is also increased due to hyperplasia, ie an increase in actual number of muscle cells.

Other changes that occur as a result of strength training include:

- increased local energy stores
- changes in muscle fibre-type composition - the percentage of type IIb can decrease with corresponding increase in type IIa fibres, while the percentage distribution of fast- and slow twitch muscle fibres remains unchanged

Little is known about resistance training for children. According to Sewall and Michelli (1986), the available evidence indicates that supervised resistance training programs that use concentric muscle actions can significantly improve the muscle strength of children without any adverse effects on bone, muscle or connective tissue. These strength gains may be primarily the result of the learning and enhancing of

neuromuscular activation rather than an increase in muscle size (Ozmun *et al*, 1994). Strength training specifically pertaining to children with CP will be discussed in section 2.8.

2.7 PROGRESSIVE RESISTED EXERCISE (PRE)

Strength improvement is generally determined by the level of tension placed on the muscle or more specifically, the intensity of the overload (McArdle *et al*, 1996). Depending on the individual's needs, either dynamic, utilising concentric and / or eccentric muscle work, or static resistance methods, using isometric muscle work, can be selected – both have produced significant increases in muscle strength.

Types of resistance that might be applied to produce strength gains are numerous and include free weights, modified sports equipment, gym training machines (pulley weights), isokinetic computer-assisted devices, water, body weight, elastic bands and springs. With PRE the resistance, regardless of type, is gradually increased as the necessary accommodation occurs in the muscle. This is possible whether the strength gains were due to improved neural adaptation or physical changes that occurred in the muscle or both (McArdle *et al*, 1996). PRE utilises a system of repetitions and sets. Research initiated by De Lorme in 1945 has shown that a load that is equal to 60-80% of a muscle's force-generating capacity is sufficient to increase strength, thereby also reducing the risk of injury. Such a load generally permits the completion of ten repetitions of a particular exercise. According to McArdle *et al* (1996) the optimal number of sets and repetitions for strength training are as follows:

three to twelve repetitions maximum (RM) x two or three sets, three times per week.

2.8 STRENGTH TRAINING IN CHILDREN WITH SPASTIC CP

Research in children with CP is complex due to the large variation that exists between individuals with the same diagnosis, between individuals with different diagnoses and between classification systems. Despite this, many studies have been conducted investigating the effect of strength training in children with CP.

Haney (1998) stated in her review article that as early as 1958 studies have demonstrated resistance or weight training (PRE) to be effective in children with CP, without apparent increase in spasticity. Furthermore, these children appear to gain strength at the same rate as persons with weakness without central nervous system pathology. Healy (1958) [in Haney (1998)], compared two methods of weight training, namely isometric work in the one leg and concentric work in the other, in five children with spastic CP. Results showed significant gains for strength and range of movement (ROM) for knee extension. The results from this study are not generalisable as the sample size was too small and no allowance was made for difference in maturity (ages ranged from eight to 16) or distribution of involvement. This study also had no control.

McCubbin and Shasby (1985) investigated isokinetic exercise and repetitive movements in 20 subjects between ten and 20 years of age in a randomised control trial (RCT). Significant strength gains were found for the elbow extensors in the group that did isokinetic resistance exercise compared to the control and repetitive movement group. However, only one muscle group, the elbow extensors, were tested and it is not clear whether the upper limbs were neurologically involved in all the subjects. Haney (1998) also reviewed a study conducted in 1990, which investigated the effects of a ten-week circuit training program in seven athletes with CP. Up to 30% increase in strength were reported. The author reported that the use of the isokinetic dynamometer to measure muscle strength in this study however lacked reliability and the study had no control, making it difficult to attribute change in muscle strength to the training program.

The researchers of these earlier studies were predominantly physical educators and from the sports medicine community. In more recent studies investigating the effect of strength training in children with spastic CP the researchers include members from the physiotherapy community.

Although the following studies were limited to selected muscles due to the uncertainty of strength training on spasticity and abnormal reactions, all demonstrated significant strength gains following strength-training.

MacPhail and Kramer (1995) studied the effect of eight weeks of isokinetic strength training of the knee flexors and extensors, on functional ability and walking efficiency in 17

adolescents with CP. Statistical analysis showed significant changes in strength. Significant changes in function but not in walking efficiency were reported (see 2.9.3). However, this study also lacked a control group and changes reported may not be attributable to strength training alone.

Damiano *et al* (1995a) while investigating the effects of quadriceps femoris muscle strengthening on crouch gait in 14 children between the ages of six and 14, with spastic diplegia also reported statistically significant increases in muscle strength. The results of this study should be interpreted with caution as it lacked a control group. In order to improve the validity, Damiano *et al* (1995b) compared the same subjects with 25 normally developing children in a follow-up study and demonstrated that resistive exercise can increase quadriceps strength to near normal levels in a small group of ambulatory children with CP. The study would have been stronger if the researchers had compared the results of the first study with a control group from within the same population.

Another study by Damiano and Abel (1998) that targeted multiple muscles of the lower extremity depending on individual areas of weakness also documented significant improvements in strength. Eleven children, between six and 12 years participated in a six-week strength training program. The two weakest muscles for each child with diplegia were identified for strengthening and for the hemiplegics two, sometimes three muscles were selected and trained. This prospective before and after trial was also observational using repeated measures, single-group design. With no control data it is difficult to attribute these outcomes to the effects of strength training on children with CP.

Darrah *et al* (1999) evaluated a community fitness program for 23 adolescents with CP. The subjects completed a ten-week program of aerobics, strength training and stretching three times per week. To assess the effect on muscle strength the authors summed the change of the four muscle groups tested - the knee extensors, hip extensors and abductors and shoulder flexors - and found significant gains in strength. The results from this study may be exaggerated as the researchers did not report on the separate changes for each muscle group tested. The mean change in shoulder flexors and extensors were summed with mean change in knee flexors and extensors and hip ab- and adductors. The inclusion of aerobic and mobility exercises may also have contributed to the findings. The study did not have a control group. However, the researchers did obtain baseline

measures 24 hours apart prior to strength training and compared these results with the results from the ten-week pre and post intervention measurements. This does not adequately control for natural variation in subject performance over longer periods though.

The classification of severity of children with CP seemed to differ in the five above-mentioned studies. Damiano *et al* (1995a, 1995b) limited their study to mild independently ambulant diplegic subjects, whereas Darrah *et al* (1999) included two subjects who used wheelchairs as the main method of locomotion and two who used walking devices. MacPhail and Kramer (1995) did not specify severity although they did include one quadriplegic subject in their study sample. Their inclusion criteria were limited to sufficient strength and coordination as well as knee extension range of movement of the subjects' most involved leg to operate the isokinetic dynamometer (Kin-Com). This difference in sample composition makes it difficult to compare subjects across the studies and hence compare the findings.

The instruments used by the researchers above also differed. Damiano *et al* (1995a, 1995b) and Darrah *et al* (1999) used the hand-held dynamometer (HHD) to assess muscle strength, whereas MacPhail and Kramer used the Kin-Com dynamometer to measure peak torque and work during concentric and eccentric muscle actions. In an investigation to compare isokinetic dynamometry (Cybex II) with the HHD, Bohannon (1990) found inter-instrument reliability to be fair. The HHD's inter-testers' reliability is dependant on adequate skill and strength of the tester and could potentially affect the reliability of the HHD. Although these authors do not specify who conducted the strength tests, measurement bias may have occurred. Isokinetic dynamometry is not tester dependent. Both outcomes are however dependent on the subjects performance which can be influenced by any number of factors including mood and motivation on the day of testing. External factors such as verbal encouragement, environmental temperature and audience may also influence performance (McArdle *et al*, 1996).

2.8.1 Strength training programs

All of the studies included in this literature review which investigated the effects of strength training in children with spastic CP, made use of progressive resisted exercise

although various types of strength training programs were followed. Significant strength gains were noted for programs using free weights (Damiano *et al*, 1995a, 1995b), gym equipment (Andersson *et al*, 2003) and isokinetic devices (MacPhail and Kramer, 1995). Some researchers investigated the use of a combination of equipment, such as Darrah *et al* (1999) in their study of a community fitness program. The sample in this particular study also did aerobic exercise and the program included a flexibility component.

The broad range of strength gains from two percent to more than 200% in targeted muscles recorded by all of the above studies cannot be compared due to the differences within the study samples including age, height and weight variance and difference in diagnosis and classification systems. Length of training also differed within the studies varying from six weeks (McCubbin and Shasby, 1985; Damiano *et al*, 1995a, 1995b; Damiano and Abel 1998) to ten weeks (Darrah *et al* 1999).

The following two studies involved longer programs and the authors' aims included assessment of exercise on body composition. A description of the use of resistance exercise and specification of type of exercise was lacking and the results should be interpreted carefully as effects may not be due to gains in muscle strength.

Van den Berg-Emons *et al* (1998) conducted a RCT on 20 children with spastic CP. The effect of a nine-month sports program was evaluated to determine the effect on daily physical activity, percentage body fat and physical fitness. Isokinetic muscle strength was measured and the authors reported that although significant gains in the strength of knee flexors and extensors were recorded for the experimental group immediately after intervention, there was no difference between the experimental and control groups. This study's intervention program consisted predominantly of aerobic-type exercise such as cycling, swimming and wheelchair propulsion. Mat exercises were also included. Whether the mat exercises included PRE was also not clearly indicated. The results did suggest though that physical exercise may reduce the deterioration that occurs with increasing age in this population, particularly relating to percentage body fat and muscle strength as no changes were reported throughout the nine month study period for these two measures.

An earlier study by Bar-Or *et al* (1976) investigated the effect of a two hourly twice a week sports rehabilitation program on aerobic capacity and adiposity, lasting for 12 months. They included 26 adolescents with CP and 26 post-poliomyelitic adolescents in the experimental group. Nine adolescents with CP served as control. The exercise program included games such as table tennis and adapted bowling for the first hour. The second hour included matwork. The use of PRE is unknown as it was not specified. The study design was not optimal as subjects were volunteers, which may have resulted in participation bias. However, nine subjects with CP did not complete the program. The control group only represented the CP population. Comparison between CP and post-polio subjects, due to the huge neurophysiological variance between them, is also difficult. The authors were unable to show that such a program may prevent deterioration in body composition.

2.8.2 Principle of exercise specificity

An important principle with strength training is the principle of specificity. Strength improvement is related to

“...a blend of adaptations that occur both in the muscle fibre itself (fibre type and muscle cross section) and in the neural organisation and excitability (effective recruitment and synchronisation for firing of the appropriate motor units) for a particular pattern of voluntary movement.”

(McArdle *et al*, 1996, p 395).

Thus training of the leg muscles through weight lifting does not necessarily mean that the performance of all subsequent leg movements will improve. To improve a specific physical performance, those muscles related to the activity must be trained in movements as close as possible to the movement or actual skill that is to be improved. The strength gains recorded in the studies that limited the strength training to muscles of the lower limb only, might be increased if strength-training programs targeted more specific muscles directly related to the components of gait. Therefore it might be that including strengthening exercises for hip extensors and hip abductors could increase hip stability. This may increase the length of the stance phase and allow for a longer step length and reduced compensatory lateral tilting of the trunk

(Norkin and Leverage, 1992; Hodges and Richardson, 1997). Similarly inclusion of strengthening exercises for the trunk movers and stabilisers, could improve trunk stability, thereby reducing the excess body motion and counterbalance the rotation of the pelvis. Upper limb movement and function should be affected with improved trunk stability (Hodges *et al*, 1996).

2.9 THE IMPACT OF STRENGTH TRAINING ON FUNCTION

A thorough appraisal of the impact strength training has on function in children with spastic CP is lacking. However, researchers have used a combination of two or more standardised outcome measures to evaluate the global effect of resistance exercise on function. Gait analysis (GA), the Gross Motor Function Measure (GMFM) and the Energy Efficiency Index (EEI) appear to be the preferred outcome measures and one or more of these were used in studies by Damiano *et al* (1995a; 1995b), Damiano and Abel (1996; 1998), Kramer and MacPhail (1994) and Darrah *et al* (1999) and are discussed in the following paragraphs.

2.9.1 Effect of strength training on gait

Three-dimensional gait analysis (GA) enables quantification of various temporal distance variables such as walking velocity, which is determined by stride length and cadence, as well as kinematic variables or joint angles and excursions. Increased velocity was shown by Kramer and MacPhail (1994) to correlate modestly with improvements in knee extensor strength. This is supported by Damiano and Abel (1996) who investigated the relationship of gait analysis to gross motor function in twenty six children with spastic CP.

Findings on the change in free walking velocity following strength training however, is contradictory. Another six-week study by Damiano and Abel (1998), using velcro-attached free weights targeting predominantly the knee extensors and hip flexors or extensors, did show an increase in free walking velocity. MacPhail and Kramer (1995) however, found no changes in free walking velocity on investigating the effect of an eight-week isokinetic strength training of the knee flexors and extensors.

GA has also shown that strength training has increased range of movement (ROM), as was demonstrated by decreased knee flexion at heel strike and resulted in increased stride length (Damiano *et al*, 1995b).

Joint kinematics are dependent on walking velocity (Damiano and Abel, 1998) and strength training programs resulting in increased velocity, makes comparison of kinematic variables difficult. The use of 3-dimensional GA as a suitable outcome measure is discussed in more detail in the next chapter (see 3.5.1).

2.9.2 Effect of strength training on functional ability

Kramer and MacPhail (1994) and Damiano and Abel (1996) also measured changes in functional ability following strength training using the GMFM and have shown modest correlation to knee extensor strength. The use of the GMFM as a suitable outcome measure to evaluate the effect of strength training on function is debatable. Participants in these studies were all ambulant, with or without walking aids and changes detected on the GMFM were minimal. The GMFM quantifies how much motor function the child is able to demonstrate (Cole *et al*, 1995) and does not evaluate quality of movement nor does it evaluate function in the context of day-to-day activities (Darrah *et al*, 1997). Damiano and Abel (1996) showed that correlations exist between gait variables and GMFM total scores and although gait analysis is a more exact measurement of changes in walking and thus more sensitive to detecting quality of movement, it is important to remember that GA and the GMFM do not measure the same components of walking.

According to Ketelaar *et al* (1998) in their review of 17 instruments used in pediatric rehabilitation and physical therapy to assess functional motor abilities in children with CP, only the GMFM and the Pediatric Evaluation of Disability Inventory (PEDI) fulfil the criteria of reliability and validity with respect to responsiveness to change. Their review did not include the Pediatric Orthopaedic Society of North America (POSNA) Musculoskeletal Functional Health Questionnaire or the Gillette Functional Assessment Questionnaire (FAQ) as described by Tervo *et al* (2002) below.

Researchers Tervo *et al* (2002) compared the POSNA Musculoskeletal Functional Health Questionnaire and the Gillette Functional Assessment Questionnaire (FAQ), as well as energy efficiency (EE) with gait analysis to determine the correlation between physical functioning and gait measures in children with CP. They calculated a Normalcy Index (NI) which is a numerical calculation of how close a given gait pattern is to a normal gait pattern typical of children without disabilities – the higher the number, the greater the deviation from the normal and compared it to the above. They found the NI to be predictive of global functioning as measured by the POSNA. However they recommended that for a more complete assessment of change these outcomes should be used in conjunction with one another. According to Tervo *et al* (2002) the predictive validity and sensitivity of these tests however, still need to be determined.

The POSNA differs from the GMFM, in that the POSNA subscales also include transfers, sport and comfort (pain free). The FAQ is a 10-level parent-report measure that audits a range of walking abilities in all community settings and terrains. It is a reliable and valid measure specific only to the task of walking (Tervo *et al*, 2002).

There appears to be no other standardised functional outcome measures suitable for adolescents, ages 13 – 19 years, that would represent a more comprehensive assessment of global functional ability in children with CP. A battery of suitable outcome measures that evaluate the quality of execution as well as development of new skills do exist for adults. The Berg Balance Scale used to identify balance impairment in the elderly and the Timed “Up and Go” test to evaluate basic mobility manoeuvres (Cole *et al*, 1995) for example, may be more appropriate. Validity of these measures for use in an adolescent population however, needs to be evaluated. As Darrah *et al* (1999) and Tervo *et al* (2002) suggested the use of a combination of outcome measures would represent a more comprehensive assessment of the impact of strength training on children with spastic CP.

2.9.3 Effect of strength training on walking efficiency

Gait velocity is highly correlated with energy expenditure (Rose *et al* (1994b)). Humans will choose a free walking speed that is most energy efficient (Abel and

Damiano, 1996). These researchers hypothesised that efficiency can be enhanced as will be evidenced by a faster free walking velocity, which is achieved by increasing stride length rather than increased cadence. Increased stride length during free walking following a strength training program which targeted the knee extensors, has been demonstrated by Damiano *et al* (1995a). Evaluation of the effect of increased stride length on walking efficiency was not covered by the scope of their study. Another study by Damiano and Abel (1998) investigating functional outcomes following strength training, however demonstrated an increased velocity without effecting walking efficiency as measured by the Energy Expenditure Index (see below). Increased velocity however, was due to increased cadence and increased stride length was not demonstrated. The relationship between stride length and walking efficiency still needs to be determined experimentally.

Several researchers have investigated oxygen cost and consumption during walking in the CP population and will be discussed in more detail.

2.9.3.1 OXYGEN CONSUMPTION DURING FREE WALKING

A study by Bowen *et al* (1998) has shown that oxygen cost and expenditure is higher in individuals with disabilities compared to their non-disabled counterparts. Rose *et al* (1990, 1991) demonstrated that there is a linear relationship between heart rate (HR) and oxygen consumption (VO_2) for both children with or without CP and many researchers have thus used the Energy Expenditure Index (EEI) to determine the energy cost of walking. The EEI is calculated by dividing the difference between walking and resting heart rates by walking velocity to derive a ratio of beats/meter. Apart from being more cost effective – only a heart rate monitor and stopwatch are required, the EEI allows children to walk freely without having to wear a mask or carry apparatus on their backs as with the Cosmed K2 portable system (Corry *et al*, 1996).

Practice effects on metabolic energy expenditure have been investigated by Lay *et al* (2002) who found a significant reduction in metabolic energy costs following ten practice sessions of 16 minutes on a rowing ergometer. Although the activity was aerobic and had more direct effect on heart and respiratory muscles, the

researchers attribute the decrease in metabolic costs to improved co-ordination and control and decreased muscle activation.

Kramer and MacPhail (1994) showed a moderate to significant correlation between EEI and knee extensor strength measurements, whereas MacPhail and Kramer (1995) and Darrah *et al* (1999) did not show improved walking efficiency following strength training, in spite of significant gains in knee extensor strength.

2.9.3.2 OXYGEN EXPENDITURE WHILE TREADMILL WALKING

Corry *et al* (1996) argued that a treadmill does not allow for irregular gait, nor for dragging feet; the speed remains pre-selected and does not accommodate a walking aid. Yet in their study that compared results using the Cosmed K2 portable system, which allows free walking, with the Quinton system on a treadmill, they found a good comparison for VO_2 between the two systems. Controlling walking speed enables more accurate comparison of various metabolic variables between groups from pre to post measures.

2.9.4 Effect of strength training on perceptions of self

Dodd *et al* (2002) stated that many studies investigating the effects of strength training in the CP population were not only limited in their investigations of the changes in activity and societal participation, but also in their investigations of personal perception of change in functional ability and body image. Only one study by Darrah *et al* (1999), attempted to evaluate change in perception of self-image and functional ability. Following a ten-week participation in a community fitness program, the researchers noted a significant improvement in self-image as measured by the Self-Perception Profile for the Adolescent (SPPA), with no significant change in perceptions of functional ability. Although there is some evidence in the literature that supports that strength gains do result in improved function, the changes that were reported in gait analysis and in the GMFM, according to Darrah *et al* (1999), did not relate to improved functional ability as perceived by the participants themselves.

The need to investigate the impact of a comprehensive strength training program targeting multiple muscle groups on adolescents with CP, using basic inexpensive free weights and resistance devices arose. The studies mentioned above that limited their investigations to strength training alone (Damiano *et al*, 1995a, 1995b; MacPhail and Kramer, 1995) also limited their intervention to selected muscles with significant results. In the current study the researcher hypothesised that inclusion of PRE for muscles of the trunk, including abdominal and trunk extensor muscles, upper limb as well as lower limb muscles (see 2.8.2 p 28) might result in more significant changes in gait function. Basic equipment was selected to provide resistance thereby increasing the clinical feasibility of future implementation of such a program in the lower socio-economic populations. Using gait analysis, the economy of movement test, isometric strength testing and a questionnaire relating to perceptions of body image and functional competence, an attempt was made to determine a more complete assessment of change.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH QUESTION

What is the impact of an eight-week progressive resisted exercise (PRE) program on adolescents with spastic cerebral palsy?

3.1.1 Objectives

To determine the effect of PRE on adolescents with spastic cerebral palsy (CP) on:

1. hip abductor and knee extensor muscle strength
2. free walking velocity
3. stride length during free walking
4. joint angles of the hip, knee and ankle at midstance during free walking
5. energy expenditure while walking
6. the adolescents' perception of his/her own physical appearance and
7. the adolescents' perception of his/her own functional competence

An additional objective was to determine whether:

8. gender and distribution of involvement influence strength gains, gait and energy expenditure

3.1.2 Hypothesis

H_0 PRE has no effect on targeted muscle strength, free walking velocity and stride length, joint angles of the ankle, knee and hip at midstance, energy expenditure while walking or perceived functional competence and physical appearance in children with spastic cerebral palsy.

H₁ PRE will result in strength gains in hip abductors and knee extensors in adolescents with spastic cerebral palsy

H₂ PRE will increase ankle, knee and hip extension at mid-stance during free walking

H₃ PRE will increase free walking velocity

H₄ PRE will increase stride length during free walking

H₅ PRE will result in more energy efficient walking

H₆ PRE will result in changes of perception of physical appearance

H₇ PRE will result in changes of perception of functional competence.

3.2 STUDY STRUCTURE

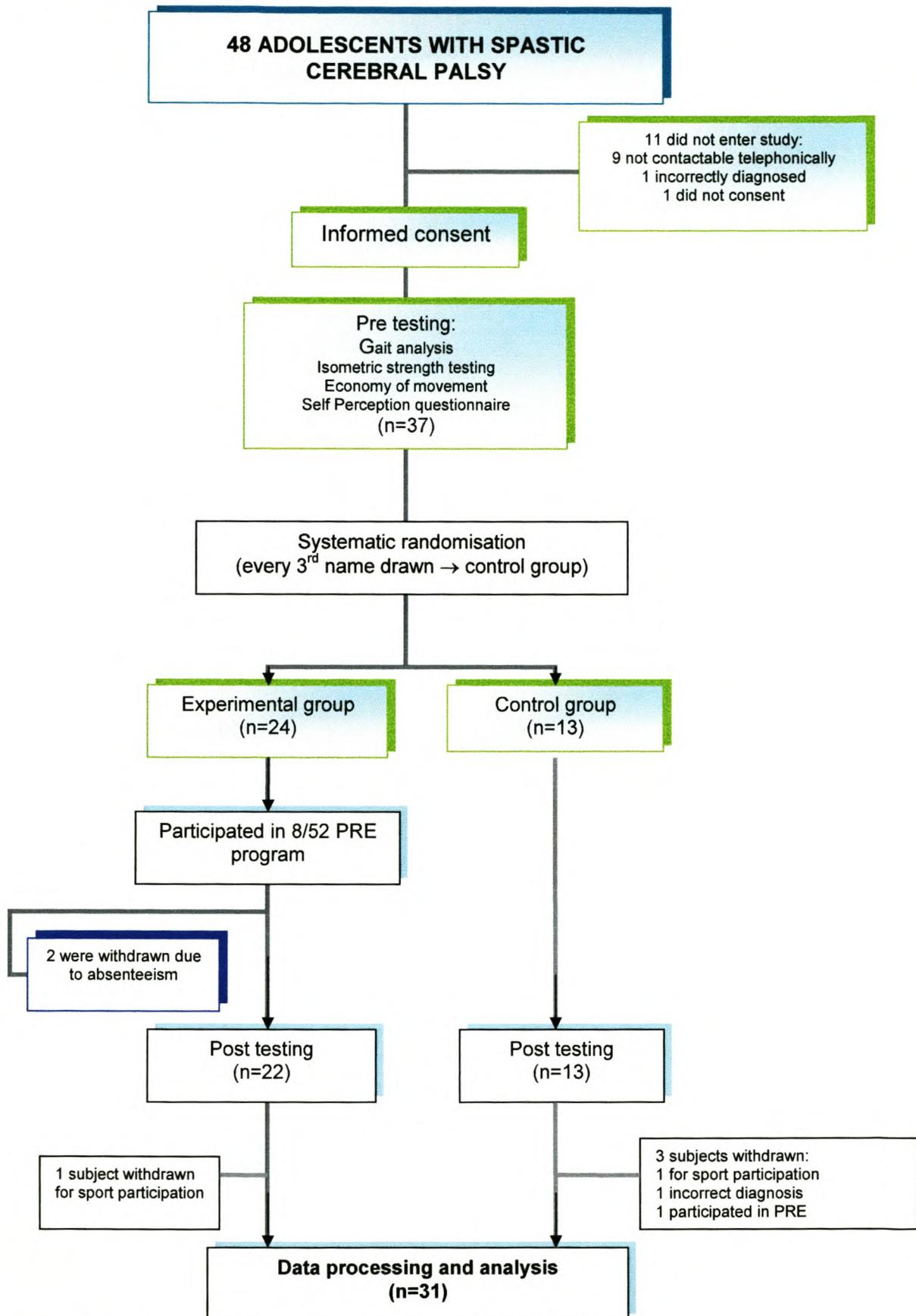


Figure 3.1 Procedure for the randomised control trial

3.3 POPULATION

The population studied were adolescents with diagnosed CP and presenting with spastic diplegia, triplegia, quadriplegia or hemiplegia.

3.4 SAMPLING

3.4.1 Inclusion criteria

All subjects had to be:

- between the ages of 13 - 18 years
- independently ambulant, with or without a walking aid
- able to walk at a minimum speed of two km/hour for five minutes on a treadmill
- a minimum of one year post orthopaedic- or neurosurgery
- a minimum of six months post Botox injection
- in good general health
- able to comprehend instructions in either English or Afrikaans

3.3.2 Exclusion criteria:

Subjects were excluded from the study:

- with history of spasticity altering surgery (baclofen pump or selective dorsal rhizotomy)
- with recent soft tissue injuries or fractures resulting in temporary, partial or complete immobilisation, which could have effected participation or testing
- participated in sport at provincial level during the trial period
- without written assent by the child
- without written consent by parent or legal guardian

A sample of convenience was used. Only children from Eros School participated in the study in order to minimise transport costs to and from the testing venues. Furthermore, as schools and centres differ in terms of number of therapists, approach to treatment, sports programs, facilities and socio-economic composition, subjects were selected for participation from one school only, thereby reducing rehabilitation protocol variability.

A physiotherapist from the school identified children diagnosed with spastic cerebral palsy (CP) from the school's medical records. All the parents or legal guardians of those children that met all inclusion criteria (n= 48), were contacted by the researcher to explain the purpose of the study and to obtain informed written consent (figure 3.1). Contact was telephonic and a consent form (addendum A) was sent home with the child for signing or faxed to one of the parents or the legal guardian. Telephone numbers of the researcher and the assistant physiotherapist from the school were provided and the parents were encouraged to contact the researcher to discuss any questions regarding participation and progress throughout the study. Informed assent (addendum B) was also obtained from the child. The researcher was unable to telephonically contact the parents of nine children. One subject's diagnosis was partially incorrect. He had a progressive disorder. Another subject was excluded as the consent form was never returned.

Following pre testing, the remaining 37 whose parents consented to participation in the study (figure 3.1) were then randomly allocated to either the experimental group (n=24) or to the control group (n=13) by drawing a name from a hat. Systematic randomisation was used, whereby every third name drawn was allocated to the control group, with the rest being allocated to the experimental group.

3.5 PROCEDURE

An outline of the procedure will precede a brief explanation and motivation of the outcome measures and instrumentation used in the current study. This is followed by the testing procedure. A description of the intervention program is also given.

All subjects were tested prior to participation and immediately following completion of the eight-week- PRE program (figure 3.1). Pre-participation testing took place in the last two weeks of the first school term in 2003. All subjects were tested on two consecutive days

before randomly being selected to either the control or the experimental group. The subjects were transported to and from the test venues by a bus and driver employed by the school due to their blanket indemnity for all transport of children enrolled at EROS.

The following four outcome measures were used to determine the impact PRE has on adolescents with spastic CP:

- isometric strength testing
- three-dimensional gait analysis (GA)
- economy of movement test (EOM) and
- self-perception questionnaire

Energy expenditure (EOM) testing was done at the Department of Physiology at Stellenbosch University (US) by research assistant A³. The self-perception questionnaire was completed at the same venue. Isometric strength testing was conducted by research assistant B⁴ and Gait Analysis (GA) by research assistant C⁵ at the Sport Science Institute of South Africa (SSISA) in the Treadmill and Motion Analysis Laboratories. Half of the subjects first went for testing at US while the other half went for testing at SSISA.

The research assistants for the EOM and GA were blinded to group allocation for both baseline testing and at eight-week testing. Research assistant C for the measurement of isometric strength was blinded for the baseline measure. The second measure however, was conducted by the researcher. Research assistant C immigrated out of SA prior to the second measure at post testing and research assistant B conducted the second GA measure but remained blinded as to which subjects participated in the strength training program.

The second term, the longest school term for 2003, was selected for the remainder of the study in an attempt to avoid disruption occurring during participation in the PRE program and re-testing. Several subjects in the experimental group were hostel residents and there

³ Masters graduate from the Department of Human Movement Studies. Currently research assistant for projects in exercise physiology in the Department of Physiology, US

⁴ An honours student in Human Movement Studies at UCT and research assistant in the Treadmill and Motion Analysis Laboratory at the Sport Science Institute of South Africa

⁵ PhD graduate in Motion Analysis from the Department of Human Movement Studies at UCT. Head: Motion Analysis Laboratory at the Sport Science Institute of SA

was no guarantee of supervised continuation of training during the holidays. The second measures were taken in the third last week of term before commencement of the exams to ensure minimal disruption to the subjects' academic program.

3.5.1 Instrumentation:

The following outcome measures were used. The motivation for selection as well as the validity and reliability of the instruments will be discussed in the following sections.

3.5.1.1 COSMED QUARK B² METABOLIC SYSTEM (Economy of Movement test)

A POLAR heart rate monitor and a computerised O₂ and CO₂ analyser were used to test energy expenditure while walking on a treadmill. The system consists of a facemask covering the child's nose and mouth and was held in place by straps. Expired air passes into a turbine, where an optio-electric sensor measures the expired volume. Analyser outputs were processed by the computer, which calculated oxygen uptake (VO₂), carbon dioxide production (VCO₂) and minute ventilation (VE) with every breath taken and used for the purpose of this study. The system was calibrated daily before each test session by research assistant A with room air and a CO₂:N₂ gas mixture of known composition.

Although treadmill walking has been criticised for assessment of performance in the disabled child (see chapter 2.9.3, p 31), comparison and analysis of metabolic variables during walking is difficult if all the subjects are walking at their own freely selected speeds. The treadmill however ensures consistent walking speeds.

The use of the Cosmed metabolic system as a suitable instrument valid and reliable for testing the performance of children with disabilities in a laboratory was demonstrated in a study by Corry *et al* (1996).

3.5.1.2 QUESTIONNAIRE

A short self-administered questionnaire (addendum C) was used to assess perceptions of body image and functional competence. The researcher was unable to obtain the Self-Perception Profile (SPP) for the Adolescent used by Darrah *et al* (1999) and thus compiled this questionnaire based on the Piers Harris Children's Self-Concept scale (1984) and personal experience as a physiotherapist, having worked with CP children at a special school for four years.

The questionnaire has two sections: Section A relating to perceptions of body image and Section B relating to perceptions of functional competence. The two sections consisted of six and five statements respectively and were based on the five-point Likert-scale. However, descriptive phrases replaced the one to five-scale to clarify the difference between values. The subject had to choose which phrase was the most applicable. Each section also had an open-ended question where opportunity was given for qualitative explanation. The questionnaire was available in both Afrikaans and English. The questionnaire was piloted prior to the start of the study on a group of 30 mainstream high school children, ranging from grades seven to 12. Minor alterations to the descriptive phrases were made to clarify distinction between the categories of the scale. The questionnaire was quick to complete.

3.5.1.3 THE KINEMATIC COMMUNICATOR (KIN-COM[®])

There are four generally accepted methods to test muscle strength and the use of each is well described by McArdle *et al* (1996):

- cable tensionometry which measures isometric muscle force,
- dynamometry, also used for static strength measurements,
- one-repetition maximum (1-RM), which refers to the maximum amount of weight lifted one time with correct form and computer assisted and
- electromechanical and isokinetic methods, which are able to quantify forces, torques and accelerations and velocities of body segments in various movement patterns.

Hand-held dynamometry is well used for testing isometric muscle strength in children with CP (Damiano *et al*, 1995a and 1995b; Damian and Abel, 1998; Darrah *et al*, 1999). The device was not locally available and the Kin-Com[®], a computer-assisted isokinetic dynamometer was therefore selected for this study to measure the isometric strength of the quadriceps at 30° and 60° knee extension and the gluteus medius and minimus at 10° and 20° hip abduction.

The machine used at the SSISA is serviced and calibrated annually; the last service date was January 2003. The reliability and validity of the Kin-Com operating system was demonstrated by Farrell and Richards (1986). A technical report by Mayhew *et al* (1994) demonstrated that the static force and lever angle(s) necessary for isometric testing are accurate and replicable. Van den Berg-Emons *et al* (1996) found strength testing using isokinetic devices (Cybex) reliable for use in children with CP and MacPhail and Kramer (1995) showed the Kin-Com to be a valid testing device for muscle strength in the young CP population.

Although isokinetic testing was initially the preferred form of muscle testing as both torque and active range of movement are measured, there is debate about the most appropriate velocity for isokinetic testing of persons with cerebral palsy due to the effect speed has on spasticity (MacPhail and Kramer, 1996). The subjects in this study experienced problems with not understanding the concept of eccentric muscle work. Andersson *et al* (2003) who investigated the effect of muscle strengthening on walking in adults with CP, stated that the results of their study were possibly unreliable as the authors also had difficulty with the subjects' understanding of how to resist the resistance pad of the isokinetic dynamometer especially during the eccentric muscle action.

3.5.1.4 VICON 370 DATA STATION (Gait Analysis)

A six camera video based motion capturing system, the VICON 370 data station (Oxford Metrics) was used to capture kinematic data (joint angles) and the data was processed using Workstation 3.2, BodyBuilder 3.53 and Microsoft Excel as described by Vaughan *et al* (1999). Fifteen retro-reflective markers, which

constitute the modified Helen Hayes marker set, reflect light that originates from multiple light emitting diodes. These are circumferentially arranged about the lens of each of the six cameras. The reflected light was captured by the six cameras and conveyed by under floor cabling to the data station and converted to digital form for processing. Calibration was done prior to each test by research assistant C.

Intrasubject repeatability of gait analysis data, although a different data station was used has been demonstrated in a study by Steinwender *et al* (2000). Although repeatability was better amongst normal children, several researchers have considered 3-D gait analysis to be a reliable outcome measure in the CP population (Wheelwright *et al*, 1994; Gage *et al* 1995; Damiano and Abel 1998; Darrah *et al*, 1999).

Additional instrumentation used in this study for measurements of body mass, height and other anthropometrics data, include:

3.5.1.5 ELECTRONIC SCALE

A BW-150 free-weight (1997) electronic scale was used to measure body mass which was recorded by research assistant A. The test was conducted at Stellenbosch University (US) in the Department of Physiology.

3.5.1.6 ANTHROPOMETER

An anthropometer, a metal calibrated rod with movable perpendicular crossbar, was used to measure the body length. Measurements were also done at US by research assistant A in the Department of Physiology prior to EOM testing.

3.5.1.7 CALLIPERS AND TAPE MEASURE

Anthropometric data needed for GA was measured using a calliper (Holtain Ltd) and a standard tape measure prior to gait analysis, by research assistant C for the

pre testing measurements and research assistant B for the second measure at post testing.

3.5.2 Testing procedure:

The following sections explain the procedure followed in the current study for each of the four outcome measures used. For the EOM, GA and isometric strength testing no pilot study was conducted as all these tests are standardised and testers were proficient in the testing procedures.

3.5.2.1 WALKING EFFICIENCY (EOM)

Subjects were not allowed to eat two hours before testing as metabolism affects the cardio-respiratory variables measured by the EOM test. Height and mass were recorded by research assistant A. The subjects only wore shorts but a T-shirt was permitted. For height measurement, the subjects stood upright with their back and heels against the wall while being measured. A polar heart rate monitor was strapped around the chest and a mask was fitted around the nose and mouth (figure 3.2). Resting heart rate was recorded in sitting. Each subject walked for five minutes on a treadmill at each of the following fixed walking speeds: two and three km/h. For subjects that could manage faster speeds, a further five minutes at five km/h were included. VO_2 , VCO_2 , V_E (minute ventilation) and heart rate were recorded with every breath taken. Subjects were allowed to rest in between each five-minute session until resting heart rate was reached.

As none of the subjects had been exposed to treadmill walking before, a trial walk was permitted before the test commenced. As soon as the subject felt confident they stopped walking and waited until their heart rate returned to its resting state.



Figure 3.2 Economy of Movement Test

Although swaying gait is reduced by holding on to the rails, to standardise the procedure, all subjects were asked to use rails for support only (figure 3.2). This was deemed necessary to ensure the safety of the participants with compromised balance and reduced or slow balance reactions. Subjects were encouraged to hold on loosely and not to push down on to the rails. Subjects that dragged their feet continued to do so, on the treadmill. Only one subject used crutches, but managed to walk on the treadmill by holding on to the handrails. For safety reasons, the researcher stood behind all the subjects.

3.5.2.2 SELF-PERCEPTION QUESTIONNAIRE

The questionnaire was completed by the subjects either while waiting their turn for energy expenditure testing or shortly thereafter. The researcher gave verbal instructions to the subjects on how to complete the form. Research assistant A served as scribe for subjects unable to write.

3.5.2.3 ISOMETRIC MUSCLE STRENGTH TESTING

Before testing each subject performed a warm-up consisting of five minutes fast walking or running on a treadmill. The affected limb in the hemiplegic subjects and the stronger leg in the diplegic or triplegic subjects were measured. The subjects identified their stronger leg themselves. The stronger and not the weaker leg were selected for di- and triplegic subjects, as the weaker leg was often too weak to complete the test protocol. This was especially true for the hip abductors. Knee extension, first at 30°, then at 60° was followed by hip abduction at 10° and then at 20°.

Knee extension

During testing of knee extension, each subject was seated upright against a backrest (figure 3.3). The lateral femoral condyle of the knee was aligned with the axis of the lever arm (Norkin and Levange, 1992). The resistance pad of the dynamometer was secured five centimetres above the lateral malleolus. Straps were placed snugly across the pelvis and chest and the subjects were allowed to grasp the sides of the test chair.

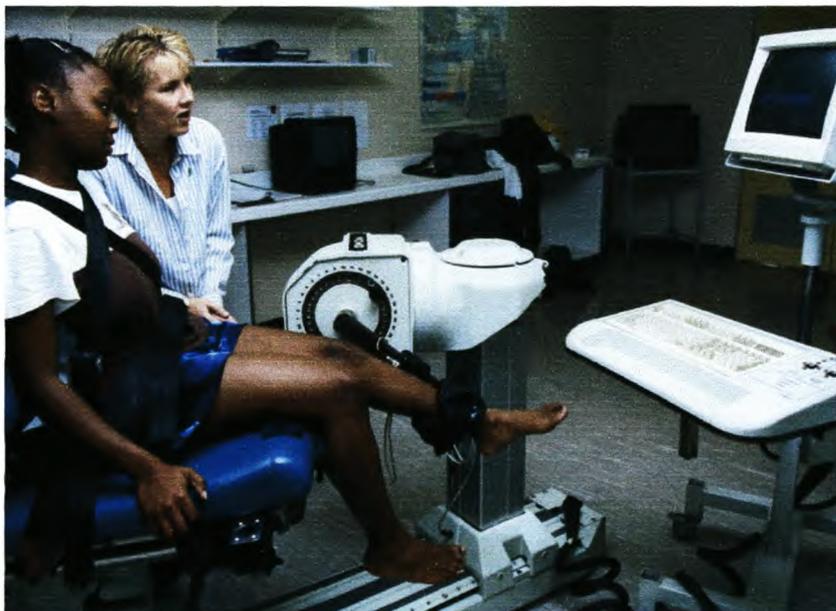


Figure 3.3 Kin-Com[®] Isometric testing of knee extension

Hip abduction

Testing of the hip abductors was conducted in supine to control the tendency to substitute hip flexion and rotation for hip abduction (figure 3.4). The mid point between the superior iliac crest spines was used to align the axis of the lever arm to allow hip abduction to occur off the table. Manual stabilisation of the pelvis was given as necessary when the subjects were unable to stabilise the pelvis themselves as observed by research assistant B. The resistance pad of the dynamometer was secured five centimetres above the lateral malleolus. Subjects were encouraged to hold on to the bed / plinth for additional support. Subjects monitored their performance on a screen which necessitated rotation of the head. The ATNR's inhibitory effect on the hip abductor being tested could not be eliminated. As the effect of the ATNR at pre and post participation testing was presumed to be unchanged, the protocol was deemed acceptable.

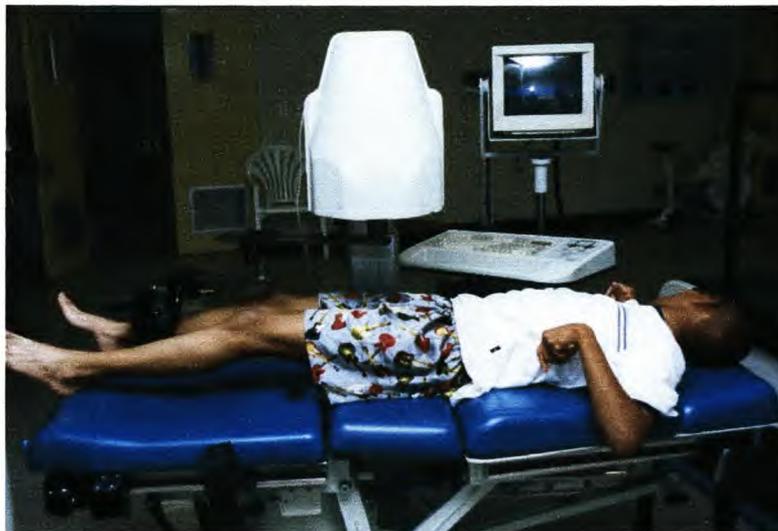


Figure 3.4 Kin-Com[®] Isometric testing of hip abduction

Providing manual resistance against hip abduction to the non-tested side was necessary in 25% of the cases in order to activate and provide over-flow to the hip abductors being tested. Where this was necessary in pre testing, it was documented and the same protocol was repeated in the post participation testing.

One practice session for each muscle was allowed to familiarize the subjects with the procedure. A maximum effort had to be maintained for five seconds followed by a resting period during which time the lever moved the limb passively into the

second position. When the subject was ready for the next attempt, the second five-sec countdown was activated. Strong verbal encouragement by research assistant B during the trials was used to encourage maximal effort. The test for each muscle group consisted of six consecutive maximum effort isometric contractions for both knee extension and hip abduction. Where no force could be generated a zero strength value was recorded.

3.5.2.4 GAIT ANALYSIS

The height and mass for each subject, as was recorded at Stellenbosch University was used. Pelvic width and other anthropometric data were measured as described by Vaughan *et al* (1999) (table 3.1).

Table 3.1 Height, mass and anthropometric data measurements

Parameter description	Measurement (mm)
Total body height (m)	At US as described above
Total body mass (kg)	At US as described above - subject wearing only shorts and a T-shirt.
ASIS breadth (mm)	With a calliper, the distance between the anterior superior iliac spines is measured.
R&L thigh length (mm)	Tape measure/calliper – the vertical distance between the superior point of the greater trochanter of the femur and the superior margin of the lateral tibia is measured.
R&L mid-thigh circumference (mm)	Tape – the circumference is measured perpendicular to the long axis of the leg at a point midway between the trochanteric and tibial landmarks.
R&L calf length (mm)	Tape/calliper – the vertical distance between the superior margin of the lateral tibia and the lateral malleolus
R&L mid-calf circumference (mm)	Tape – is measured perpendicular to the long axis of the lower leg, at the maximum circumference.
R&L knee diameter (mm)	Callipers – maximum diameter of the knee across the femoral epicondyles
R&L foot length (mm)	Callipers – the distance from the posterior margin of the heel to the tip of the longest toe
R&L foot breadth (mm)	Callipers – the breadth across the distal ends of the metatarsal I and V is measured
R&L malleolus height (mm)	Callipers – with the subject standing, the vertical distance from the standing surface to the lateral malleolus
R&L malleolus width (mm)	Callipers – the maximum distance between the medial and lateral malleoli

Various kinematics data was monitored using 15 retro reflective spherical markers taped on the following anatomic locations of both lower extremities: the anterior superior iliac spines, the sacrum, the lateral aspects of the mid thigh, the knee and the mid calf, the lateral malleolus, the base of the heel and the dorsal aspect of the foot between the second and the third metatarsals. According to Steinwender *et al* (2000), a major cause for variation in the gait analysis data is attributed to the errors of marker re-application. According to Noonan *et al* (2003) substantial variations also exist in data when the same CP patient is evaluated by different people. An attempt was made to minimise this effect and the same research assistant C therefore measured anthropometric data and applied the markers. However, due to time constraints this was not always possible and research assistant B took some of the measurements at baseline testing. Research assistant B took all measurements and applied the markers for the second measure as assistant C immigrated out of SA prior to the second testing.

The subjects walked barefoot, without orthotics, down an 11m carpeted walkway independently if possible, but were allowed a walking aid if necessary, and instructed to walk at their normal comfortable walking speed (figure 3.5). Three to eight trials were recorded to ensure that at least three trials captured a complete full stride length of the selected side.



Figure 3.5 Gait Analysis

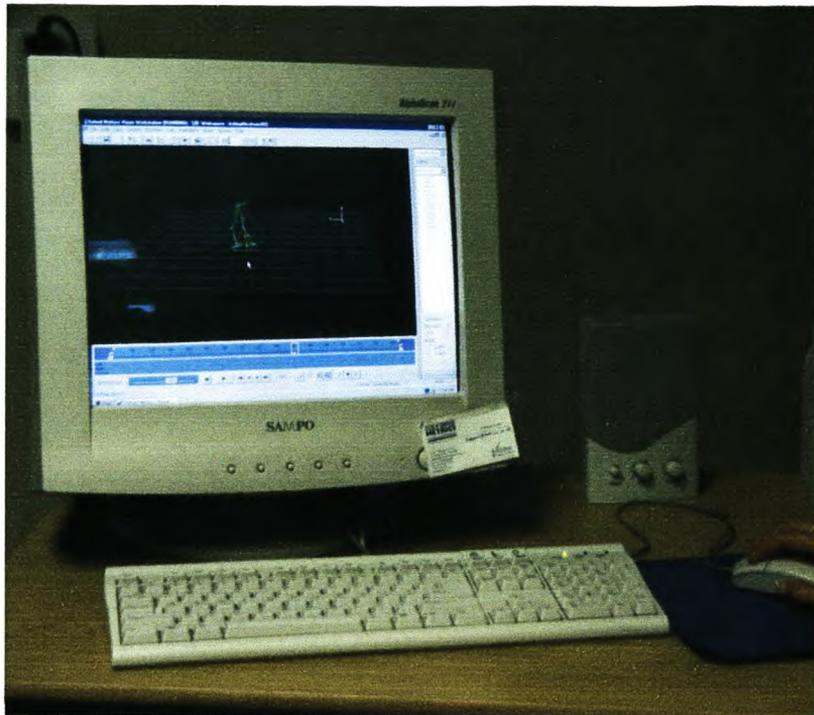


Figure 3.6 BodyBuilder® 3.53

The kinematic variables recorded for the purpose of this study by the BodyBuilder® 3.53 (figure 3.6), included:

- Knee, ankle and hip joint angles at mid-stance phase (°)
- Maximum knee extension during terminal swing phase (°) / knee flexion at initial floor contact (°)
- Maximum hip extension during stance (°)

The temporal distance parameter variables recorded for the purposes of this study, included:

- Stride-length (mm)
- Stride frequency (cadence) (steps/min)
- Velocity (mm/s)
- Vertical oscillation of the sacrum (mm)
- Vertical oscillation of the heel marker (mm)

These measurements of gait function are indicative of overall gross motor function and correlate directly with levels of neurological involvement in persons with CP (Abel and Damiano, 1996). The vertical oscillations of the sacrum and the heel marker have been correlated with energy efficiency during walking for normal people (Williams and Cavanagh, 1987) and were measured for comparison with the EOM test results.

3.6 INTERVENTION:

THE PROGRESSIVE RESISTED (PRE) STRENGTH TRAINING PROGRAM

The experimental group took part in a strength-training program, three times a week for eight weeks at Eros school. These training sessions took place during their free periods. The available time per session depended on how fast the subject walked to and from the gym and classroom and whether the subject had a single or double free period (one periods = 30 min). The available time per session determined the number of exercises completed. A minimum of eight exercises (see section 3.6.1) had to be executed to consider successful completion of that session.

The exercises were selected individually according to the subject's ability and needs as was determined in consultation with each subjects' own therapist. The importance of correct selection of exercises was demonstrated in a study by Damiano and Abel (1998). Their intervention targeted hip flexors without including exercises for hip extensors, and found corresponding weakening in already weak hip extensors resulting in even shortened stride length. The exercises in the current study were recorded on a participation record (addendum D). The participants were responsible for ticking off each completed exercise throughout the duration of the trial.

3.6.1 Program format

The core component with the emphasis on strength training, not endurance nor cardio-respiratory fitness, was conducted in circuit format. Flexibility and aerobic exercise were thus excluded from the program to ensure that changes in gait

variables were attributable to strength gains, although free active movement was permitted to *loosen tight muscles*. The exercises comprised a 28-station circuit (table 3.2) of which each subject had to execute a minimum of eight exercises, including three lower limb (LL), two trunk and three upper limb (UL) exercises. A maximum of twelve - five LL, three trunk and four UL exercises were permitted. Where time allowed for more than eight, the subject was allowed to select his own exercises from the four remaining exercises on his/her participation record (addendum D).

The program included a five-minute warm-up on a stationery bicycle. The circuit was completed at the subject's own pace individually or in groups. The subjects were supervised and assisted by the researcher and / or physiotherapist⁶. The physiotherapist was given instructions on performance criteria by the researcher. Supervision and assistance were to ensure correct alignment and execution of movement patterns. Adjustments to resistance were made as required and documented by the supervisor on the subject's participation record. The supervisor also randomly checked the forms for accurate and honest completion. Exercises were sometimes changed by the supervisor to ensure sufficient challenge and to avoid boredom. The composition of the program however, regarding UL, LL and trunk exercises remained the same. Only exercises as illustrated in table 3.2 were selected.

3.6.2 Targeted muscles and muscle groups

From table 3.2 it can be seen that exercises specifically targeted by this program were the trunk muscles, including abdominals and extensors - due to their role in promoting movement control and functional ability (Butler, 1998), hip extensors and abductors - to improve forward propulsion and hip stability (Darrah *et al*, 1999), and knee extensors - to increase range of movement and facilitate forward propulsion (Damiano *et al*, 1995a; Abel and Damiano, 1996). Exercises of the upper limb were also included as execution directly targets the stabilisers. For example while doing bilateral arm abduction with free weights while sitting on a ball, trunk stabilisers are active in order to maintain balance (Styer-Acevedo, 1994; Cholwicki *et al*, 2000).

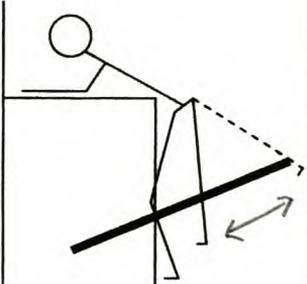
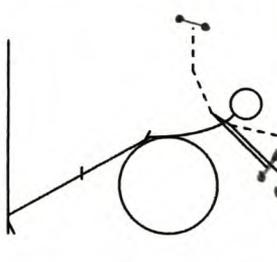
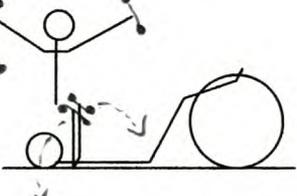
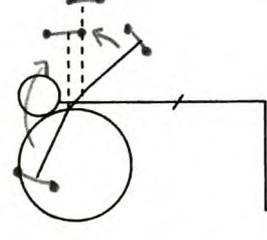
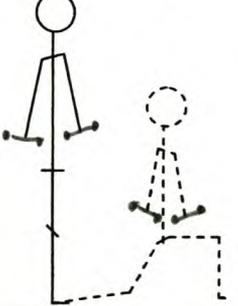
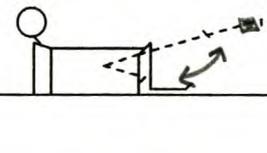
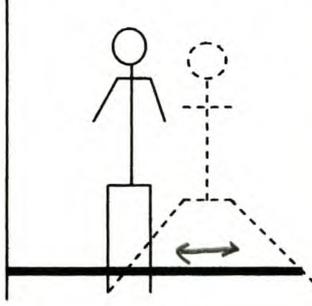
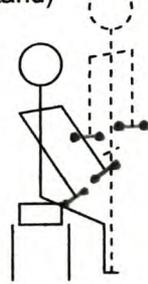
⁶ NDT trained registered physiotherapist employed full time at Eros school

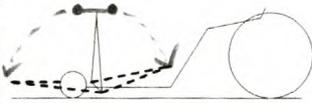
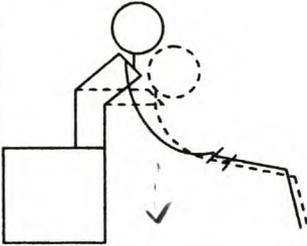
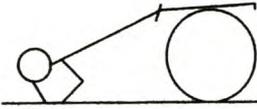
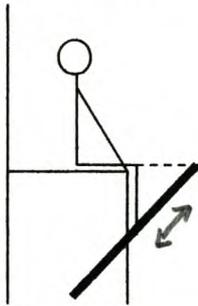
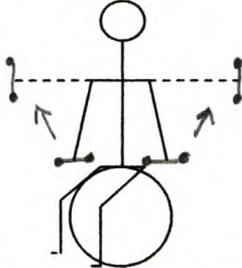
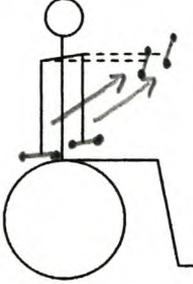
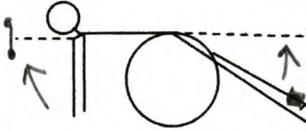
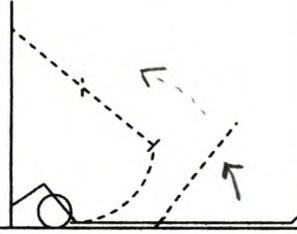
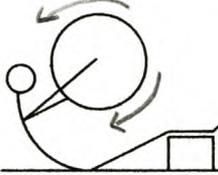
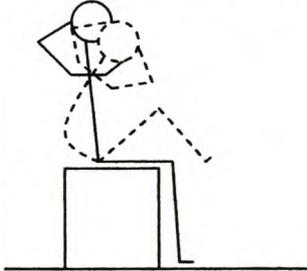
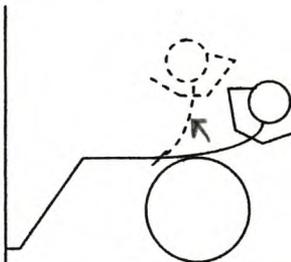
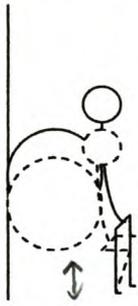
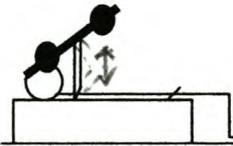
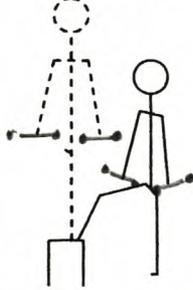
3.6.3 Resistance

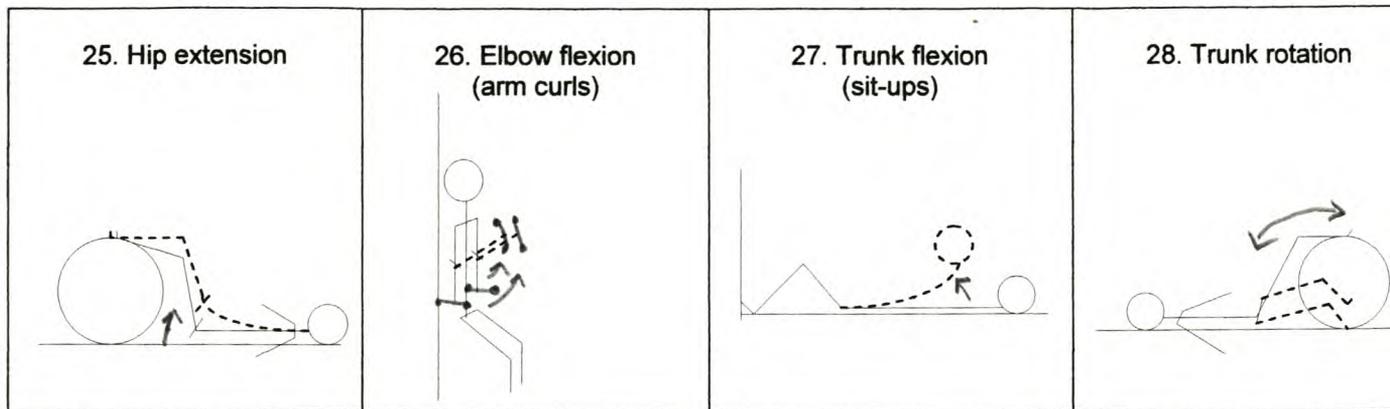
Resistance was provided by free weights, including dumbbells, ankle and wrist cuff weights and bar-with-disc weights, elastic and rubber bands, and balls. Some exercises, for example exercise 11 and 12 (table 3.2), relied on body weight to provide resistance. Initial resistance was set to allow the subject to manage at least one set of six to ten repetitions. The guidelines for PRE training as outlined by McArdle *et al* (1996) were followed.

The speed of execution of each exercise was self-selected – movements had to be controlled and smooth. As soon as three sets of 12 repetitions were reached resistance was increased and repetitions reduced. The process was repeated again as soon as the subject was able to complete 3 x 12 reps.

Table 3.2 Twenty eight station strength training circuit

<p>1. Hip extension</p> 	<p>2. Horizontal shoulder extension (reverse fly's)</p> 	<p>3. Horizontal shoulder flexion (fly's)</p> 	<p>4. Horizontal shoulder flexion (fly's)</p> 
<p>5. Forward lunges</p> 	<p>6. Hip extension</p> 	<p>7. Hip abduction</p> 	<p>8 Hip & knee extension (sit ↔ stand)</p> 

<p>9. Bilateral shoulder flexion & extension</p> 	<p>10. Elbow extension</p> 	<p>11. Elbow extension (dips)</p> 	<p>12. Elbow extension (push ups)</p> 
<p>13. Knee extension</p> 	<p>14. Shoulder abduction</p> 	<p>15. Shoulder flexion</p> 	<p>16. Trunk & hip extension (arm & opposite leg)</p> 
<p>17. Trunk flexion</p> 	<p>18. Trunk flexion & rotation</p> 	<p>19. Trunk flexion & rotation (elbow to opposite knee)</p> 	<p>20. Trunk flexion (sit ups)</p> 
<p>21. Squats</p> 	<p>22. Bench press</p> 	<p>23. Elbow flexion (arm curls)</p> 	<p>24. Hip & knee extension (step up)</p> 



3.7 STATISTICAL ANALYSIS

The services of a statistician were utilised during the development of the protocol and the analysis of the results. Data was analysed using Statistica (version 6).

To determine differences between the control and experimental groups from pre- to post measurement, repeated measures ANOVA was used. In all cases violations of assumptions were checked. In some cases where there was uncertainty about the validity of the standard analysis, non-parametric re-sampling techniques like the Bootstrap test and the Kruskal-Wallis test was done. For determining the relationship between categorical variables, the chi-squared test was used. Correlation coefficients were calculated for continuous variables. A five percent significance level was used as guideline for determining significant differences.

Paired t-tests were also done to determine strength performance differences between the sexes and between the diplegic and hemiplegic groups following strength training for all the variables tested for isometric strength testing, the EOM test and GA. In all cases violations of assumptions were checked.

3.7.1 Effect of randomisation

Subject characteristics pertaining to age, height, weight, gender, distribution of involvement and severity of crouch gait as determined by the knee angle in mid-stance phase were assessed to determine the effect of randomisation.

3.7.2 Isometric strength testing

Most subjects in the current study demonstrated a marked lack of muscle endurance throughout the five second test period. To enhance reliability of measurement, the highest workload (N) at each angle was recorded (Damiano *et al*, 2002). As it can be argued that the sum of the changes is more representative of the total effect, for each subject the average change for each muscle group ie knee extensors and hip abductors, was also determined and then summed and analysed for comparison with individual effect sizes.

3.7.3 Gait Analysis

Biomechanical characteristics were determined using Workstation, BodyBuilder®, GaitLab® and Microsoft Excel®. The values for the temporal distance and kinematic data for the three trials recorded were averaged and used for analysis.

3.7.4 Economy of Movement test

The mean of the values for each variable, HR, VO₂ and VE, over the last two minutes was calculated for each workload (2km/h, 3km/h and 5km/h) and used for analysis

3.7.5 Questionnaire

Although the value of composite scoring is debatable, composite scores were calculated for the Lickert scale type questions for both sections A and B relating to perceptions of body image and functional competence respectively and used for

analysis. Individual scores were also analysed for comparison using ANOVA and Bootstrap analysis

Qualitative analysis and descriptive statistics were used to discuss responses to the open-ended questions.

3.8 ETHICAL ASPECTS

The following ethical considerations were addressed:

1. Confidentiality: All participants and their parents or legal guardian were assured that all the information collected would be treated as confidential. The results will be published, without disclosure of the participants' identity. (Addendum A)
2. Informed written consent from the parents or legal guardians of the participants was obtained. (Addendum A)
3. Informed assent from the child was obtained. (Addendum B)
4. Consent was obtained from the Department of Education and the Headmaster of Eros School. (Addendum E)
5. The study was registered with Research and Ethics Committee from the Faculty of Health Sciences, Stellenbosch University (ref. no. 2003/021/N)
6. Consent for photographs taken during testing and participation for use in presentations and publications was obtained from the subjects and their parent / legal guardian.
7. The exercise program was performed under the supervision of the researcher, a registered physiotherapist and a registered Physiotherapist employed at EROS school.
8. A registered nurse or doctor was available at the school should any accidents or injuries have occurred during or as a result of participation in the exercise program.
9. The results will be made available to Eros School, the school doctor, the physiotherapy department, and to the parents upon request.
10. Both groups continued as usual with Physiotherapy, Occupational Therapy and Speech Therapy as well as with school and sport programs.

11. Participants in the experimental group were encouraged to continue with the program, with or without supervision. Organization of supervision and times were their responsibility but were monitored by a physiotherapist from the school.

CHAPTER 4

RESULTS

Following the demographic representation of the study sample and a summary of the effect of randomisation, the results of the outcome measures used to investigate the impact of PRE strength training on adolescents with CP will be represented in accordance with the objectives set in chapter 3 (3.1.1).

4.1 DEMOGRAPHICS

Thirty seven subjects originally participated in the study, n=13 in the control group and n=24 in the experimental group. Two subjects from the experimental group were withdrawn due to a prolonged period of absenteeism. Four subjects were withdrawn from the statistical analysis, one from the experimental group and three from the control group, for the following reasons:

- one subject was selected to participate in sport at provincial level
- one subject had unexpected international sport commitments
- one subject was inaccurately diagnosed and
- one subject although allocated to the control group insisted on participating in resistance training

A description of the remaining subjects (n=31) appears in table 4.1.

Table 4.1 Description of subjects

Characteristics	Experimental group (n=21)	Control group (n=10)
Age mean(range)	15.86 years (13.5yrs – 18.92yrs)	16.28 years (14.0yrs - 18.33yrs)
Male: Female	13: 8	6: 4
Diagnoses (♂ : ♀):		
Hemiplegics (L)	4 (3:1)	4 (3:1)
Hemiplegics (R)	4 (3:1)	4 (1:3)
Diplegics	12 (6:6)	2 (2:0)
Triplegics	1 (1:0)	0
Quadriplegics	0	0
Height mean (range)	157.47cm (140cm – 180.4cm)	152.34cm (141.2cm – 169cm)
Weight mean (range)	51.1kg (35.4kg – 70.5kg)	43.3kg (28kg – 71.7kg)
Assistive devices:		
crutches	1	0
wheelchair	1	0
Orthotics:		
SMO	1	0
AFO	0	0
KAFO	0	0

To enable comparison with other studies, severity was classified according to the magnitude of crouch. Knee angle at midstance, where the swing foot passes the weight bearing foot (Vaughan *et al*, 1999), was used for this classification (table 4.2).

Table 4.2 Classification of severity of crouch according to knee angle at midstance

Characteristic	Experimental group (n=21)		Control group (n=10)	
	Diplegics	Hemiplegics	Diplegics	Hemiplegics
Knee angle at midstance				
> 20° (severe)	9	5	2	2
10 – 20° (moderate)	3	2	0	6
< 10° (mild)	1	1	0	0

4.2 EFFECT OF RANDOMISATION

The process of systematic randomisation used in this study was successful for age, height, gender and severity allocation (as determined by the knee angle at midstance phase). However the subjects in the control group differed significantly from the experimental group for weight ($p=0.02$, see figure 4.1) and distribution of involvement ($p=0.03$, see figure 4.2). Although randomisation appeared to be effective, the control group did differ significantly from the experimental group at pre-testing for the following variables assessed: total muscle strength, maximum hip extension in stance phase and minute ventilation (VE) at 2, 3 and 5 km/h.

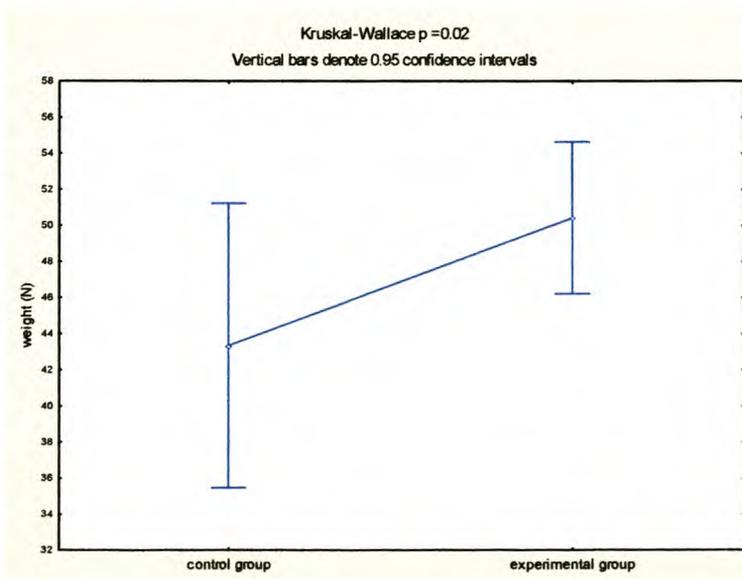


Figure 4.1 Weight difference between control and experimental groups

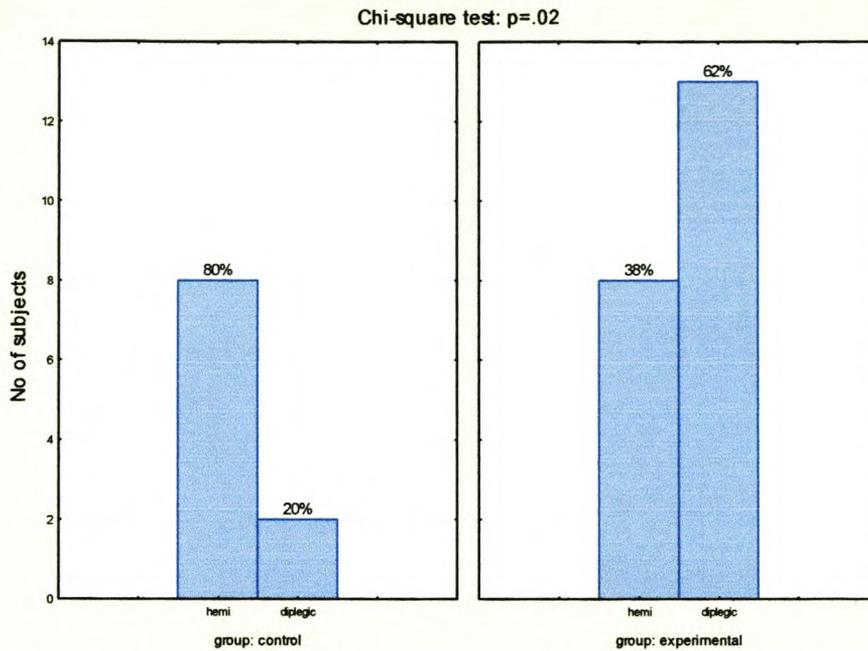


Figure 4.2 Categorized histogram of the difference in diagnosis between the control and experimental groups

4.3 EFFECT OF PRE ON MUSCLE STRENGTH

The means and standard deviations for knee extension and hip abduction force for each subject is represented in table 4.3. The changes in muscle strength between the control and experimental groups were not statistically significant for any of the measures at 30 and 60° knee extension or at 10 and 20° hip abduction, or for total muscle strength.

Table 4.3 Mean, standard deviation and range of isometric knee extension and hip abduction force (in Newtons) across angles and assessment times

	Pretraining		Post training	
	Experimental group	Control group	Experimental group	Control group
Knee extension				
30°				
mean	177	168	206	164
SD	61	49	73	60
range	63 – 254	100 – 253	54 – 328	91 – 308
60°				
mean	310	292	334	296
SD	102	70	88	48
range	150 – 504	217 – 441	200 – 525	231 – 392
Hip abduction				
10°				
mean	65	62	78	65
SD	33	10	36	16
range	0 – 120	47 – 73	33-193	40 – 75
20°				
mean	57	55	71	59
SD	33	14	34	12
range	0 – 150	35 – 77	30 – 152	35 – 75
Total muscle strength (knee ext + hip abd)				
mean	609	588	689	596
SD	203	114	212	116
range	213 - 856	436 - 736	328 - 1193	407 - 107

However bootstrap analysis of total muscle strength change between the experimental and control group was statistically significant (figure 4.3). Bootstrap analysis also showed significant trends for knee extension at 30° as well as hip abd at 10° and 20° (figures 4.4a, b and c).

To compensate for significant weight differences between the control and experimental groups, analysis was done for both absolute strength values (N) as well as values corrected for weight (N/kg) and compared. Variation in weight did not effect results significantly, with $p=0.09$ for total muscle strength (N) and $p=0.18$ for corrected total muscle strength (N/kg).

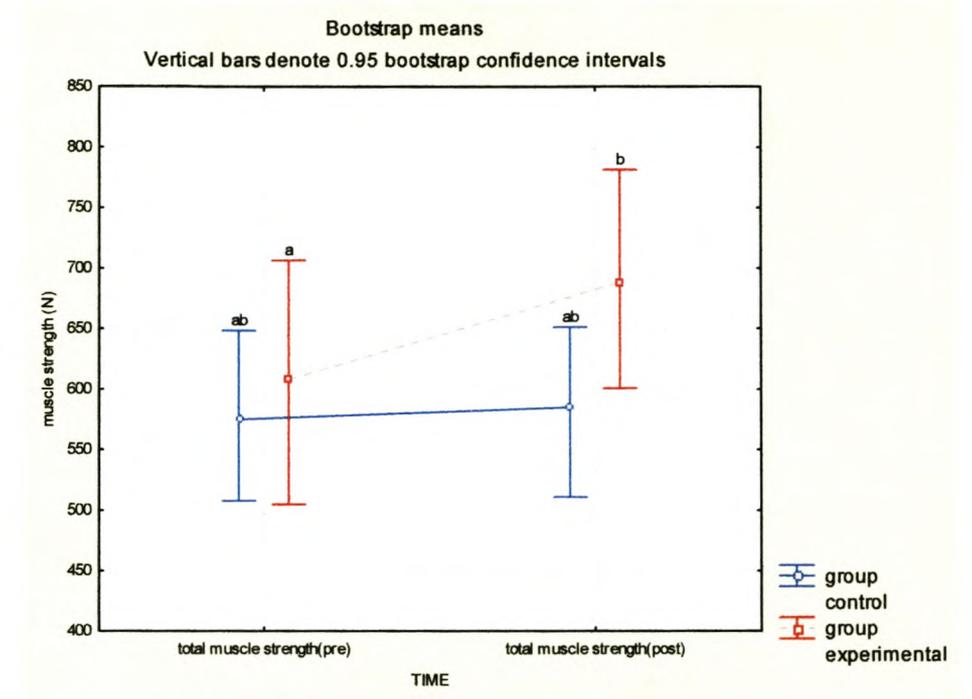


Figure 4.3 Graph depicting average total muscle strength (pre to post) for the control and experimental groups. Different letters indicate significant differences on a 5% level.

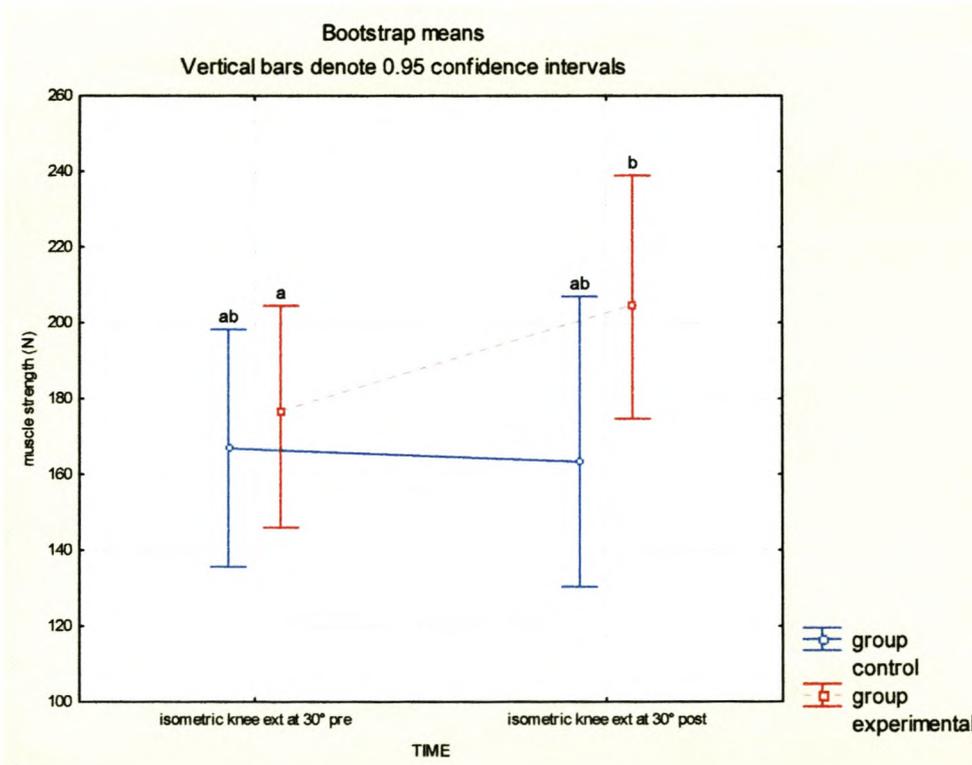


Figure 4.4a Graph depicting knee extension muscle strength (pre to post) at 30° knee flex for the control and experimental groups. Different letters indicate significant differences on a 5% level.

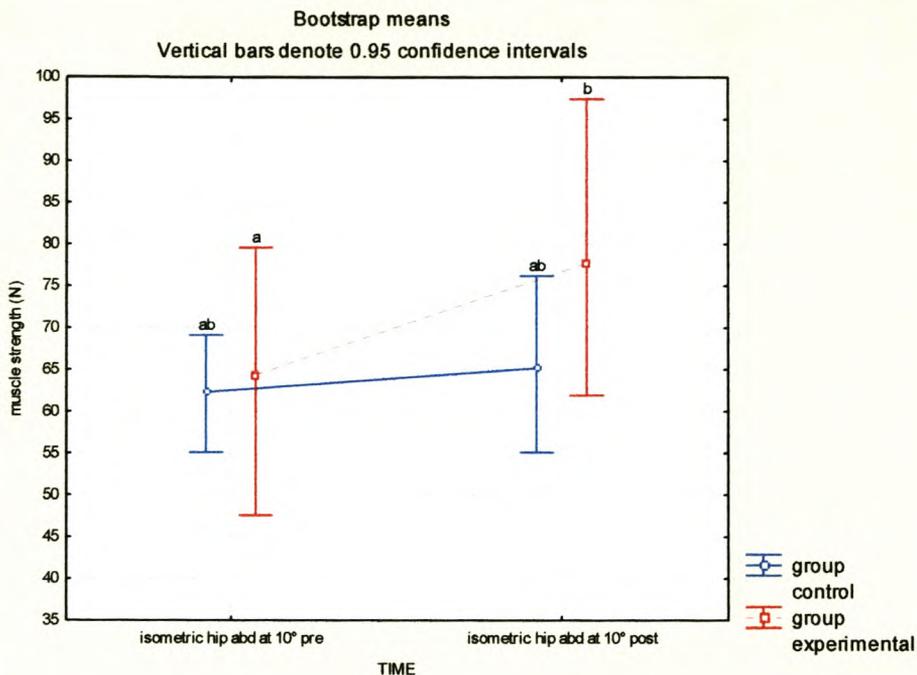


Figure 4.4b Graph depicting hip abduction muscle strength (pre to post) at 10° hip abd for the control and experimental groups. Different letters indicate significant differences on a 5% level.

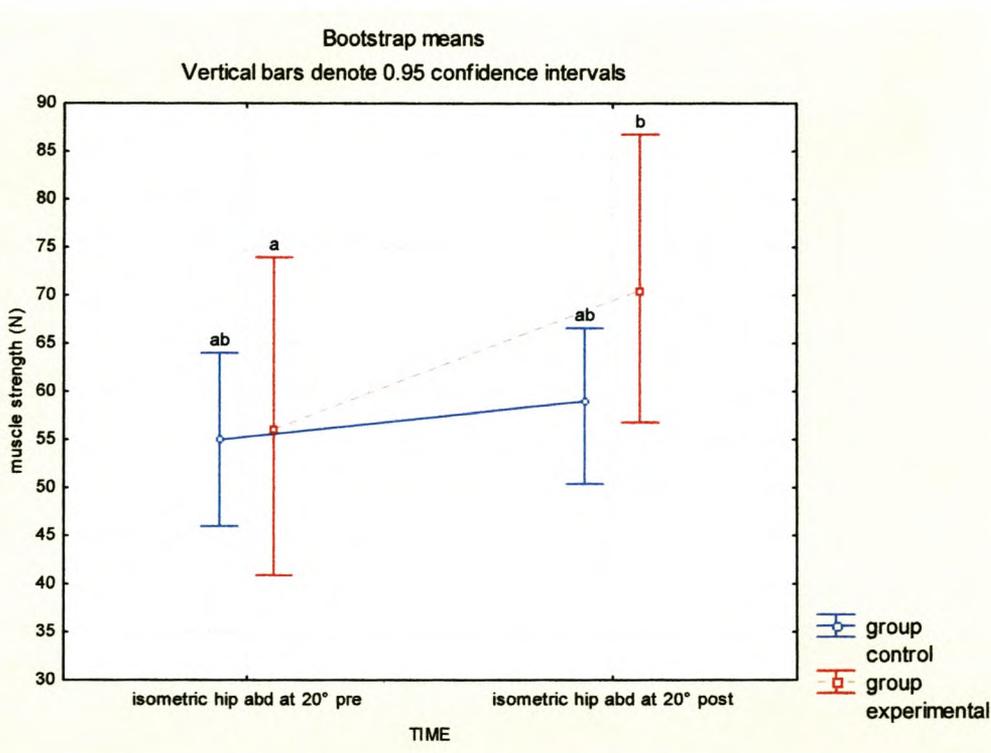


Figure 4.4c Graph depicting hip abduction muscle strength (pre to post) at 20° hip abd for the control and experimental groups. Different letters indicate significant differences on a 5% level.

Paired t-test analysis for selected groups, showed statistically significant strength gains for the experimental diplegic group for knee extension at 60° and hip abduction at 10° and 20° as well as for total muscle strength (table 4.4). Paired t-test could not be done for the diplegic control group as n=2 was too small for analysis.

Table 4.4 Comparison between the diplegic and hemiplegic groups for knee extension and hip abduction muscle strength (N)

		Diplegic experimental			Hemiplegic experimental			Hemiplegic control		
		mean	SD	p	mean	SD	p	mean	SD	p
Knee ext 30° (N)	pre	160.8	56.5		203.6	61.0		166.1	50.0	
	post	188.4	65.9	0.11	234	78.9	0.2	171.5	62.0	0.70
Knee ext 60° (N)	pre	266.8	75.1		380.1	103.4		288.8	63.5	
	post	313.9	73.0	0.03*	366.8	105.3	0.55	290.0	35	0.93
Hip abd 10° (N)	pre	52.7	29.7		84.1	30.1		63.3	11.1	
	post	64.0	21.8	0.03*	101.8	43.1	0.09	67.4	14.4	0.4
Hip abd 20° (N)	pre	46.5	35.2		73.6	22.6		56.6	13.8	
	post	60.3	32.1	<0.01*	88.0	32.1	0.10	61.0	9.8	0.37
Total muscle strength (N)	pre	562.8	163.7		741.5	199.4		574.6	87.9	
	post	626.6	172.5	0.01*	791	242.2	0.24	590.8	88.6	0.64

* p < 0.05

No significant differences were found between males and females.

With the outliers removed (red circled blue dots), the severity of crouch as classified according to the knee angle in midstance during walking, correlated only with the change in muscle strength of the hip abductors at 20° (figure 4.5). There was no significant correlation for severity and change in muscle strength for the group for either knee ext at 30 and 60°, or for hip abduction at 10°.

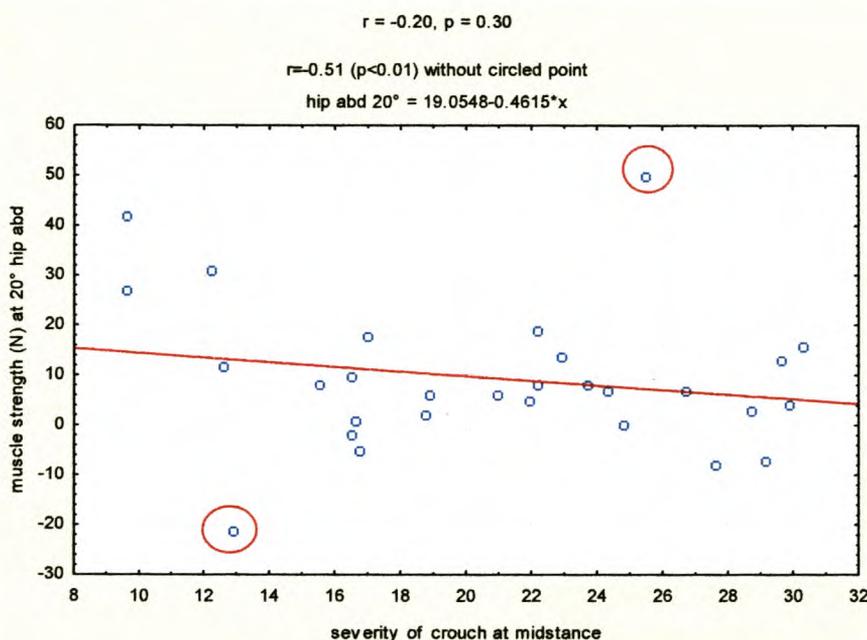


Figure 4.5 Graph depicting the correlation between the change in muscle strength for the whole group, at 20° hip abduction and change in magnitude of crouch in midstance

Even when corrected for weight (N/kg) a negative correlation existed for severity and the change in hip abductor strength at 20° ($r = -0.38, p = 0.05$). For the experimental group alone this correlation was even higher ($r = -0.6, p < 0.01$).

No correlations were found for number of exercise sessions or number of exercises and any of the variables tested, including muscle strength, all gait variables as well as EOM test variables.

4.4 EFFECT OF PRE ON GAIT

For all gait variables measured, no statistical difference existed between the control and experimental groups regarding characteristic allocation at pre-participation testing, except for maximum hip extension in stance phase. Table 4.5 illustrates the changes that occurred in the temporal distance and kinematic data variables measured. Statistically there were no significant differences for any of the variables between the control and the experimental groups.

Table 4.5 Mean, standard deviation and magnitude of change in gait variables before and after training program

	Free speed									
	Pretraining				Post training				Mean change	
	exp		control		exp		control		exp	control
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Knee angle at midstance phase (°)	19.3	9.2	19.1	5.5	17.8	9.2	19.2	7.8	+1.5	-
Ankle angle at midstance phase (°)	-8.6	6.1	-9.6	2.1	-7.7	6	-11	5.2	+0.9	-
Hip angle at midstance phase (°)	20.1	8.9	14.6	7.7	18.4	7.9	15.8	5.5	+1.6	-
Knee angle at heel strike (°)	26.74	6.61	26.62	6.66	25.36	8.17	25.23	7.97	-1.38	-1.
Max hip ext in stance phase (°)	-5.67	9.24	1.36	7.62	-4.95	8.45	-1.18	7.87	+0.72	-2.
Velocity (mm/s)	1075.6	235.4	1128	132	1075.6	235.4	1171.4	141.9	+43.7	+4.
Stride length (mm)	1111.9	207.3	1135.4	144.7	1129.4	201.5	1143.9	128.7	+17.5	+
Cadence (steps/min)	114.5	15	119.9	11.6	116.9	15.8	123.1	11.7	+2.4	+

4.4.1 Effect of PRE on free walking velocity

The mean free walking velocity (table 4.5) increased for the experimental group by 4.1% and for the control group by 4.3%. Statistically this change from pre to post, as well as the difference between the two groups was not significant ($p=0.88$).

4.4.2 Effect of PRE on stride length

Mean stride length improved by only 17.5mm (1.6%) for the experimental group compared to 8.5mm (0.7%) for the control group (table 4.5). The difference between the two groups was not statistically significant ($p=0.67$).

4.4.3 Effect of PRE on crouch gait

To determine whether PRE resulted in more erect alignment, the ankle, knee and hip angles were measured in midstance phase. A more upright posture, more accurately represented by the sum of all the changes that occurred, was noted between the experimental and control groups in that the mean for the experimental group decreased from pre to post whereas it increased for the control group ($p=0.05$, see figure 4.6). The mean in the experimental group for each angle at midstance phase showed slight improvement compared to the control group, which showed a slight decline in all three angles. However, none of these changes were individually statistically significant (table 4.5).

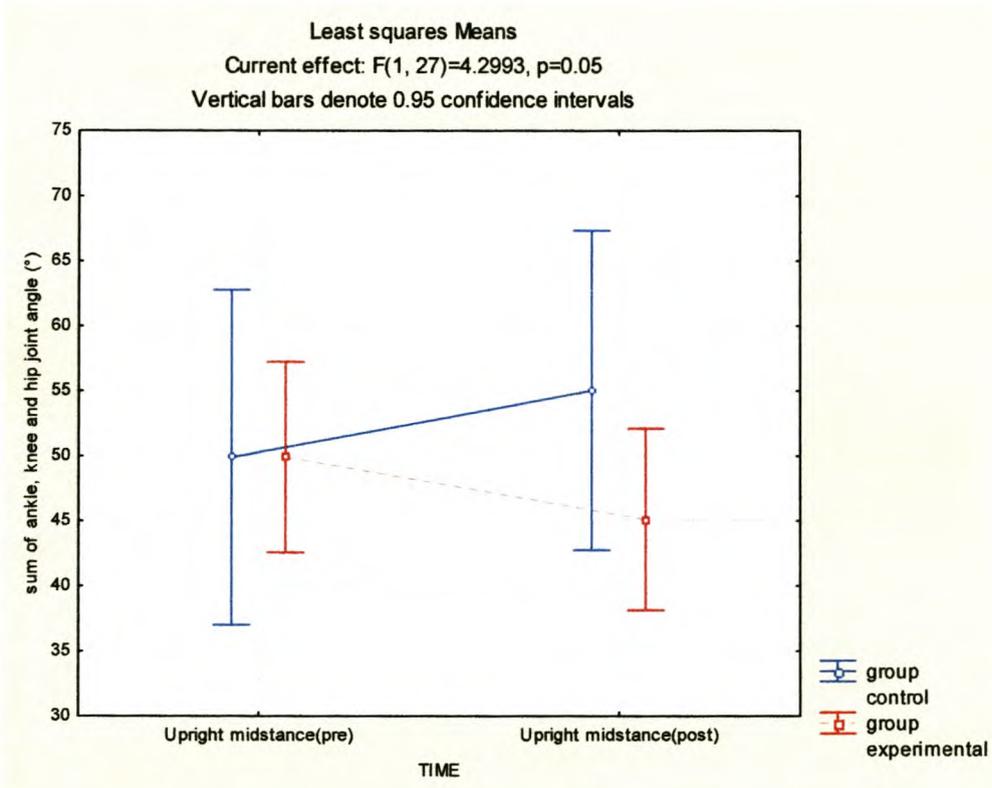


Figure 4.6 Graph depicting the average sum of the joint angles (pre to post) for the control and experimental groups

Mean knee flexion at terminal swing phase and maximum hip extension angle during stance phase also showed no statistically significant change from pre to post (table 4.5).

Paired t-tests did not show any difference between the diplegic and hemiplegic groups or between male and females for any of the gait variables measured.

4.4.4 Effect of PRE on cadence

Cadence (table 4.5) remained effectively unchanged for both control and experimental groups ($p=0.7$). Bootstrap analysis also showed no significant tendencies.

4.4.5 Effect of PRE on sacrum and heel oscillation

Sacrum and heel oscillation showed no significant difference for either variable before and after PRE ($p=0.2$ and $p=0.6$ respectively).

4.5 THE EFFECT OF PRE ON ENERGY EXPENDITURE WHILE WALKING

Mean heart rate (HR), oxygen consumption and minute ventilation showed a slight decline for both the experimental and control groups (table 4.6). From the experimental group five subjects were unable to complete the 5km/h trial and of those subjects one was also not able to complete the 3km/h trial. Results were not significant for either pre- and post analysis or between the two groups. However, one subject who was unable to complete the 3km/h and 5km/h trials at pre testing, was able to complete the 3km/h trial after the training program and even managed three minutes at 5km/h. Another subject also unable to complete the 5km/h trial at pre testing was able to do so following the training program.

There were no significant correlations found for severity of crouch and change in any of the metabolic variables measured, except for the experimental group for change in heart rate at 2km/h ($r=-0.47$, $p=0.05$)

Table 4.6 Mean and standard deviation of change in heart rate, oxygen consumption and minute ventilation before and after the training program

	pretraining				post training			
	exp		control		exp		control	
	mean	SD	mean	SD	mean	SD	mean	SD
2km/h (n)	21		10		21		10	
HR	126	31	124	24.5	118.8	29.8	112.1	20.4
VO ₂ /kg	17.9	7	15.7	4	15	4.2	11.9	2.5
VE	26.4	8.5	20.5	6.6	25.2	9.4	16.2	3.5
3km/h (n)	20		10		21		10	
HR	133.4	37.2	127	29	127.1	35.5	121.6	22.3
VO ₂ /kg	20.4	6.6	17.5	5	18.4	6.7	14.9	4.7
VE	32.4	11.6	25	9.2	30.8	11.6	20.6	6.6
5km/h (n)	16		10		17		10	
HR	147.9	33.1	145.1	24.8	145.6	37	141.4	22.1
VO ₂ /kg	25.5	6.2	22.2	7.4	24.6	6.6	20.5	6
VE	43.5	16.6	33.4	14.5	43.9	15.4	28.4	9.4

Paired t-tests for both the diplegic and hemiplegic experimental groups also showed no significant difference and remained relatively unchanged following strength training (table 4.7). There were also no significant differences between males and females.

Table 4.7 Comparison between the diplegic and hemiplegic experimental groups of mean heart rate, O₂ consumption and minute ventilation at 2, 3 and 5km/h

Metabolic variables		Diplegic experimental			Hemiplegic experimental		
		mean	SD	p	mean	SD	p
HR(bpm)2km/h	pre	140.77	29.71		105.72	21.64	
	post	135.45	27.86	0.34	96.38	14.09	0.15
HR(bpm)3km/h	pre	152.36	36.9		110.6	23.68	
	post	146.85	35.43	0.07	101.24	17.08	0.13
HR(bpm)5km/h	pre	168.36	34.07		132.37	24.68	
	post	170.11	31.51	0.77	121.38	24.61	0.14
VO ₂ /kg(ml/min/kg)2km/h	pre	20.35	8.08		14.17	3.58	
	post	16.53	4.59	0.08	12.78	2.94	0.22
VO ₂ /kg(ml/min/kg)3km/h	pre	23.83	6.36		16.04	4.12	
	post	22.58	6.61	0.26	13.75	2.72	0.07
VO ₂ /kg(ml/min/kg)5km/h	pre	29.03	6.65		22.4	4.68	
	post	28.45	7.19	0.7	20.77	3.79	0.13
VE(l/min)2km/h	pre	28.93	9.5		22.61	6.23	
	post	23.78	7.45	0.07	27.59	12.59	0.24
VE(l/min)3km/h	pre	37.59	11.83		26.42	8.29	
	post	34.28	9.29	0.10	28.73	14.22	0.64
VE(l/min)5km/h	pre	52.75	20.0		36.83	9.65	
	post	51.45	17.7	0.7	36.64	9.38	0.96

4.6 EFFECT OF PRE ON PERCEPTIONS OF BODY IMAGE AND FUNCTIONAL COMPETENCE

4.6.1 Effect of PRE on perceptions of body image

The composite score from the Lickert scale measure relating to perceptions of body image showed a significant improvement for the experimental group compared to the control with $p=0.01$ (figure 4.7).

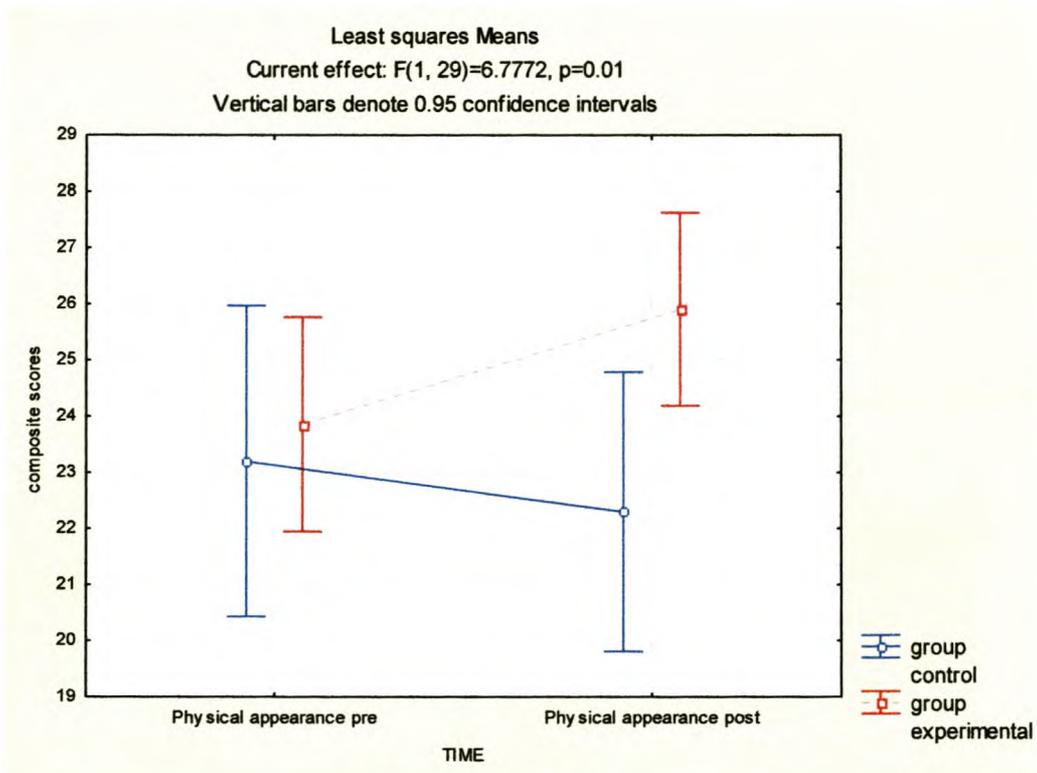


Figure 4.7 Graph depicting average composite scores relating to perceptions of body image (pre to post) for the control and experimental groups

On qualitative analysis of the open-ended questions, responses to “make a list of all the things you like about yourself and your body” (addendum C) related predominantly to body parts with only three subjects commenting on personality and interpersonal behaviour or qualities. Nineteen subjects reported acceptance of their bodies with comments such as “ek hou van al die dinge in my liggam [sic] want die god het vir ons

geskape” and “ek hou van allis [sic] op my ligaam” and “I like my body just the way God mayed [sic] it”.

At pre-participation testing, responses to what the subjects did not like about themselves or their bodies, related mostly to arms and legs and “ek hou nie van my gebrek nie”. In the experimental group nine subjects reported negatively about their arms and legs, three “hou glad niks van die operasie snye op my liggaam nie, want dit lyk nie baie mooi nie” and one subject commented that she was overweight and had “fat thighs, stomach and big chics [sic]”. Responses at the post intervention testing for the experimental group following strength-training, placed less emphasis on body parts with only four comments relating to arms and legs. There were no comments relating to surgical scars or being overweight. Focus was shifted towards “drinking and smoking and using drugs”, “puisies op my gesig”, “nail biting” and “fighting” as things subjects did not like about themselves.

Responses from the control group were similar, with seven subjects happy with their bodies and four subjects referring to arms and legs as body parts they do not like about themselves. At second measure those four subjects still did not like either their arms or legs.

4.6.2 The effect of PRE on perceptions of functional competence

The composite score for the Lickert scale measure relating to perceptions of functional competence, showed no significant difference ($p=0.9$, see figure 4.8).

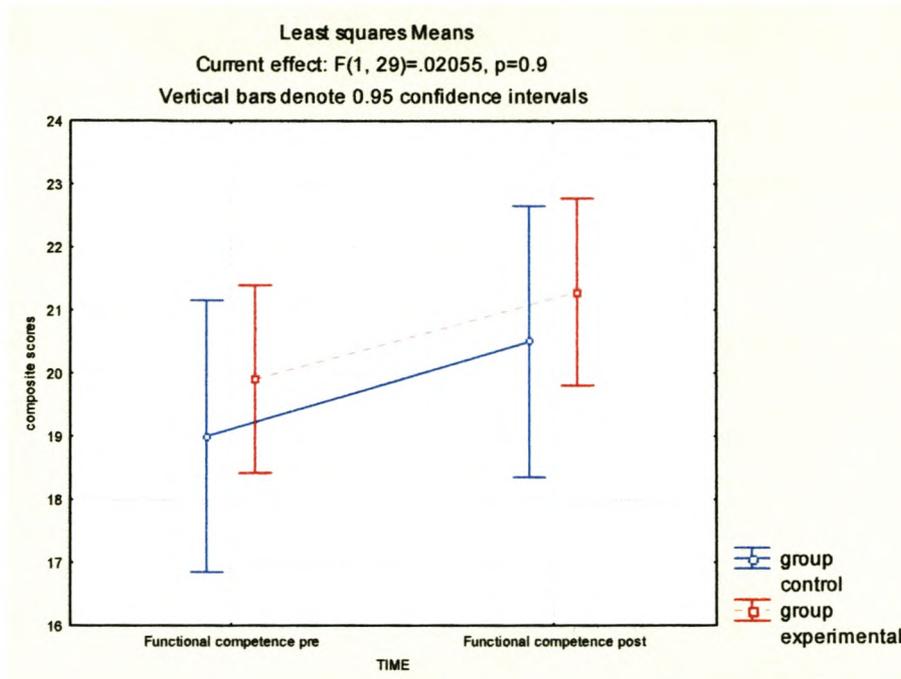


Figure 4.8 Graph depicting average composite scores relating to perceptions of functional competence (pre to post) for the control and experimental groups

When analysing the individual scores for perceptions of functional competence, bootstrap analysis did however show positive significant tendencies for questions 1 (figure 4.9) and 5 (figure 4.10) relating to walking ability between classrooms and managing stairs without support respectively (addendum C).

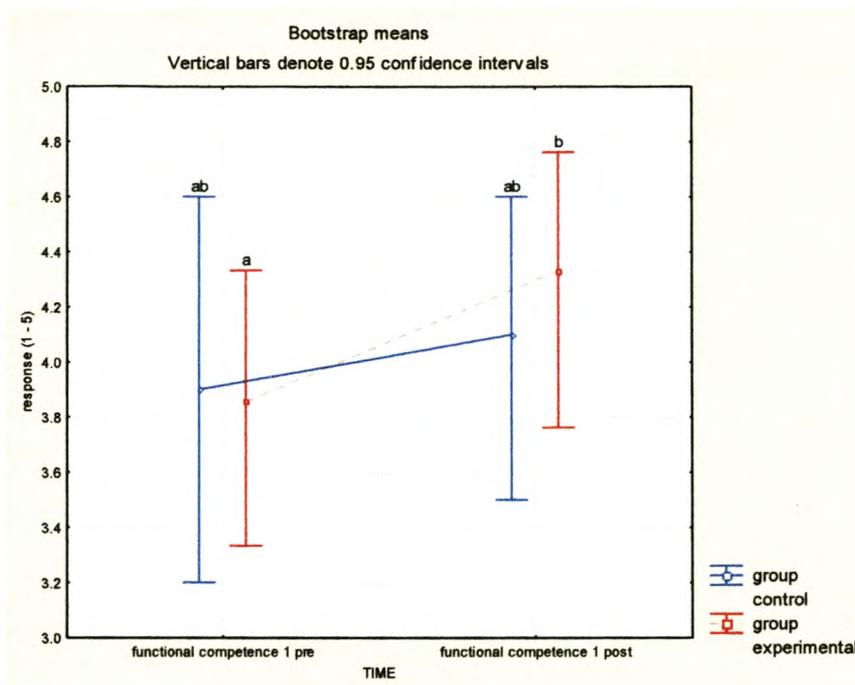


Figure 4.9 Graph depicting average no of responses to question 1 relating to walking comfortably between classes (pre to post) for the control and experimental groups. Different letters indicate significant differences on a 5% level.

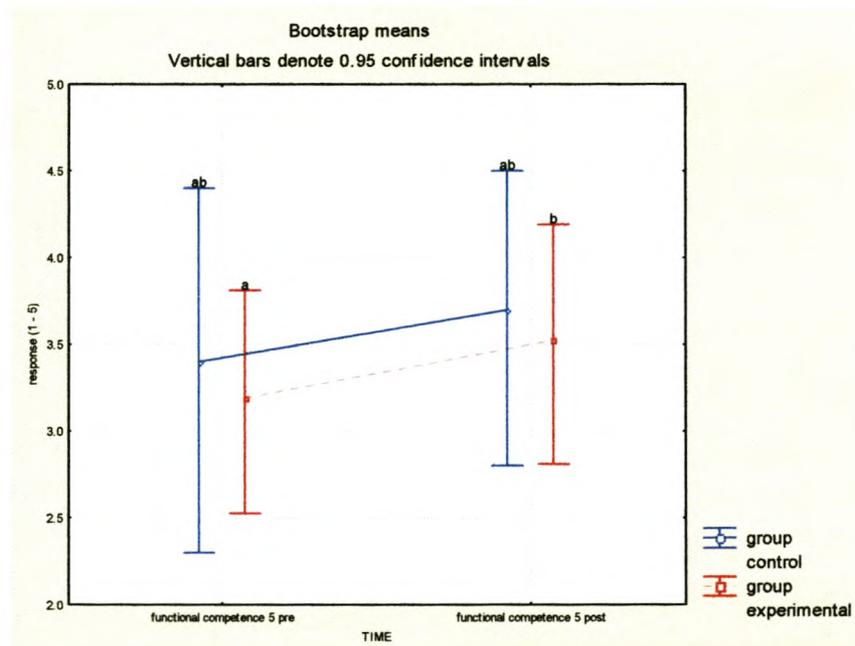


Figure 4.10 Graph depicting average no of responses to question 5 relating to stair climbing without arm support (pre to post) for the control and experimental groups. Different letters indicate significant differences on a 5% level

At pre-participation testing, from the responses to the open-ended question relating to sport, 22 out of 31 subjects (15 in the experimental and 7 in the control group) responded positively to enjoying taking part in sport. Sports such as cricket, soccer, athletics and table tennis were listed. Reasons listed for enjoyment of sport participation included:

- “it is enjoyable [sic] for me”
- “dit hou my bene sterk”
- “dit gee my enirgie[sic]”
- “laat my spiere oefening kry”
- “like to keep myself in shape”

Reasons listed for not enjoying sport participation, included:

- “dit maak my moog[sic]”
- “there is no sport offered that interests me at school”
- “when I was injured there was no one to help me”

Following participation in the strength-training program, responses from the control group remained the same, whereas for the experimental group, nine subjects included exercise or gym training as one of the sports they liked doing and two subjects changed their opinion about sports participation.

In the current study adolescents with CP demonstrated significant improvement for the degree of crouch gait, as measured by the sum of the ankle, knee and hip angles in midstance following comprehensive progressive resisted exercise. Perceptions of physical appearance also demonstrated significant change. Bootstrap analysis showed significant tendencies for the experimental group for increased total muscle strength, as well as for knee extension at 30° and hip abduction at 10° and 20°. No significant changes were demonstrated for walking efficiency, velocity, stride length or cadence. The following chapter will discuss these results in more detail and compare them with findings in the literature.

CHAPTER 5

DISCUSSION

The main purpose of the current study was to determine the impact of a comprehensive resistance training program on children with spastic cerebral palsy (CP). It was postulated that if limited strength-training of two or three muscle groups of the lower limb produced significant strength gains and improvement in function (MacPhail and Kramer, 1995; Damiano and Abel, 1998, Dodd *et al*, 2003), targeting more muscle related to gait, in accordance with the principle of specificity, may result in even better performance. The results from this randomised control trial suggest that progressive resisted exercise does have not only physical benefits but psychological benefits as well.

A discussion of the results of the current study and comparison to studies that investigated similar aspects will be presented. Due to the complexity of the diagnosis of CP and the diverse clinical presentation, it is inevitable that within study samples variation will exist for several characteristics, including distribution of involvement and severity of functional disability. Therefore a brief discussion of the demographic characteristics of the study sample and the effect of the systematic randomisation process and the implications thereof on the statistical analysis of the data used in the current study will first be discussed.

5.1 DEMOGRAPHIC REPRESENTATION

The subjects in the current study were adolescents between the ages of 13 – 18 years and were only of the spastic-type CP. The sample included hemiplegics, diplegics and one triplegic participant (see table 4.1). Their age distribution differed from the demographic description of the samples used in studies by Damiano *et al* (1995a, 1995b) and Damiano and Abel (1998) where ages ranged from six to 14. In studies by MacPhail and Kramer (1995) and Darrah *et al* (1999) ages ranged from 11 – 20 years. Age particularly in children, is related to muscle strength (McArdle *et al*, 1996) as well as to gait parameters such as stride length and velocity and joint angles (Norkin and Levangie, 1992). The differing age ranges in children makes comparison between the studies difficult. For the

current study as well as for the study of MacPhail and Kramer (1995), the researchers attempted to correct for age with body mass. This ratio however does not make allowances for the large variation in body composition that may occur within age groups and may therefore have influenced the results. Deterioration in gait occurs with age in the CP population. According to Johnson *et al* (1997) the double support phase increases while the single support phase decreases with time and growth. Kinematic analysis also revealed loss of range of movement about the knee, ankle and pelvis in their longitudinal study conducted over a mean of 32 months on 18 subjects with spastic diplegia, ranging from four to 14 years. The natural variation in body mass and stature together with the deterioration in gait parameters that occurs over time in this population make comparison between the studies difficult.

Gender distribution was very similar between the studies and did not appear to be a contributing or influential variable. There were no significant differences between male and female subjects for any of the variables measured in all of the above studies. These findings concur with Heyward *et al* (1986) [in McArdle *et al* (1996)], who stated that in the normal population men and woman do not differ significantly in either upper or lower body strength when corrected for body mass.

All subjects in the current study were independently ambulant with only one subject using crutches as an assistive device. One subject did however require a wheelchair to cover distances further than 400m. Subjects in the current study were not classified according to their level of functional impairment and were only classified according to the severity of crouch. This enabled comparison with results from the studies by Damiano *et al* (1995a, 1995b) and Damiano and Abel (1998) regarding the magnitude of crouch. Although diplegics are generally considered to be more impaired as was confirmed by analysis using the Gross Motor Function Measure (GMFM) in the studies by Damiano *et al* (1995a; 1995b) and MacPhail and Kramer (1995), the current study was only able to display similar degrees of severity of crouch for both diplegic as well as hemiplegic subjects (see table 4.2).

All participants in the current study were selected from one special school to minimise variability in daily activity and to facilitate supervision of the program. Although the current study lacks a random selection from the general population of adolescent CP learners, the

process of randomisation and the presence of a control group do increase the validity of the study. Generalisability to the whole population of persons with spastic CP however is limited. Comparison studies with samples from other special schools, including schools with higher socio-economic status would have strengthened the study. Not only may variation in therapy protocols and sports programs differ between the schools, modern, high-tech facilities and equipment and after hours accessibility may also influence motivation and compliance.

5.2 EFFECT OF RANDOMISATION

A process of systematic randomisation was used in the current study, whereby every third name drawn from a hat was selected for the control group. Prior to the statistical analysis of the variables measured, the effect of randomisation was determined to ensure representative comparison between the control and experimental groups. Subject characteristics that were measured included: age, height, weight, gender, distribution of involvement and severity of crouch gait. The severity of crouch was determined by the knee angle at midstance which was recorded during gait analysis (Vaughan *et al*, 1999).

Randomisation appeared to be effective for age, height, gender and severity allocation, but the control group did differ from the experimental group at pre-participation testing for weight (see figure 4.1) and distribution of involvement (see figure 4.2). A curvi-linear relationship exists between weight and muscle strength (McArdle *et al*, 1996). To compensate for the weight differences between the control and experimental groups, absolute strength measures in newtons (N) were corrected for weight and compared. Variation in weight however did not affect the individual isometric strength test results or the total muscle strength analysis (see 4.3). The ratio method used in the current study however did not take into account variation in body stature and thus the heavier subjects were possibly penalised by the larger denominator. Using allometric scaling as described in McArdle *et al* (1996), a mathematical procedure that incorporates fat-free body mass and relates the body size variable to another variable, in this case, muscle strength, would have been more accurate.

To compensate for the weight differences between the control and experimental groups for the measurement of oxygen consumption during walking in the Economy of Movement test, oxygen consumption (VO_2) was also corrected for weight. The use of allometric scaling would have provided a more accurate measure. However, the formula millilitres per minute per kilogram ($\text{ml}/\text{min}/\text{kg}$), is accepted for analysis by researchers in the field of sports physiology (American College of Sports Medicine, 1998).

The hemiplegic group in the current study was equally represented in the control and experimental groups. However in the control group there were only two subjects with diagnosed spastic diplegia, compared with the 12 in the experimental group. This limited the statistical comparison between the two groups to paired t-tests. Analysis for the diplegic control group could not be done as sample size was too small.

The sample was one of convenience and the size ($n=31$) was small due to an attempt to reduce environmental and treatment protocol variability. As a result, the sub-groups as determined by the various characteristics (see table 4.1) within the study sample were too small to enable sufficient analysis of comparison between the control and experimental groups. Larger sample sizes and or more stringent inclusion criteria are recommended.

The process of systematic randomisation used for the current study appeared to be successful, although the control group differed from the experimental group at pre-participation testing with analysis of the following variables: total muscle strength, maximum hip extension and minute ventilation (VE) at two, three and five km/h . However, these differences did not seem to affect the statistical analysis used in the current study.

5.3 THE EFFECT OF STRENGTH TRAINING ON THE MAGNITUDE OF CROUCH GAIT

Crouch gait is manifested by increased knee flexion at heel strike, with maintenance of a flexed knee posture throughout the stance phase of gait (Damiano *et al*, 1995a). The results from the current study verify that a strength training program targeting multiple muscle groups does result in a more upright posture while walking at freely selected speed. The sum of the change that occurred at the joint angles of the ankle, knee and hip in midstance, showed statistically significant improvement (see figure 4.6).

The current study at pre-participation testing verified the findings of Kramer and MacPhail (1994) and Damiano *et al* (1995a), that isometric muscle strength at 30° knee flexion was inversely related to the magnitude of crouch as determined by the knee angle at heel strike during gait. Damiano *et al* (1995a) concluded from their observational study of single-group design that increased quadriceps muscle strength resulted in the degree of crouch being improved to a more extended position. These authors demonstrated this by measuring the knee angle at heel strike across free and fast walking speeds. However, they only found statistically significant change for knee extension at free walking. They also recorded the maximum knee extension attained by each subject during stance, but statistical analysis showed no significant change in this variable. The results from the current study demonstrated that although a significantly more extended position at midstance was obtained following comprehensive strength training, knee angle at terminal swing did not improve, despite increased quadriceps muscle strength as measured at 30°. A possible explanation for this could be that the strength gains noted at 30° were clinically too small. Statistical analysis for knee extension muscle strength did not indicate significant change between the control and experimental groups. However, to avoid type II error, where one fails to reject the null hypothesis, when in fact it is not true, probability plots and bootstrap analysis indicated significant trends for increased muscle strength in the experimental group (see figure 4.3).

Damiano *et al* (1995a) and MacPhail and Kramer (1995) demonstrated a decrease in the degree of crouch gait by targeting the knee musculature only. However, the magnitude of crouch, although per definition focuses on the knee joint only, is also determined by plantar flexion and hip extension force generation. The composition of the strength training circuit in the current study therefore included exercises targeting hip extensors such as squats, with or without support, steps, as well as open-chain hip extension exercises with cuff weights and elastic bands (see table 3.2). The circuit however, did not include specific exercises for musculature around the ankle and foot. According to the subjects' therapists many of them had fixed foot and ankle deformities, including tendon Achilles contracture and equines deformities or exhibited excessive plantar flexion with resultant zero or very weak muscle power. Exercises executed in standing and sitting on the ball however, should have recruited the ankle and foot stabilisers. Only the step exercise utilised the plantar flexors as movers.

The role of the ankle musculature as contributing factor to the magnitude of crouch should not be underestimated. This is further supported by Norkin and Levangie (1992) who stated that the role of the plantar flexors combined with knee and foot movements during gait is crucial and effects changes in vertical displacement of the body's centre of gravity (COG) throughout the stance phase as well as the ability to propel the body in a forward direction. The subject's COG was not determined for the purpose of this study however, vertical sacrum oscillation was recorded during gait analysis and did not demonstrate a significant change from pre to post intervention measures. Inclusion of more specific exercises for plantar flexion may have demonstrated improved upward and forward motion and reduced the total excursions of the hip, knee and ankle as well as the vertical displacement of the body and which may have also resulted in increased stride length.

During the study it was noted that some subjects had joint contractures of the hip, knee and / or ankle. Passive range of movement (ROM) measurement post participation indicated that 13 subjects had no knee or hamstring contractures and should have had the potential to improve knee extension at initial floor contact. However, statistical analysis of those 13 subjects did not demonstrate significant change for knee extension at heel strike. Furthermore, ten subjects had hip flexion contractures and one subject had excessive dorsiflexion, which also influences the ability to extend the hip and knee and stabilise the ankle at mid-stance phase thereby minimising the effect of a more upright posture (Damiano *et al*, 1995a). Excluding subjects from the study with knee flexion, hip flexion or hamstring contractures as well as those with excessive dorsiflexion, could have potentially strengthened the results of the current study.

Another explanation for the relatively minor improvement seen in the subjects may be their changed behaviour observed during testing. Gait variations exist when one is being observed (McArdle *et al*, 1996). Many of these children develop what the therapists at Eros school term a "physio"-gait, where children walk more upright, show improved heel strike and stride length compared to their habitual walking pattern. This is usually characterised by a more slumped posture with less hip and knee flexion during the swing phase and a shorter stride length. This may have occurred, as both the test venue and tester for gait analysis were unknown to the subjects at pre testing. A more relaxed atmosphere was observed by both the researcher and research assistant at the second

testing session which may have contributed to the small effect size seen in both the temporal distance and kinematic variables tested.

Despite the fact that the results from the current study as well as those from Damiano *et al* (1995a) suggest that the magnitude of crouch decreased following strength training, these findings were based on a single variable measurement and the clinical significance of this change still needs to be determined. Confirmation of improvement from a second variable measure, which both these studies were unable to do, and possibly a third variable measurement would reflect a more valid improvement of crouch gait.

5.4 EFFECT OF STRENGTH TRAINING ON OTHER GAIT VARIABLES

Results from the current study showed minimal increases in free walking speed, stride length and cadence following strength training. The results however did not differ significantly between the control and experimental groups. The results of strength training on free walking velocity, stride length and cadence vary between studies (see chapter 2.6) and will be discussed further below.

5.4.1 Free walking velocity

Free walking speed increased for both the experimental and the control groups in the current study, although the change was relatively small and did not differ significantly between the groups (see table 4.5). A six-week study by Damiano and Abel (1998), using velcro-attached free weights targeting predominantly the knee extensors and hip flexors or extensors, showed an increase in free walking velocity. On the other hand a study by MacPhail and Kramer (1995) that investigated the effect of an eight-week isokinetic strength training program for the knee flexors and extensors, found no change in free walking velocity, despite significant increases in muscle strength.

A possible explanation for this discrepancy regarding the effects of strength training on free walking velocity may be attributable to difference in study samples as well as intervention protocols. The sample in the study of MacPhail and Kramer (1995) were all ambulant and walked without any assistive devices. Strength training of the quadriceps

was limited to 20° knee flexion by the isokinetic device used in this study. More than half of the sample in a study by Damiano and Abel (1998) were dependant on assistive devices for all ambulation and had greater potential for increasing their ROM at the knee as they exhibited a greater degree of crouch at pre-testing and the training protocol encouraged knee extension through full range. Damiano *et al* (1995b) attributed the increased walking velocity to increased knee extensor strength, and to increased stride length due to increased knee extension at heel strike. Although not measured in their study, the sample from MacPhail and Kramer's (1995) investigation might not have experienced significant decrease in knee flexion at heel strike, which therefore may be attributable to the unchanged walking speed. A possible explanation for the small effect size demonstrated in the current study, may be that the strength gains in the quadriceps produced by the strength-training program were too small to produce clinically significant decreases in knee flexion at heel strike and changes in stride length and therefore also in free walking speed.

5.4.2 Stride length

Stride length increased minimally for both the experimental and control groups, with 17.5mm and 8.5mm respectively. The change was however was not significant for either group or between the groups. The researcher theorised that increasing the stability of the hip, by inclusion of strengthening exercises for the hip abductors and extensors as well as the trunk for core stabilisation, the length of the stance phase could be increased allowing a longer step length (Norkin and Levangie, 1992). The effects of a comprehensive program on hip extensor strength, and the effect of hip extension and abduction on the length of the stance phase, was not within the scope of the current study and should be further investigated.

From the investigations utilising gait analysis to measure the effect of strength-training in children with CP (see chapter 2.5) different strength programs produced different results. Despite the significant increase found in stride length by Damiano *et al* (1995a) following strength training limited to the quadriceps only, results from Damiano and Abel (1998), and the current study, indicate that strength training does not significantly effect stride length at free walking speed. Damiano and Abel (1998) utilised three exercises targeting the knee extensors, hip flexors and ankle plantar flexors, while the

current study was more comprehensive and included up to 12 exercises and included the trunk and upper limbs. This may have caused the reduced resultant net effect on the knee extensors, needed for improved knee extension at terminal swing as well as increased stride length. Damiano and Abel (1998) also demonstrated that strengthening hip flexors without strengthening the hip extensors concurrently resulted in corresponding weakness in the hip extensors. This result emphasises the importance of correct selection of targeted muscles as incorrect selection may negate the effect of strength training in other muscle groups.

Both stride length and cadence are linearly related to speed in children without CP (Abel and Damiano, 1996). Damiano *et al* (1995a) and Damiano and Abel (1998) however, concluded that increasing cadence without corresponding stride length, is the strategy implemented by both hemiplegic and diplegic CPs for increasing walking speed. Damiano and Abel (1998) however did demonstrate that for fast walking, diplegics increased their stride length and thereby reduced the exaggerated cadence following strength training. In the current study walking was limited to free walking velocity and comparison with fast walking was not made.

5.4.3 Cadence

The effect of the current strength training intervention also had a limited effect on the number of steps walked per minute (see table 4.5). Change from pre to post participation testing as well as between the control and experimental groups were not significant. Free walking velocity only increased minimally following a comprehensive progressive resisted exercise program and due to its linear relationship with cadence and stride length, the effect on cadence was therefore also small.

One possible explanation for the effectively unchanged walking speed, stride length and cadence in the current study may be the reduced hip excursion for ten of the subjects noted with passive testing of the hip flexors following completion of the program for ten of the subjects. Also no significant change for knee extension at terminal swing was recorded and could therefore not contribute to increased stride length.

Another possible contributing factor for the small effect sizes for velocity, stride length and cadence, could be that the testing venue could only accommodate an 11m walkway. It was observed by the researcher as well as the research assistant responsible for the testing, that the walkway was not long enough to allow a normalised, consistent stride. Often subjects were either still accelerating or beginning to decelerate during the motion captured for processing. Subjects could have continued walking around the cameras and data captured on the second, third and possibly fourth turn down the walkway to ensure even paced captured trials.

5.5 EFFECT OF STRENGTH TRAINING ON PERCEPTIONS OF PHYSICAL APPEARANCE

The current study found a significant improvement in perceptions of body image following participation in a strength training program as did Darrah *et al* (1999) in their investigation of the effect of a community fitness program. The questionnaire excluded direct questions relating to the perceptions of change for both body image and functional competence in order to avoid influencing responses and causing response bias. If the impact was impressionable, responses to the Lickert-scale and open-ended questions would reveal the changes. The composite score from the Lickert-scale section of the questionnaire demonstrated significant change for perceptions of body image for the experimental group as compared to the control group following strength-training (see figure 4.9). This change was also confirmed anecdotally by comments from some of the participating subjects towards the end of the eight-week program. Two girls "...could not wait for summer..." to be able to wear sleeveless tops to "...show off their toned arms and muscles". And two boys measured their upper limb girth and proudly advertised the increase in size to their peers.

The study by Darrah *et al* (1999) utilised a single group design. Comparison with a control group would have increased the strength of their findings and possibly have supported the concept that exercise contributes significantly to psychological well-being for all (McArdle *et al*, 1996). The subjects from their study performed their strength-training in a community fitness centre. Most of the participants were integrated into the regular school system and had never had the opportunity of socially interacting with other teenagers with CP before. Although they also trained among normal individuals there was opportunity for comparison

with their own. The experimental group in the current study has not been exposed to training with normal individuals but rather trained in the school gym either individually or in groups. Although the impact, albeit positive or negative, of training amongst people with CP versus training amongst normal individuals was not evaluated by either of these two studies, individual differences regarding level of confidence and personality of the subjects should however be taken into account and could have influenced the results.

At pre-participation testing, for more than half (19/31) of the sample in the current study, the responses to the open-ended questions reported acceptance of their bodies. However several individual body parts, predominantly relating to arms and legs and “my gebrek” were listed as aspects which they disliked about themselves or their bodies at pre testing. Following completion of the strength training program this emphasis on body parts for the experimental group was less and responses related more towards behaviour and included aspects such as smoking, drugs and nail biting.

Furthermore, comments from the therapists at the school such as “besides improving physically he has become more socially confident, is less reserved and keen to participate in school activities now”; “even those not on the program want to know when the gym classes will resume again” and one therapist even stated that her client now comes to physiotherapy for weight training, “...which is a definite improvement from not coming at all before”, suggest that subjects are motivated to continue. It is important that for exercise to become an integral part of an individual’s lifestyle, the drive must come from within and not be solely determined by external factors. Not only the control group, but learners not involved in the current study also expressed interest and wanted to take part in gym exercise. This might have been due to the enthusiasm of the participants in the program or the physical change that occurred in these individuals. Evaluation of the success of the program regarding long term commitment is not covered in the scope of the current study and follow up of this group is recommended.

5.6 EFFECT OF STRENGTH TRAINING ON PERCEPTIONS OF FUNCTIONAL COMPETENCE

Composite score results from the current study found no significant change in perception of functional ability and concur with the findings from Darrah *et al* (1999). However,

analysis of the individual scores relating to the Lickert-scale section of the questionnaire did show significant trends for two of the questions relating to walking ability between classrooms and stair climbing without arm support (see figures 4.9 and 4.10). Subjective comments by some of the subjects also confirm that improvement in functional ability did occur. One subject, who usually uses a wheelchair for mobility over longer distances, stated he didn't use his wheelchair this year for the school's annual surf-walk fundraiser. Another subject noted that stair climbing was easier and reported that: "...feel my legs are getting much stronger". Another male subject was very proud of himself after beating a schoolmate at arm wrestling for the first time. Physiotherapists are generally more observant of abnormal gait and therefore their comments regarding the subjects' improvement in gait, were also encouraging.

The open-ended questions, related to "liking" or "disliking" sport. Participation and more specifically continuation of participation in any sport, is largely dependent on the quality of skill of the participant as well as the level of enjoyment experienced during participation. Liking a sport might be closely related to ability and a change towards liking sport might be related to perceptions of quality of performance. Twenty two of the 31 subjects enjoyed taking part in sport at the start of the trial. Following strength training nine subjects in the experimental group added gym training or exercise to their list of sports, with two of the six subjects who did not enjoy sport initially, changing their opinion to liking sport.

During completion of the questionnaire, it was observed that many of the subjects had trouble understanding the Lickert-scale concept and might therefore be responsible for the small effect size of the responses. A pilot study was conducted on normal senior school learners, but intra-subject reliability within the CP population was not tested. Despite the subjects in the current study following a mainstream academic syllabus and having average academic ability (according to school medical records), many experienced difficulties with reading, writing and comprehension. The incidence of learning difficulties among children with CP is high according to Olney and Wright (2000) (see chapter 2.4.3). Instructions for completion of the questionnaire were not standardised and may also have influenced the understanding of the questionnaire. Piloting the questionnaire on adolescent CP children is recommended to ensure basic level of comprehension and thereby ensure reliability of the outcome measure. The researcher found that subjects were very eager to participate and be subjected to testing, but were not enthusiastic about

completing a questionnaire. A standardised personal interview by an independent assistant may have been more valuable to recognise comprehension and avoid potential misunderstanding.

5.7 EFFECTS OF STRENGTH-TRAINING ON WALKING EFFICIENCY

The researcher hypothesised that a comprehensive strength-training program would improve oxygen consumption and result in more energy efficient walking, regardless of exclusion of exercises directly targeting the cardio-respiratory muscles. Rose *et al* (1991) maintained that change in walking efficiency could be expected due to improved alignment and improved stride length. The current RCT demonstrated that following such a program improved vertical alignment at midstance during walking (see figure 4.7)

According to Moore *et al* (1987) $VO_{2\text{ max}}$ may increase by six to ten percent when sedentary people participate in a six to ten-week, low intensity training program. Practice effects on metabolic energy expenditure have been investigated by Lay *et al* (2002). These researchers attributed the decrease in metabolic costs demonstrated by their observational study to improved co-ordination and control, and decreased muscle activation, regardless of the fact that the exercise activity, rowing, was aerobic. Each session was less than six minutes which is too short to affect heart and respiratory muscles. According to the American College of Sports Medicine (1998) a minimum of 20 - 60 minutes aerobic exercise at 50 – 80% $VO_{2\text{ max}}$ three to five days per week is the minimum requirement for detecting change in enhanced efficiency. The researcher expected activity levels to be low in the current sample as physical education classes at Eros school were discontinued two years ago. Furthermore, sport participation is inconsistent and limited to those children with potential for participation at provincial level. The school is situated in a lower socio-economic neighbourhood and facilities and equipment for sport are insufficient and in poor condition.

The outcome measures used to evaluate walking efficiency for the current study differed from the Energy Expenditure Index (EEI) (see chapter 3.5.1) used by MacPhail and Kramer (1995) and Darrah *et al* (1999). Increasing cadence is the strategy used by both diplegic and hemiplegic children with spastic CP to increase their walking speed (Damiano

and Abel, 1998). Increased velocity due to increased cadence may physiologically result in increased metabolism and hence increase heart rate (HR), thus not resulting in significant change in energy expenditure. Another possible explanation for the unchanged EEI in the investigation by Damiano and Abel (1998), is that the free walking speed for the pre and post test sessions differed and the increased velocity denominator [$EEI = (\text{walking HR} - \text{resting HR}) / \text{walking velocity}$] may therefore have influenced the results. For this reason, the researcher opted for the Economy of Movement (EOM) test where speed could be controlled while walking on an electronic treadmill.

Results from the EOM test demonstrated that heart rate, oxygen consumption and minute ventilation did not improve for either the experimental or the control group. These concur with the findings from MacPhail and Kramer (1995) and Darrah *et al* (1999) who also reported no change in walking efficiency following strength training. The community fitness program followed by the subjects in the study by Darrah *et al* (1999) included aerobic exercise, which started with ten minutes and progressed to 30 minutes over the ten weeks. A possible explanation for the effectively unchanged results in these studies may be attributable to the intensity and the relatively short duration of the programs. Darrah *et al* (1999) concluded that the more severely disabled subjects were unable to moderate and maintain the intensity level of the aerobic activity and that the training period was too short.

Activities that occurred at Eros school throughout the duration of the trial included a surf-walk fundraising event, a school concert and fête as well as a visit from a local music pop group, which resulted in hours of dance practice. This suggests that despite the barriers experienced, these children are not inactive. This perception is strengthened by the responses regarding perceptions of functional competence, as an unexpected 71% enjoyed participating in sport. This level of activity would have influenced the effect of strength training on an alleged sedentary population.

Another possible explanation for the similar pre and post measure results from the current study might be due to the relatively low whole-body metabolic demand of resistance training compared to vigorous walking, running or cycling, which were not included in the intervention program of this study. Also subjects who participated in the exercise program were not always able to comply with exercising three times per week due to timetable constraints. However correlation analysis of number of exercises and number of exercise

sessions were insignificant (see chapter 4.3). More favourable results due to practice effects as described by Lay *et al* (2002) - when improved patterns of movement become automatic and less muscle fibres are recruited - may be demonstrated with extended participation in the program.

Despite significant improvement in joint angles of the ankle, knee and hip at midstance, resulting in a more upright posture in the lower limbs, the current study could not support the statement of Rose *et al* (1991) that a more upright posture will result in more efficient walking. However, exaggerated and compensatory movements of the trunk as well as upper body posture, which were not determined by the current study may have remained unchanged and therefore influenced the findings. The measure of walking efficiency in the current study was conducted while walking on a treadmill and holding onto the handrails for support (see chapter 3.5.2). This may have affected the influence of upper body posture on walking efficiency at pre testing and minimised detection of improved walking efficiency due to decreased upper body movement at post participation testing.

Although not an objective of the study, analysis of sacrum and heel oscillation recorded during gait, which has been associated with energy expenditure while walking by Williams and Cavanagh (1987) in a normal population also demonstrated no significant change (see section 5.3). This possibly verifies that this association between sacrum and heel oscillation and energy expenditure while walking is also true for adolescents with spastic CP and warrants further investigation.

5.8 EFFECT OF STRENGTH TRAINING ON INDIVIDUAL MUSCLE STRENGTH

There is evidence in the literature that children and adolescents with CP are able to increase muscle strength following strength training without any adverse effects such as increased spasticity or abnormal reactions (Damiano *et al*, 1995a; MacPhail and Kramer, 1995; Fowler *et al*, 2001). For the current study the testing of muscle strength was therefore limited to two muscles of the lower limb only and served merely for verification that the changes which occurred in gait analysis and walking efficiency as well as perceptions of body image and functional competence were due to increased muscle strength. Until recently most studies were of single group design thereby limiting the

confirmation that gains in muscle strength were due to the specific strength training intervention and may have overestimated the effect of strength training on muscle strength. Dodd *et al* (2003) published the first RCT investigating strength training of selected lower limb muscles in children with spastic CP. The individual strength gains reported by this study as well as the results from the current study following strength training did not differ significantly between the control and experimental groups and will therefore be discussed in more detail following a brief explanation of the limb and muscle group selection criteria for the current study.

The involved limb in hemiplegic subjects and the self-reported strongest limb in diplegic subjects were selected for testing. As knee extension and hip abduction are directly related to stride length (Kramer and MacPhail, 1994; Damiano *et al*, 1995a), these muscle groups were selected for strength testing. Another reason for selecting these two muscle groups was that the strength test protocol for these two muscles is more objective than for hip extension and is easily reproducible using the Kin-Com[®] dynamometer. Although hip extensors are more directly related to stride length than hip abductors, testing hip extensors with the Kin-Com involves internal stabilizing of the trunk during execution, a component that is often severely lacking in many children with CP (Olney and Wright, 2000).

It could be argued that the sum of all the changes contribute to the overall effect. However, totalling the mean changes for ankle, knee and hip angles at midstance and analysing the effect thereof, only showed a significant tendency between the control and experimental groups for the current study when Bootstrap analysis was applied. Similarly, Dodd *et al* (2003) also found no significant differences when summing the change for all three muscle groups – ankle plantar flexors, knee and hip extensors - targeted by their intervention program. Only when summing the changes of ankle plantar flexors and knee extensors did the authors demonstrate significant pre to post change. A possible reason for the unchanged effect following summing of the changes in the current study may be that only two muscles were tested as discussed above while several more muscles were targeted by the strength-training program. Another possible explanation for the lower effect sizes seen in both these two RCTs could be that the intensity of training was not optimal due to minimal therapist supervision. A home-based program was followed by the subjects in the study by Dodd *et al* (1999). In the current study supervision was also limited with time

spent mostly on the more severely disabled subjects who required assistance with some of the exercises.

These small effect sizes of the strength gains that occurred in spastic muscles following strength training as demonstrated by these two studies and discussed above however, should not be underestimated. Bootstrap analysis in the current study for total muscle strength as well as muscle strength at 30° knee extension and at 10° and 20° hip abduction (see chapter 4.3) did show significant tendencies for increased muscle strength. When comparing the performance of the diplegic with the hemiplegic group, the diplegic group also demonstrated significant gains in muscle strength for both knee extension and hip abduction.

Furthermore clinical observation and confirmation as evidenced on the subjects' participation records of upper limb muscle strength was seen by the increased weights pushed. For the bench press exercise the mean resistance increase was 7.5kg for boys and 5kg for girls. One subject increased his weights from 10kg to 30kg by the end of the eighth week. Strengthening of the trunk flexor muscles was also evidenced by six subjects who were unable to do a sit-up without arm support but with feet supported at the onset of the study. Within three weeks of exercise, they were able to do so. For those individuals that did the step up-and-down exercise they increased their weights by an average of 5kg and the four boys that were able to do a squat with the bar-weight, increased their resistance each by 10kg over the eight-week period.

With comparison of these findings to some of the observational pre and post studies investigating the effect of strength training in the young CP population it was found that their results relating to changes in muscle strength also only reached significant levels when summing the change that occurred in the individual muscles tested. Darrah *et al* (1999) did not report on individual strength gains but documented significant gains when totalling the change in muscle strength of all four of the muscles tested. These were the hip and knee extensors, hip abductors and shoulder flexors. It is questionable whether summing the effect sizes for upper limbs with lower limbs is justified and this may have exaggerated the significance of their results. Their results also cannot be attributed to strength training alone as their exercise intervention included aerobic exercise as well as a flexibility component. Notwithstanding, the significant results from their assessment of

flexibility as well as the perceptions of physical appearance justifies the success of their community fitness program.

Damiano and Abel (1998) measured the isometric strength of eight muscles in the lower limbs before and after strength training and also demonstrated a significant increase in muscle strength, but did not mention individual results. The aim of their investigation however was not to determine whether strength gains occurred in muscles following strength training, but rather to correlate these changes with changes in gait variables and function as measured by the Gross Motor Function Measure (GMFM). The significant changes detected on the GMFM following selective strength training also justify and further demonstrate the effectiveness of strength training in this population.

In contrast to the results from studies by Damiano *et al* (1995a), MacPhail and Kramer (1995) and Dodd *et al* (2003) not all subjects in the experimental group of the current study demonstrated an increase in muscle strength. This effect however occurred in less than 10% of the subjects in the experimental group and evident primarily when testing knee extension at 30°. This could be due to normal error variation in measurement. This was especially possible as the testers at baseline measurement and at eight weeks were not the same person.

Not all subjects in the current study performed the same exercises. A minimum of eight and a maximum of 12 exercises was permitted (see chapter 3.6.1) and were selected individually from a pre-determined 28-station circuit (see table 3.2) and different modes of resistance were selected depending on the individual's abilities. All of these factors may have contributed to the wide range of effect size demonstrated by the experimental group in muscle strength for the knee extensors and hip abductors. The sixteen weaker individuals, who were unable to do a squat without support, used the elastic bands for strengthening of the knee extensors. During knee extension in the seated position, the band offers the most resistance when fully stretched, that is when the knee is close to full extension. The effect of the resistance thus decreases with knee flexion. Only four subjects who had sufficient strength and balance performed squats and lunges with the bar weight and discs or with hand-held free weights. Consequently more equal resistance was experienced throughout the range. This could explain why the current study showed

significant trends for knee extension at 30° but not for knee extension at 60° (see figure 4.4a).

5.9 EFFECT OF STRENGTH TRAINING ON FUNCTION

To fully appraise the global effect of strength training on children with CP, function in terms of activities of daily living (ADL), hobbies, sport, school and community participation as well as social interaction, need to be assessed. Only the GMFM (MacPhail and Kramer, 1995; Damiano and Abel, 1998) has been used to assess change in function following strength training (see chapter 2.6.2). However, this standardised measure is limited in the assessment of quality of movement as well as in community and societal participation. Perceptions of change in physical appearance and functional ability are also lacking (see chapter 2.6.2). As outcome measures such as the GMFM and POSNA have been correlated with gait analysis by MacPhail and Kramer (1995), Damiano and Abel (1998) and Tervo *et al* (2002), the researcher assumed that changes in gait would be representative of changes in function as measured by these two tests.

It was thought that the change reflected by responses in the self perception questionnaire relating to functional competence together with changes as measured during gait analysis would be sufficient to relate the impact strength training to level of participation as described by the International Classification of Function (WHO, 2002). However, due to the shortcomings of the questionnaire, the representation of the outcome measure to participation was not sufficient. For perceptions of self-image, the questionnaire did not allow for, nor indicated inclusion of personal and behavioural attributes such as self-confidence and interpersonal relationships. Although the questionnaire included six statements relating to various functional activities such as walking ability through to activities requiring upper limb function and ADL (see addendum C), it did not sufficiently cover global function. A wider variety of activities such as hobbies, specific ADL such as grooming and social activities including shopping should have been included. The open-ended question in this section was limited to sports participation only. There is a need for development of a more suitable outcome measure to assess perceptions of change at both functional and participation levels within this population of children and adolescents with spastic CP and which is also relevant to SA conditions.

5.10 FEASIBILITY OF IMPLEMENTATION OF A COMPREHENSIVE STRENGTH TRAINING PROGRAM

A strong motivation for this study exploring the effect of strength-training using basic, inexpensive equipment was to provide people with CP a potential therapeutic self-help option to reduce the occurrence and severity of secondary complications that occur as they grow older (Gajdosik and Cicirello, 2001) (see chapter 2.1.4). The effect of the rationalisation of government funding has resulted in not only a reduction in therapy posts at special schools, but elective surgery has also been drastically reduced for individuals relying on public health care. Operations to restore or improve biomechanical alignment as a result of the formation of contractures and deformities can no longer be freely done.

The RCT by Dodd *et al* (2003) who investigated a home-based strength training program in children also using basic equipment found such a program to be effective. Darrah *et al* (1999) demonstrated successful participation in a community fitness program and Jahnsen *et al* (2003) in their study investigating strength training in adults with CP were also able to show improvement in strength and walking ability following unsupervised training in the local community gym.

Most of the exercises as well as the equipment selected for the current study were suitable for independent use. For the current study subjects in the exercise group trained as independently as possible, following instruction on the use of the equipment. Supervision was limited to the more severely involved subjects mainly requiring assistance with exercises on the ball. Although the subjects had to record the exercises successfully completed on a daily basis, time restrictions resulted in incomplete sessions and quality of execution was not always monitored. Ball exercises could be executed independently by the less severely disabled subjects, but were cumbersome for the more severely involved subjects especially when the ball kept rolling away. However, the ball could be replaced by a block even if the effect on the trunk and hip stabilisers will be reduced.

The results from the study conducted in the adult CP population by Jahnsen *et al* (2003) as well as the results from the current study indicate that basic strength training may reduce or at least postpone the deterioration which occurs in the CP population as they

grow older. Implementation of a strength training program at schools and community health centres as well as in home-based programs, using basic resistive devices such as dumbbells, velcro-attached ankle and wrist cuff-weights and elastic bands, is economically feasible. Equipment is inexpensive and the program requires minimal monitoring. However, it should also be noted that for optimal results, correct selection of exercises, correct execution and appropriate progression as well as optimal effort by the individual are essential. It is therefore recommended that design and implementation of such programs should be done under the supervision of a professional with an interest and understanding of the problems associated with spastic CP. Principles for implementation of PRE however are very basic and any interested individual can quickly become skilled in these and can take over management and supervision of these program. Individuals with CP with an average level of intelligence should also be able to continue on their own and make necessary adaptations to continue benefiting from exercise.

As the purpose of the current study was to evaluate the impact of strength-training, the intervention program was limited to progressive resisted exercise only and aerobic and mobility exercises were omitted. However, it is recommended that any comprehensive strength-training program should also include a flexibility component (McArdle *et al*, 1996). This is even more relevant to persons with spasticity and muscle *tightness*. Obtaining optimal length prior to strengthening is essential to reduce or prevent imbalance within the muscle which may result in further decrease in range of movement.

5.11 RESULTS PERTAINING TO THE CONTROL GROUP

It was surprising to note improvements for the control group in muscle strength, albeit that the change was insignificant. The results pertaining to the control group in the RCT by Dodd *et al* (2003) were more consistent from pre to post testing. Possible explanations for the performance of the control group in the current study are discussed below:

- a) Hawthorn effect – as participants could not be blinded to the intervention, the need to please the researcher may have influenced performance during testing. This effect however was applicable to both the control and experimental groups and may therefore have effected the validity of the results seen in the current study.

- b) The time of the year this study was conducted may have influenced the results. There were many school activities at Eros during the second term and included a surf-walk, school concert and fête and a visit from a local pop group (see section 5.7). These were all activities that required prolonged walking and repetitive execution of familiar and less familiar tasks.

- c) Although physiotherapy intervention in Damiano *et al's* (1995a) study did not appear to influence the results of their strength training in children with spastic diplegia, it could have had an effect on this control group who were not taking part in any form of resistance training. Four subjects in the control group continued or restarted with physiotherapy during the trial period, whereas none of the subjects from the experimental group received any physiotherapy. Physiotherapy treatment protocol at Eros school involves intervention prior to an operation in an attempt to optimise surgical outcome. These four subjects, two diplegic and two hemiplegic subjects, were on the list for orthopaedic intervention in the third term.

- d) The control group came from the same population as the experimental group and were often classmates. Experimentation with the exercises could have occurred without the researcher's knowledge.

The results from the current study indicate that targeting multiple muscle groups does produce gains in strength and improvement in the degree of crouch. The effect of the strength-training program also resulted in significant improvement in perceptions of body image. The implications of these findings will be discussed in the next chapter. Recommendations for future studies will also be made.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

The results of this randomised control trial to determine the impact of a comprehensive resistance training program on adolescents with spastic CP indicate that such a program did result in improvement in crouch gait as well as in perceived appearance of body image. The results also verified that adolescents with spastic CP were able to increase strength in targeted muscles following strength-training. The results from the current study however also suggest that while learners with spastic CP are still enrolled at special schools, the activity level appears to be sufficient to at the very least maintain physical status in terms of muscle strength and gait function. This was demonstrated by the results recorded for the control group. In spite of this, the impact participation in a strength-training program had on perceptions of physical appearance demonstrated by the results from the current study as well as by Darrah *et al* (1999), warrants early promulgation of exercise programs at schools.

Due to the decline in social and community participation which occurs once these children have left school (Gajdosik and Cicirello, 2001) and due to the very limited adult medical and rehabilitation services available (Murphy *et al*, 1995; Andersson and Mattsson, 2001), the implementation of such a strength-training program while still at school, should also be considered. Basic strength-training with inexpensive equipment, some of which could be replaced by home-made equipment using sandbags or weighted vests, offers a means whereby persons with CP can take on responsibility for their own health. This view is strongly supported by organisations advocating for the rights of the disabled such as Disabled People South Africa (DPSA website, 2003).

Furthermore, Damiano and Abel (1998) demonstrated the importance of correct selection of exercises and the potential outcome of such a program could be optimised by professional confirmation of correct selection and execution. Instruction and guidance from the physiotherapists at the schools might equip these children to safely and effectively implement such strength-training programs once they have left school. Successful participation at school may also motivate individuals to continue with exercise in the future.

The results from this study furthermore suggest that participation in such a program might reduce the workload on therapists within these schools. Likewise the therapists working in community health centres and who are not NDT-trained, the prescription of strengthening exercises is well within their scope of practice.

Results from the current study support the suggestions of Damiano *et al* (1995a; 1995b), MacPhail and Kramer (1995) and Dodd *et al* (2003), that PRE should become part of routine physiotherapy. Where muscle weakness has been identified to be the underlying reason for the functional impairment, progressive resisted exercise should optimise treatment outcome. No adverse effects were recorded or observed during and after all of the trials, although the long term effect of resistance training in children with CP still needs to be investigated.

Objective, valid and reliable outcome measures are crucial for demonstrating efficacy of therapy interventions. The lack of availability of measures used in populations from developed countries, the high costs and relevance of measures, hinder evidence-based practice in our country. Not only does the development and standardisation of measures need to be addressed, but more suitable outcome measures for the assessment of the impact of any therapeutic intervention aimed at improving function needs to be developed. These measures should include assessment of impairment, activity limitation as well as participation level as based on the ICF (WHO, 2001). Scales or scoring should allow for both quality of execution as well as acquisition of a new skill(s) and include subjective perception of the effect.

As suggested in the last paragraph in chapter 5.2, in order to improve the generalisability of a comprehensive strength training program to all adolescent learners with spastic CP, it is recommended that comparison studies should be conducted in various special schools to compensate for variability in therapy protocols as well as differences in activity and sport programs. Piloting the use of all instruments and outcome measures on adolescents with CP prior to conducting the current study, would have avoided the need to adapt standardised test procedures thereby effecting the validity and reliability of the tests.

Further recommendations for future studies within the CP population as well as future studies regarding strength-training in the CP population include:

- a) Familiarisation of participants in the study to the testing apparatus and protocol in order to reduce stress and anxiety levels. This could be done by introducing another session of testing a week into the program or if the exercise is to be conducted over a longer period, a mid-training test should be conducted.
- b) More stringent selection criteria, minimising the variability within the study sample or increasing the sample size. This is to enable statistical analysis of the sub-groups as well as comparison between the various characteristics within a CP population as the diagnosis of CP is complex and multi-faceted and the clinical presentation diverse.
- c) Power studies to ensure sample size is representative of the study population. This is necessary due to the large variety within the population as well as due to the variety in results data.
- d) Researchers / testers should be blinded as to the group in which the subjects are allocated to avoid measurement bias.
- e) Similar studies to demonstrate the effect of strength-training in other CP types such as those with ataxia, athetosis and dystonia. This is to streamline services at these special schools and to be able to offer strength-training as possible self-help therapy to all learners with CP.
- f) Allowing for a longer walkway for a constant pace to develop when using gait analysis for measuring effect size following strength-training or any other intervention in the CP population. At least 20m is recommended for analysing gait in individuals with CP. It was observed that subjects in the current study needed five to ten meters before settling into an even stride. Five meters are required for recording and a further meter or two was needed for deceleration.
- g) More suitable standardised outcome measures that not only detect change in impairment and functioning but include assessment of societal participation and

perceptions of self, is needed for a full appraisal of the impact of strength training. A combination of one or more of the following is suggested: timed up and go test, timed speed walking or timed stair-climbing. Alternatively, using two or three items from the TELER (Mawson, 2002), a flexible outcome measure that indicates change or lack of change in a patient's ability to perform any selected motor task, will provide more information on the activity component. These used in combination with standardised measures that assess participation level is recommended.

- h) For assessment of perception of physical appearance and functional competence in children and adolescents with CP, a standardised, structured interview is recommended. The high incidence of perceptual and spatial orientation problems as well as learning difficulties experienced by learners with CP affect reading, writing and comprehension of self-administered questionnaires and may result in unreliable responses.
- i) In keeping with the principle of specificity of training (McArdle *et al*, 1996), it is suggested that resistance exercise in a more functional position e.g. on a stair-climber or a treadmill may have greater transfer to gait performance. Inclusion of isometric exercise should also result in bigger effect sizes when testing muscles strength using isometric dynamometry.
- j) The use of appropriate field tests used in combination with isometric dynamometry might demonstrate a more accurate assessment of change in muscle strength. Improvement in muscle strength in children is largely due to improved neural input (McArdle *et al*, 1996). Control, a component of muscle strength is also dependent on improved neural input. Isometric dynamometry does not allow free active movement, whereas a standardised field test, for example a stand-and-reach test is dependent on balance and control.

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ADDENDUM A:

INFORMATION AND INFORMED CONSENT DOCUMENT

English and Afrikaans

INFORMATION AND INFORMED CONSENT DOCUMENT

TITLE OF THE RESEARCH PROJECT:

The effect of a progressive resisted exercise program on children with spastic cerebral palsy.

REFERENCE NUMBER: 2003/021/N

PRINCIPAL INVESTIGATOR: **Mrs Marianne Unger**

Address: **University of Stellenbosch
Faculty of Health Sciences
Department Of Physiotherapy**

DECLARATION ON BEHALF OF PARTICIPANT:

I, **THE UNDERSIGNED**, in my capacity as parent / legal guardian of (*name of your child*)....., scholar at EROS School for the Physically Disabled,

A. HEREBY CONFIRM AS FOLLOWS:

1. My child was invited to participate in the abovementioned research project, which is being undertaken by the Department of Physiotherapy, Faculty of Health Sciences, Stellenbosch University.
2. The following aspects have been explained to me:

2.1 Aim:

This study hopes to determine whether participating in a strengthening exercise program can influence the walking pattern - possibly enabling him/her to walk further and faster - in children with spastic cerebral palsy. The study also aims to determine if participation can also effect his / her self-image.

2.2 Procedures:

Informed assent will be obtained from your child in which the benefits of participation in this study will be explained to him/her. 40 children will participate in the study. 30 of those will be selected to take part in a strengthening exercise program conducted by the researcher (a physiotherapist from the University of Stellenbosch) together with Mrs

Heidi Arbuckle (a physiotherapist from EROS School). All the children selected will undergo 4 tests. Gait analysis (videoing my child's walking pattern) and strength testing on a Cybex machine will take place at the Sport's Science Institute of South Africa. Energy consumption will be tested in the Department of Physiology at Stellenbosch University while walking on a treadmill. My child will also be asked to complete a questionnaire regarding perceptions of self-image. These tests will be conducted 3 times: at the start of the study, 3 months later and again 3 months thereafter. All transport to testing venues will be organised through the school and a designated school bus driver and transport will be provided. My child may or may not be selected to participate in the exercise program. If selected, he / she will exercise 3x per week for 12 weeks under the supervision of the researcher and her assistant. Any therapy(ies) as well as classes that my child is receiving at Eros will continue as before and will not be withdrawn because my child is participating in this study.

2.3 Confidentiality:

All the information gathered will be treated as confidential. Results will be used, without disclosing the identity of any of the children, in a thesis and may be published in a professional journal.

2.7 Access to findings:

I will have access to the findings concerning my child.

2.8 Voluntary participation/refusal/discontinuation:

Participation is voluntary and either myself or my child may refuse to participate and he / she may discontinue participation at any time and such refusal or discontinuation will not prejudice his / her future treatment at EROS School. The investigator may withdraw my child from the study if she feels that it would be in the child's best interest.

3. The information above was explained to me by **Mrs Marianne Unger**. I was given the opportunity to ask questions and all these questions were answered satisfactorily.
4. No pressure was exerted on me to consent to participation and I understand that I, or my child may withdraw voluntarily at any stage without any penalization.

5. Participation in this study will not result in any additional costs to myself.

B. HEREBY CONSENT VOLUNTARILY THAT MY CHILD MAY PARTICIPATE IN THE ABOVEMENTIONED STUDY.

Signed/confirmed at on 20

(place)

(date)

.....
*Signature or right thumb print of
parent / legal guardian*

.....
Signature of witness

STATEMENT BY OR ON BEHALF OF INVESTIGATOR (S):

I,, declare that

- I explained the information given in this document to
(*name of the child*) and/or his/her parents/legal guardian(*name*)
- he/she was encouraged and given ample time to ask me any questions;
- this conversation was conducted in English and no translator was used.

Signed at on20
(*place*) (date)

.....
Signature of investigator

.....
Signature of witness

IMPORTANT MESSAGE TO PARENT OR LEGAL GUARDIAN:

Dear parent / legal guardian,

Thank you for support in this study. Should, at any time during the study,

- an emergency arise as a result of the research, or
- you require any further information with regard to the study, or
- should your child sustain an injury or becomes ill and is unable or does not want to continue,

kindly contact the researcher, **Marianne Unger** at telephone number 083 556 5321 or 938 9300(w) or 975 7421(h) or **Heidi Arbuckle** at 637 9080 (Eros)

INLIGTINGS- EN INGELIGTE TOESTEMMINGS-DOKUMENT

TITEL VAN DIE NAVORSINGS-PROJEK:

Die effek van 'n progressiewe weerstandsoefenprogram op kinders met spastiese serebrale verlamming.

VERWYSINGSNOMMER: 2003/021/N

HOOFNAVORSER: **Mev Marianne Unger**

Adres: **Stellenbosch Universiteit**

Fakulteit Gesondheidswetenskappe

Departement Fisioterapie

VERKLARING DEUR OF NAMENS PASIËNT/*DEELNEMER:

EK, DIE ONDERGETEKENDE, in my hoedanigheid as ouer / wettige voog van (*naam van u kind*)....., 'n skoolier aan Eros Skool vir Fisiesgestremdes,

A. BEVESTIG HIERMEE DIE VOLGENDE:

1. My kind is uitgenooi om deel te neem aan bogenoemde navorsingsprojek wat deur die Departement Fisioterapie, Fakulteit Gesondheidswetenskappe, Universiteit Stellenbosch, onderneem word.
2. Die volgende aspekte is aan my verduidelik:

2.1 Doel:

Die studie hoop om te bepaal of deelname aan 'n versterkende oefenprogram die looppatroon van kinders met serebrale verlamming kan beïnvloed - sodat hy / sy vinniger en verder kan loop. Die studie hoop ook om te bepaal of deelname ook persepsie van sy / haar selfbeeld kan verander.

2.2 Prosedures:

Ingeligte goedkeuring sal van u kind verkry word, waarin die voordele van deelname aan hierdie studie, aan hom/haar verduidelik sal word. 40 kinders sal aan die studie deelneem. Uit die groep sal 30 gekies word om deel te neem aan 'n versterkende oefenprogram, wat deur die navorser

('n fisioterapeut van Stellenbosch Universiteit) saam met Mev Heidi Arbuckle ('n fisioterapeut van Eros Skool) uitgevoer sal word. Al die kinders sal 4 toetse ondergaan. Loop analise (video neem van my kind se looppatroon) en spiersterkte sal getoets word met behulp van die Cybex masjien, by die Suid Afrikaanse Instituut vir Sport Wetenskappe. Energieverbruik sal getoets word in die Departement Fisiologie by Universiteit Stellenbosch terwyl hulle op 'n trapmeul loop. My kind sal ook gevra word om 'n vraelys oor persepsies van selfbeeld in te vul. Hierdie toetse sal 3 keer uitgevoer word: aan die begin van die studie, 3 maande later en weer 3 maande daarna. Alle vervoer na die toets areas sal deur die skool gereël word. Die skool sal 'n bestuurder en bus voorsien. My kind mag geselekteer word om deel te neem aan die oefenprogram. Indien hy / sy geselekteer word sal hy / sy 3x per week vir 12 weke onder toesig van die navorser en haar assistent oefen. Enige terapie(ë) en klasse wat my kind tans by Eros ontvang, sal voortgaan en sal nie gestaak word as gevolg van deelname aan die studie nie.

2.3 **Vertroulikheid:**

Al die inligting bekom uit die studie sal as vertroulik hanteer word. Resultate sal gebruik word in 'n tesis, sonder om die identiteit van enige van die kinders bekend te maak en mag dalk gepubliseer word in 'n wetenskaplike joernaal.

2.7 **Toegang tot bevindinge:**

Ek sal toegang hê tot alle bevindinge rakende my kind.

2.8 **Vrywillige deelname/weiering/staking:**

Deelname is vrywillig en ek of my kind mag deelname weier en hy / sy mag deelname op enige tydstip staak. Weiering of staking sal geen toekomstige behandeling by Eros Skool beïnvloed nie. Die navorser mag ook die kind onttrek van die studie indien sy voel dat dit in belang van die kind is.

3. Die inligting hierbo is deur **Mev Marianne Unger** aan my verduidelik. Ek is 'n geleentheid gebied om vrae te vra en al die vrae is bevredigend beantwoord.
4. Daar is geen dwang op my geplaas om toe te stem tot deelname nie en ek verstaan dat ek of my kind deelname te enige tyd mag staak sonder enige penalisering.

5. Deelname aan die projek hou geen addisionele koste vir my in nie.

**B STEM HIERMEE VRYWILLIG IN DAT MY KIND AAN DIE BOGEMELDE PROJEK
MAG DEELNEEM.**

Geteken/bevestig teop20.....
(plek) (datum)

.....
*Handtekening or regter duimafdruk van
verteenwoordiger van die kind*

.....
Handtekening van getuie

VERKLARING DEUR OF NAMENS NAVORSER(S):

Ek,, verklaar dat

- ek die inligting vervat in hierdie dokument aan(naam van kind) en/of* sy/haar ouer / wettige voog(naam) verduidelik het;
- sy/hy* aangemoedig en genoeg tyd gegun is om enige vrae aan my te stel;
- hierdie gesprek in Afrikaans plaasgevind het en geen tolk gebruik is nie.

Geteken te op 20.....
(plek) (datum)

.....
Handtekening van navorsers

.....
Handtekening van getuie

BELANGRIKE BOODSKAP AAN OUER / WETTIGE VOOG:

Geagte ouer / wettige voog,

Baie dankie vir u ondersteuning aan hierdie studie. Indien daar te enige tyd tydens die duur van die projek:

- 'n noodsituasie ontstaan wat spruit uit die navorsing, of
- u enige verdere inligting aangaande die projek verlang, of
- u kind 'n besering opgedoen het of siek geword het en nie verder kan of wil deelneem nie,

sal u asseblief vir **Marianne Unger** by telefoonnommer 083 556 5321 of 938 9300(w) of 975 7421(h) of Heidi Arbuckle by 637 9080 (Eros) kontak

ADDENDUM B:

DECLARATION BY THE CHILD

English and Afrikaans

DECLARATION BY THE CHILD (PARTICIPANT) FOR AGREEING TO PARTICIPATE IN THE STUDY

TITLE OF THE RESEARCH PROJECT:

The effect of a progressive resisted exercise program on children with spastic cerebral palsy.

REFERENCE NUMBER: 2003/021/N

PRINCIPAL INVESTIGATOR: **Mrs Marianne Unger**

Address: **University of Stellenbosch
Faculty of Health Sciences**

Department Of Physiotherapy

I *name of participant*) hereby agree to participate in this study.

It has been explained to me what the study is about and what will be expected of me throughout the study.

I understand that I may withdraw from the study at any time without any repercussions.

.....
Signature of participant

.....
Date

VERKLARING DEUR DIE KIND (DEELNEMER) VIR GOEDKEURING AAN DEELNAME

TITEL VAN DIE NAVORSINGSPROJEK:

Die effek van 'n progressiewe weerstandsoefenprogram op kinders met spastiese serebrale verlamming.

VERWYSINGSNOMMER: 2003/021/N

HOOFNAVORSER: **Mev Marianne Unger**

Adres: **Stellenbosch Universiteit**
Fakulteit Gesondheidswetenskappe
Departement Fisioterapie

Ek(naam van deelnemer) gee hiermee my goedkeuring om deel te neem aan hierdie studie.

Dit is aan my verduidelik waarom die studie gaan en wat van my verwag sal word tydens die duur van die studie.

Ek weet ek mag enige tyd onttrek sonder enige nagevolge.

.....
Handtekening van deelnemer

.....
Datum

ADDENDUM C:

**QUESTIONNAIRE: PERCEPTIONS OF PHYSICAL APPEARANCE AND
FUNCTIONAL COMPETENCE**

English and Afrikaans

QUESTIONNAIRE:

.....

SECTION A

PERCEPTIONS OF PHYSICAL APPEARANCE

1. I am happy with the way I look

I am very unhappy with the way I look	I am not happy with the way I look	I am sometimes happy	I am usually happy with the way I look	I am very happy with the way I look
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2. I like my body

I am very unhappy with my body	I dislike my body	I like my body sometimes	I usually like my body	I am very happy with body
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3. I feel I am good-looking / attractive

I feel I am very unattractive / good-looking	I don't feel attractive / good-looking	I sometimes feel attractive / good-looking	I feel I am attractive / good-looking	I feel I am very attractive / good-looking
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4. I look good in shorts / skirt

I look terrible in shorts / a skirt	I do not look good in shorts / a skirt	I sometimes look good in shorts / a skirt	I look good in shorts / a skirt	I look very good in shorts / a skirt
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5. I feel confident when walking in a shopping center or on the street

I feel very self-conscious walking on the road / in a shopping center	I have little confidence	I sometimes feel confident	I usually feel confident walking on the road / in a shopping center	I walk with around with a lot of self confidence
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6. My friends think I am good-looking / attractive

They think I am ugly	They think I am not attractive / good-looking	They think I am slightly attractive / good-looking	They think I am usually attractive / good-looking	They think I am very attractive / good-looking
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7. a) Make a list of what all the things you like about yourself and your body.

b) Make a list of all the things you do not like about yourself and your body.

QUESTIONNAIRE:

.....

SECTION B

PERCEPTIONS OF FUNCTIONAL COMPETENCE**1. I can walk comfortably between classes at school**

I am always last	I struggle to keep up with the class	I can usually keep up with the class	I can walk comfortably	I can walk quickly between classes
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2. I can easily climb into the school bus, mini bus, taxi or train

I cannot without help	It is difficult to climb in alone	I struggle a little bit	I can climb in alone	I can climb in very easily
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3. I can dress myself

I cannot without help	It is difficult to dress alone	I struggle a little bit	I can dress myself	I can dress myself very quickly
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4. I can make my bed on my own

I cannot without help	Difficult on my own	I struggle a little bit	I can make up my bed	I can make up my bed very quickly
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5. I can manage stairs easily without support

I cannot climb stairs without using my hands	It is difficult to climb without my hands	I struggle a little bit	I can climb stairs without hands	I can climb stairs quickly
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6. I like taking part in sport

yes	no
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→ **If your answer was yes:**

- **What sport do you do?**

- **WHY do you like it?**

→ **If your answer was no:**

- **Why do you not take part in sport?**

VRAELYS:

.....

AFDELING A**PERSEPSIES VAN FISIESE VOORKOMS****1. Ek is gelukkig met hoe ek lyk**

Ek is baie ongelukkig met hoe ek lyk	Ek is nie gelukkig met hoe ek lyk nie	Ek is soms gelukkig	Ek is meestal gelukkig met hoe ek lyk	Ek is baie gelukkig met hoe ek lyk
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2. Ek hou van my liggaam

Ek is baie ongelukkig met my liggaam	Ek hou nie van my liggaam nie	Ek hou soms van my liggaam	Ek is meestal gelukkig met my liggaam	Ek is baie gelukkig met my liggaam
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3. Ek voel ek is aantreklik

Ek voel baie onaantreklik	Ek voel ek is nie aantreklik nie	Ek voel soms aantreklik	Ek voel ek is aantreklik	Ek voel ek is baie aantreklik
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4. Ek lyk goed in 'n kortbroek / romp

Ek lyk baie sleg in 'n kortbroek / romp	Ek lyk nie goed in 'n kortbroek / romp nie	Ek lyk soms goed in 'n kortbroek / romp	Ek lyk meestal goed in 'n kortbroek / romp	Ek lyk baie goed in 'n kortbroek / romp
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5. Ek loop met selfvertroue in winkelsentrum of buite op straat

Ek is baie selfbewus op straat / in 'n winkel	Ek het min selfvertroue op straat / in 'n winkel	Ek loop soms met selfvertroue	Ek loop meestal met selfvertroue	Ek loop met baie selfvertroue op straat / in 'n winkel
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6. My vriende dink ek is aantreklik

Hulle dink ek is lelik	Hulle dink ek is nie aantreklik nie	Hulle dink ek is bietjie aantreklik	Hulle dink ek is meestal aantreklik	Hulle dink ek is baie aantreklik
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7. a) Noem al die dinge wat jy van jouself en jou ligaam hou.**b) Noem al die dinge wat jy nie van jouself of jou ligaam hou nie.**

VRAELYS:

AFDELING B

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PERSEPSIES VAN FUNKSIONELE VERMOË**1. Ek kan in die skool gemaklik tussen klasse loop**

Ek is altyd laaste	Ek raak agter	Ek kan meestal byhou by die res	Ek loop gemaklik	Ek loop vinnig tussen klasse
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2. Ek kan maklik op 'n bus, in 'n taxi of in 'n trein klim

Ek kan glad nie sonder hulp nie	Moeilik om alleen in te klim	Ek sukkel soms	Ek kan in klim	Ek kan baie maklik in klim
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3. Ek kan myself aantrek

Ek kan glad nie sonder hulp nie	Moeilik om alleen aan te trek	Ek sukkel soms	Ek kan myself aantrek	Ek kan baie vinnig aantrek
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4. Ek kan my bed alleen opmaak

Ek kan glad nie	Moeilik om alleen bed op te maak	Ek sukkel soms	Ek kan my bed opmaak	Ek kan baie vinnig bed opmaak
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5. Ek kan maklik trappe klim sonder ondersteuning

Ek kan glad nie sonder hande trappe klim nie	Moeilik om sonder hande te klim	Ek sukkel soms	Ek kan sonder hande klim	Ek kan vinnig sonder hande trappe klim
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6. Ek neem graag deel aan sport

ja	nee
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→ Indien jy ja geantwoord het:

- Aan watter sport neem jy deel?

- Waarom hou jy daarvan?

→ Indien jy nee geantwoord het:

- Waarom neem jy nie deel aan sport nie?

ADDENDUM D:

SUBJECT'S PARTICIPATION RECORD

ADDENDUM E:

LETTER OF CONSENT FROM THE DEPARTMENT OF EDUCATION

021 425 7445

Navrae
Enquiries **Dr Ronald Cornelissen**
IMibuzo

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IFoni

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IFeksi

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Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISEBE IeMfundo IeNtshona Koloni

Ms Marianne Unger
Department of Physiotherapy
University of Stellenbosch
MATIELAND
7602

RESEARCH PROPOSAL: THE EFFECT OF PROGRESSIVE RESISTED STRENGTH TRAINING ON CHILDREN WITH SPASTIC CEREBRAL PALSY.

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **3rd March 2003 to 27th June 2003**
6. Should you wish to extend the period of your survey at the school(s), please contact Dr R. Cornelissen at the contact numbers above quoting the reference number.
7. A photocopy of this letter is submitted to the principal of the school where the intended research is to be conducted.
8. Your research will be limited to the following School: **Eros School for Cerebral Palsied.**
9. A brief summary of the content, findings and recommendations is provided to the Director: Education Research.
10. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Education Research
Western Cape Education Department
Private Bag 9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards.

HEAD: EDUCATION

DATE: 2003.02.26