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A COMPARISON OF EXERCISE ENDURANCE LEVELS BETWEEN CHILDREN DIAGNOSED WITH DEVELOPMENTAL CO-ORDINATION DISORDER AND ENDURANCE LEVELS OF NORMAL CHILDREN, BETWEEN THE AGES OF SEVEN AND TEN YEARS

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Physiotherapy.

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ABSTRACT

In South Africa, the concept of Developmental Co-ordination Disorder (DCD) is relatively unfamiliar and not well understood. The exact epidemiology is unknown, but the Diagnostic and Statistical Manual of Mental Disorders (DSM IV, 2000) indicate that the value could be between five and ten percent of the American population. Many studies on DCD have been conducted and most highlight the immense difficulties these children experience with motor activities, both in sport and daily tasks. However, few studies specifically investigated endurance and the impact it has on the child's ability to function normally without too much effort and fatigue due to the condition.

The main aim of this study was to determine the difference in submaximal endurance levels between children diagnosed with DCD and normally developing children. Children between the ages of seven and ten years were included in the study.

The Six Minute Walk Test (6MWT) was employed to determine the average distance covered by each of two groups that were selected to participate in the study and thus, the submaximal endurance levels of each group. The first group of participants consisted of children having a diagnosis of DCD (n=31) and the second comparative group consisted of normally developing children (n=17). The results were analysed and compared using the Student t-test. Anthropometric data of height, age, gender and weight as well as baseline data of breathing rate, heart rate and peak flow were taken. These were compared to normative data as determined by the growth charts of the Centre for Disease Control and Prevention (CDC) as well as previous research on the various topics.

The average distance covered by the DCD group was 375.89 metres with a standard deviation of ±73.33 and the mean distance covered by the normal comparative group was 430.48 metres with a standard deviation of ±60.85. When the two groups were compared it produced a p-value of 0.0086 which was a statistically significant difference. The normally developing group covered on average 54.6 metres more distance than the group with co-ordination difficulties. In comparison to studies that determined normal age (Lammers et al, 2008) and height (Li et al, 2007) reference values, the children within the eight-year age band for the normally developing group fell within the determined values. The other age bands fell below average for both the DCD and normally developing groups.

The finding of the current study is important as it highlights the discrepancy in the submaximal endurance levels of children with DCD when compared to normally developing children of the same age. This is important when considering that most of the activities of daily living are performed at submaximal endurance levels and it is particularly important to note that these are the activities that children with DCD find challenging.

The 6MWT can be performed by children as young as four years of age, with explanation and encouragement. This is particularly helpful in the clinical setting, as other tests of physical fitness require more time, equipment and generally good co-ordination in the individual being tested. The 6MWT is easy to apply and requires few tools, making it a cost and time effective means of testing submaximal fitness in children. It is thus a useful measure to determine whether therapeutic intervention has impacted endurance for activities of daily living.

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DECLARATION

I declare that this research report is my own unaided work, except to the extent indicated in the reference citation and acknowledgements. It is being submitted in partial fulfilment of the requirements of the degree of Master of Science (Physiotherapy) at the University of the Witwatersrand. It has not been submitter before for any other degree or examination in any university.

Natalie Benjamin

_____ day of _____2010

TABLE OF CONTENTS

Page

ABSTRACT……..**ii**

ACKNOWLEDGEMENTS……**iv**

DECLARATION……**v**

TABLE OF CONTENTS……**vi**

LIST OF ABBREVIATIONS……**xii**

Chapter One – Introduction……**1**

1.1 Background……**1**

1.1.1 Pathophysiology……**2**
1.1.2 Epidemiology……**2**
1.1.3 Diagnosis……**3**
1.1.4 Current management……**3**

1.2 Significance of study……**4**

1.3 Problem statement……**4**

1.4 Research question……**4**

1.5 Aim of the study……**4**

1.6 Objectives of the study……**5**

Page

Chapter Two – Literature Review……6

2.1 Developmental Co-ordination Disorder……..6
2.1.1 Definition……..6
2.1.2 Epidemiology……..7
2.1.3 Pathophysiology……..8
2.1.4 Diagnosis and clinical presentation……10
2.1.5 Assessment of DCD……12

2.2 Endurance in children……15

2.3 Six Minute Walk Test (6MWT)……16

2.3.1 Description of the 6MWT……16

2.3.2 Validity and Reliability of the 6MWT……17

2.3.3 Application of the 6MWT……20

2.4 Endurance and Education……22

Chapter Three – Methods……24

3.1 Location……24

3.2 Permission to conduct research……24

3.3 Ethical clearance……25

3.4 Sample selection……25

3.4.1 Inclusion criteria……25

3.4.2 Exclusion criteria……26

3.5 Assessment tool……26

3.6 Procedure……27

3.6.1 Recruitment……27

3.6.2 Age and Gender……27

3.6.3 Measurement……28

3.7 Statistical Considerations……29

3.7.1 Data Analysis……30

Page

Chapter Four- Results ……**31**

4.1 Demographics……**31**

4.2 Submaximal Endurance Levels……**37**

4.3 Six Minute Walk Distance (6MWD)……**39**

Chapter Five – Discussion……**42**

5.1 Anthropometric Data……**42**

5.2 Baseline Data……**45**

5.3 Submaximal endurance levels ……**48**

5.4 Post-test results……**50**

5.5 Limitations of the study……**51**

5.6 Suggestions for further research……**51**

Chapter Six – Conclusion……**53**

Chapter Seven – References……**54**

Page

APPENDICES:

APPENDIX I - Research Protocol……**62**

APPENDIX II - Ethical clearance……**74**

APPENDIX III -Permission from the Department of education……**76**

APPENDIX IV -Informed consent and information letters……**77**

APPENDIX V -Demographic data sheet……**86**

APPENDIX VI - Nine test items for the Test of Physical Fitness……**87**

APPENDIX VII - Reference values for heart rate and breathing rate in South African children of four to sixteen years (Taken from: Wallis et al, 2005, pg 1118)……**89**

APPENDIX VIII - Summary of results for peak flow measures in relation to age (Taken from: Mohammadzadeh et al, 2006, pg 196)……**90**

APPENDIX IX - **Figure 2:** Graph combining male and female percentile curves for the 6MWT in healthy children aged seven -16 years.

(Li et al, 2007, pg 179)……**91**

APPENDIX X - **Figure 3:** Reference values for the 6MWT in children of four to eleven years (Lammers et al, 2008, pg 466)……**92**

Page

LIST OF TABLES:

Table 4.1.1 A comparison of the DCD group and normal comparative group with respect to age……**31**

Table 4.1.2 Table representing number of female and male participants for each age group……**32**

Table 4.1.3 Anthropometric data collected prior to the 6MWT……**33**

Table 4.1.4 Comparison of DCD group height results to the CDC growth charts……**34**

Table 4.1.5 Comparison of normal group height results to the CDC growth charts……**34**

Table 4.1.6 Comparison of DCD group weight results to the CDC growth charts……**35**

Table 4.1.7 Comparison of normal group weight results to the CDC growth charts……**35**

Table 4.1.8 Comparison of the DCD group head circumference results to the CDC growth charts……**36**

Table 4.1.9 Comparison of the normal group head circumference results to the CDC growth charts……**36**

Page

Table 4.2.1 Baseline data collected prior to the 6MWT……..**37**

Table 4.2.2 Comparison of post-test measured parameters of DCD and normal groups……**38**

Table 4.2.3 Comparison of DCD group to normal group with respect to the results of the 6MWT, using the Student-test……..**39**

Table 4.2.4 Summary of the mean distance covered for each age band and gender……**40**

LIST OF FIGURES:

Figure 1: Summary of studies assessing reliability and validity of the 6MWT (Sadaria and Bohannon, 2001, pg 129)……**18**

LIST OF ABBREVIATIONS

APA -American Psychiatric Association

ATC - American Thoracic Society

ADD -Attention deficit disorder

ADHD -Attention deficit hyperactivity disorder

BCH -Benign congenital hypotonia

BMI -Body mass index

BPM -Breaths per minute (breathing rate) or beats per minute (heart rate)

BOTMP -Bruininks- Oseretsky Test of Motor Proficiency

BOTMP-SF -Bruininks- Oseretsky Test of Motor Proficiency –Short Form

BR -Breathing rate

CDC -Centre for Disease Prevention and Control

DCD - Developmental Co-ordination Disorder

DSM -Diagnostic and Statistical Manual of Mental Disorders

FIS -Floppy infant syndrome

HC -Head circumference

HR - Heart rate

ICF -International Classification of Functioning

LMT -Low muscle tone

M-ABC -Movement ABC

MBD -Minimal Brain Dysfunction

MS - Multiple sclerosis

PEFR -Peak Expiratory Flow Rate

PF - Peak flow

6MWD - Six Minutes Walk Distance

6MWT -Six Minutes Walk Test

TBI - Traumatic Brain Injury

UK - United Kingdom

WHO -World health Organization

Chapter One: Introduction

1.1 Background

Developmental co-ordination disorder (DCD) is defined as being motor co-ordination markedly below expected levels for the child's chronological age and intelligence, which significantly interferes with academic achievement or activities of daily living, is not due to a medical condition, does not meet criteria for pervasive developmental disorder, and if mental retardation is present, the motor difficulties are in excess of those usually associated with mental retardation. *Diagnostic and Statistical Manual of Mental Disorders [DSM IV] (American Psychiatric Association, 2000).*

DCD can occur on its own or in combination with mental retardation, genetic disorders (e.g. Down's syndrome), neurologic disorders (e.g. cerebral palsy), brain tumours or loss of sensory function. Some children may even present with attention deficit disorder (ADD) and attention deficit hyperactivity disorder (ADHD) (David K S, 2006, Chapter 19 – Physical Therapy for Children).

Hamilton (2002) described developmental co-ordination disorder as a delay in the development of motor co-ordination in otherwise healthy children of normal intelligence. Parush et al (1998) further added that it is a condition in which the low muscle tone affects gross and fine motor skills in a developing child. This impairs the development of the child as a whole and his/her participation in normal functional and school activities. This is particularly important as it has an impact on the child's ability to concentrate long enough to learn. DCD is also strongly associated to behaviour problems such as fearfulness and clumsiness (David KS, 2006).This implicates socio-emotional development and thus peer interaction. Signs of motor developmental delay is generally only noted when the children are of school going age and display signs of difficulty with fine motor activities, handwriting, co-ordination and being generally clumsy.

In previous years, DCD has also been referred to as low muscle tone (LMT), Benign Congenital Hypotonia (BCH), the Floppy Infant Syndrome (FIS), Clumsy Child Disorder and Idiopathic Hypotonia.

1.1.1 Pathophysiology

The aetiology and pathophysiology of DCD is still unknown, affected children appear to have underlying difficulties in motor planning, the timing and the amount of force needed during movement and the integration of information from sensory and motor systems (Missiuna et al, 2006). By definition, DCD is not related to muscle pathology, peripheral sensory abnormality or central nervous system damage (that causes symptoms such as spasticity, athetosis or ataxia). (David KS, 2006)

Castrodale and Carlson (2003) described DCD as children who present with hypotonia since birth, diminished active movement with preserved tendon reflexes, mild motor retardation or normal development, normal investigations, muscle enzymes, Electromyography, nerve conduction studies and muscle biopsies.
According to Prasad and Prasad (2003) the children may have joint laxity or hypermobility. In general they have a good prognosis.

1.1.2 Epidemiology

The incidence of DCD in countries such as Britain, United States of America and Australia has been recorded but local data is still vague. Dawson and Puckree (2006) found in their study in KwaZulu Natal, that males are more affected. Also, almost 58% of children testing positive for DCD were from rural areas. The study revealed that there is a high prevalence of DCD in KwaZulu Natal. It was associated with the low levels of activity. The study also revealed a much higher prevalence of DCD as compared to westernised countries. However, local data is still vague.

However, authors state that accurate diagnosis of DCD is difficult and that the reported prevalence rates may be misleading.

1.1.3 Diagnosis

An accurate and definitive diagnosis of DCD is difficult but some of the literature attempts to list differentiating criteria.

One of the diagnostic criteria as described by Hamilton (2002) is poor performance in sports. However, little evidence exists to substantiate why this is so and whether cardiovascular fitness and general exercise endurance may play a role. By comparing the exercise tolerance of physically normal children to that of children diagnosed with DCD, we would gain a better understanding into the disorder and the impact it has on the normal motor development. If discrepancies do exist, it would be easier to address the issue of physical performance, which in turn, would enhance concentration and thus the ability to learn in the classroom environment.

1.1.4 Current management

There are currently three intervention approaches in the management of DCD.

1. Guided imagery which is based on the efference-copy-deficit hypothesis.
2. Cognitive approaches based on the hypothesis that children with DCD have poor problem-solving skills.
3. Task-specific interventions based on motor learning principles.

These are described by David KS (2006).

1.2 Significance of study

By determining endurance levels of children with DCD and comparing it to normal developing children, this study aims to establish whether endurance is impaired in children with DCD. The six minute walk test is a measure requiring few tools and some space. This makes it cost effective, and potentially useful in providing the therapist with some indication of how the disorder affects the child's performance. This objective measure may be useful in determining the outcome of therapeutic intervention.

1.3 Problem statement

Current research reveals little with regard to the aetiology of developmental co-ordination disorder. Diagnostic criteria are based on the observation of the motor development and behaviour of the child. However, the measure of endurance is not included in the assessment.

1.4 Research question

Are there differences in exercise endurance levels of normal children aged between seven and ten years of age when compared to children diagnosed with developmental co-ordination disorder (DCD), of the same age?

1.5 Aim of the study

A cross-sectional (comparative) study aimed at establishing whether there are differences in exercise endurance levels between normal children and children diagnosed with developmental co-ordination disorder (DCD), between the ages of seven and ten years.

1.6 Objectives of the study

1.6.1 To determine submaximal endurance levels of normally developing children.

1.6.2 To determine the submaximal endurance levels of children diagnosed with DCD.

1.6.3 To establish whether differences in submaximal endurance do exist between the two groups.

1.6.4 To establish whether differences in anthropometric data/ values exists between the groups.

Chapter Two: Literature Review

It is important to understand the concept of developmental co-ordination disorder, its definition, mechanisms and diagnostic criteria. This literature review aims to describe DCD and how it influences daily activities as well as a child's ability to concentrate in the classroom environment. It will also be discussed in relation to endurance in activities in daily living. The literature was obtained through comprehensive searches on major databases (Pubmed, PEDro, Swetswise, Science Direct, Medline and Biomed central via the Wits website as well as Googlescholar). Keywords used in the searches were: developmental co-ordination disorder, childhood clumsiness, motor dyspraxia, low muscle tone, endurance, fitness, exercise testing, six minute walk test, body mass index, normal development, peak expiratory flow rate, paediatric peak flow.

2.1 Developmental Co-ordination Disorder (DCD)

2.1.1 Definition

Developmental co-ordination disorder is defined as being motor co-ordination markedly below expected levels for the child's chronological age and intelligence, which significantly interferes with academic achievement or activities of daily living, is not due to a medical condition, does not meet criteria for pervasive developmental disorder, and if mental retardation is present, the motor difficulties are in excess of those usually associated with mental retardation. *Diagnostic and Statistical Manual of Mental Disorders (DSM IV, 2000).*

The International Classification of Disease (ICD 10) of the World Health Organization (1992) also defines the disorder in terms of a marked impairment in the development of motor co-ordination that is not explicable in terms of general intellectual retardation or of any specific congenital or acquired neurological disorder (Peters et al, 2001).

Hamilton (2002) described developmental co-ordination disorder (DCD) as a delay in the development of motor co-ordination in otherwise healthy children of normal intelligence. Parush et al (1998) further added that it is a condition in which the low muscle tone affects gross and fine motor skills in a developing child. These impair the development of the child as a whole and his participation in normal functional and school activities. This is particularly important as it has an impact on the child's ability to concentrate long enough to learn. It is also strongly associated to behaviour problems such as fearfulness and clumsiness (Lunsing et al, 1993) this implicates socio-emotional development and thus peer interaction.
DCD has, in previous years, also been referred to as low muscle tone (LMT), Benign Congenital Hypotonia (BCH), the Floppy Infant Syndrome (FIS), Clumsy Child Disorder, Motor Dyspraxia and Idiopathic Hypotonia. Signs of motor developmental delay are generally only noted when the children are of school going age and display signs of difficulty with fine motor activities, handwriting, co-ordination and being generally clumsy. In the home environment they would experience difficulties with activities such as dressing or tying their shoelaces.

The American Psychiatric Association (APA) identifies functional tasks such as dressing, writing, and cutting with scissors, copying from the board and gross motor skills as being difficult for these children. This leads to frustration and in some instances, to behavioural problems. In addition to the problems described, they are less likely to be physically fit or to participate voluntarily in motor activity (Cairney, et al 2005 and Watkinson et al, 2001)

2.1.2 Epidemiology

According to the American Psychiatric Association (2000), five to six percent of school-aged children (between five and eleven years) have movement difficulties, which are not due to specific neurological problems or cognitive impairment and which limit their classroom potential and affect their long-term academic achievement.

Gaddes (1985) and Gillberg (1982) estimated that 5% to 10 % of the school-aged population display minimal brain dysfunction (MBD) with soft neurologic signs. Clements and colleagues (1971) also found that 98% of children with MBD have motor problems as seen by their poor, slow, laboured handwriting.

The incidence of DCD in countries such as Britain, United States of America and Australia has been recorded but local data is still vague. This is mainly due to the fact that there is still little known about DCD in South Africa and not many therapists use standardised assessment tools, for example, the Movement – ABC or the Bruininks-Oseretsky tests for baseline assessments, especially in government settings (where resources and time are very limited). Specific paediatric statistics are therefore are not readily available. In 2006, Dawson and Puckree conducted a study on the prevalence of DCD in KwaZulu Natal. They found that in their study population males were more affected than females and that almost 58% of children testing positive for DCD were from rural areas. The study concluded that there is a high prevalence of DCD in KwaZulu Natal and that it is generally associated with the low levels of activity. The study also revealed a much higher prevalence of DCD as compared to westernised countries. However, they also state that accurate diagnosis of DCD is difficult and that the reported prevalence rates may be misleading. It is important to note that this study sample was quite small and the results can therefore not be generalised. The authors also do not mention use of the diagnostic criteria as determined by the DSM IV or whether the researchers were trained in using the standardised test that was employed.

2.1.3 Pathophysiology

To date, the exact pathophysiology of DCD has not been pin-pointed and various hypotheses around the subject exist. When taking the definition of DCD into account, there is no relation to muscle pathology, peripheral sensory abnormality or central nervous system (CNS) damage that causes spasticity, athetosis or ataxia (as seen in cerebral palsy).

Research done by Maruff et al (1999) and Wilson et al (2001) concluded that in some cases of DCD there are deficits in efference copy signals. This is based on the control-based learning theory (COBALT). Kathryn David (2006) describes the COBALT theory as follows: - an environmental goal triggers activity in the dorsolateral frontal areas of the brain. The frontal areas send signals to the posterior parietal lobes so that intentions can be integrated with previous visual and kinaesthetic perceptions. The parietal lobe's specialized circuits connect to the motor areas of the brain. The sequencing of the actions and control parameters take place in the supplemental motor area and the basal ganglia. The primary motor cortex receives these inputs and sends efferent signals to the spinal cord. Immediately prior to execution of the motor action, an efference copy of the motor is sent via a corollary pathway to the parietal lobe and is stored there. The theory hypothesises that in DCD this pathway does not exist or cannot be established normally. COBALT suggests that if no internal representation of a movement exists in the parietal lobe, either because the motor action is being performed for the first time or because of a deficit in CNS processing, the specific motor control factors such as force, timing and distance have to be selected without reference to past experience. In relation to the COBALT theory, Wilson et al (2001) therefore hypothesised that the impairment in the ability to generate the internal representation of the motor action (efferent copy) may be responsible for the slow, uncoordinated movement that is so often observed in children with DCD.

In 2007 Cantin and colleagues explored a hypothesis involving the motor adaptation area of the cerebellum. The researchers used strict inclusion criteria, and used both the M-ABC and the DCD-Questionnaire for the diagnosis of the subjects involved. However, the sample size was quite small, with a DCD group of nine participants and a control group of 11 subjects. The age range for the sample was wide, varying from six years and eleven months to eleven years and ten months, making generalisability of the results difficult. They utilised the throwing section of the Prism Adaptation Test, generally used to test cerebellar function and compared the performance of children with DCD to that of an age and gender matched control group. In their findings, the DCD group was more variable and less accurate, but showed adaptation to gaze shift. The findings did not confirm that a cerebellar dysfunction exists, but it was not refuted either. Some of the DCD children did have some cerebellar dysfunction. Hence, true pathophysiology remains a mystery still.

2.1.4 Diagnosis and clinical presentation

The diagnostic criteria outlined in the Diagnostic and Statistical Manual-IV (2000, pp 54-55) are as follows:

A. Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (eg. walking, crawling and sitting), dropping things, "clumsiness", poor performance in sports or poor handwriting.
B. The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.
C. The disturbance is not because of a general medical condition (eg. Cerebral palsy, hemiplegia or muscular dystrophy) and does not meet criteria for a pervasive developmental disorder.
D. If mental retardation is present, the motor difficulties are in excess of those usually associated with it.

As described, in some cases the problems may be severe enough to impact on functional daily skills. This results in a cycle of frustration and a lack of motivation that may even lead to feelings of anger, aggression or them wanting to give up completely. Additional aspects that were identified by Missuina (2003) are withdrawal, avoidance and "off-task" behaviours. They may act out in class and become disruptive to the teacher and classmates. Behaving in a disruptive (or even non-disruptive way) may be a strategy used to cope with motor difficulties, or may be related to co-occurring learning and attention problems, which have been shown to be highly associated with DCD (Rivard et al, 2007; Missuina 2003) explain that most of the motor and behavioural problems are observed in the classroom environment or on the playground. This theory is substantiated by the literature review done by Hamilton (2002). He said that associated problems magnify with time and as teenagers these children have higher rates of educational, social and emotional problems. Teachers and parents therefore play a vital role in identifying the children experiencing difficulties because children with DCD are commonly under-recognized until academic

failure begins (Miller et al, 2001). Rivard et al (2007) supports this finding, stating that the classroom environment provides a unique opportunity for teachers to observe children with motor difficulties in relation to their peers. Evidence also indicates that children with DCD often perform at a level substantially below what is expected for their age (Hill et al, 1998).

Polatajko and Cantin (2006) conducted a systematic review of the literature on DCD. The authors classified the evidence according to The Hierarchy of levels of evidence for evidence-based practice (meta-analytic studies were studies were classified as level 1, experimental studies that involved at least one randomised control group were classified as level 2 and experimental studies with single-group designs or no subject randomisation were classified as level 3). The classification yielded three level 1 studies, seven level 2 studies and 15 level 3 studies). The results of the review enabled them to integrate the description of DCD with the International Classification of Functioning (ICF) as set out by the World Health Organization (WHO) in 2001. The ICF provides a framework that helps us understand the impairment in relation to daily life. The ICF suggests that context plays a role in mediating or compounding the life consequences of impairments and it highlights the multiple interactions between health and health related components impacting on human health and functioning (Polatajko and Cantin, 2006). The model recognises the importance of participation and acknowledges this in the classification. The ICF highlights the importance of interaction between the person and the environment in producing health or disability.

The ICF model is composed of two sets of components: - components of functioning and disabilities and components of context. The components of functioning and disability consist of two domains: systems of body function and structures and activities and participation. The negative correlates are impairments (of systems of body function and structures, activity limitations and participation restrictions. The components of context consist of two factors: environmental (eg social attitudes and physical build) and personal factors (eg. gender and age). Functional outcomes are the result of interactions between health conditions, components of functioning and disabilities, and components of context. The model is based on the notion that impairment influences a person's ability to carry out

activities and participate in everyday life and that the manner and extent of that impact depends on the impairment and contextual factors (World Health Organization, 2001)

2.1.5 Assessment of DCD

In research studies conducted to investigate DCD, the most common standardised tests used, are the Movement ABC® (M-ABC) (Henderson and Sugden, 1992) and/ or the Bruininks-Oseretsky Test of motor Proficiency® (BOTMP) (Bruininks, 1978).
The M-ABC has been normed for children 4-10 years of age and it includes a screening checklist to be used by teachers and parents. The norm-reference examination is done by a therapist to establish the specific areas of difficulty. The checklist has four sections with twelve questions and a fifth section with questions about the child's behaviours related to motor activities. Each of the first four sections has questions regarding the child's performance in one of the following environments: Child stationary, environment stable (e.g. cutting); child moving, environment stable (e.g. walking); child stationary, environment changing (e.g. catching); and child moving, environment changing (e.g. running and kicking a ball). A total score is calculated and used to determine if the child is at risk for movement problems (below 15% but above 5% cut-off score) or has movement problems (below the 5% cut-off score).

The norm-referenced examination has three sections, each section containing items for each of three age bands: 4 - 6 years; 7 – 8 years and 9 – 10 years. Items are divided into manual dexterity, ball skills and static and dynamic balance sections including activities such as threading beads, putting pegs in a pegboard, catching and throwing a bean bag, balancing on one leg, jumping, hopping and heel-to-toe walking. A total score is used to determine if performance is within normal ranges, if a motor impairment is present or if the impairment is serious (Henderson and Sugden, 1992).

The Bruininks-Oseretsky Test of Motor Proficiency is a test of gross and fine motor function for children from 4.5 to 14.5 years of age (Bruininks, 1978). The test has subscales for running speed and agility, balance, bilateral co-ordination, strength, upper limb co-ordination, response speed, visual-motor control and upper limb speed and dexterity. The test is largely one of co-ordination and balance but it has subtests with items that are clearly related to functional demands for school-age children, such as cutting within lines and ball activities and physical education skills such as sit-ups, shuttle-runs and long jumping. The test was normed on 765 United States subjects. The test takes 45 – 60 minutes to administer. The quicker test, Bruininks-Oseretsky Test of Motor Proficiency-Short Form (BOTMP- SF) is an abbreviated form and takes 15 – 20 minutes to complete. These are examples of test used to determine developmental delay and they are not designed to be used for the identification of DCD. Cairney and colleagues (2009) conducted a study to determine whether the BOTMP would be a valid and useful alternative to the M-ABC for identification of DCD. The short form of the BOTMP was administered to 2058 children and 24 subjects were randomly selected for further testing using the M-ABC. The results yielded a positive predictive value of 0.88 with a 95% confidence interval. They concluded that the short form of the BOTMP was a reasonable alternative, but also emphasised that further research is needed to determine the sensitivity and the specificity of the short form.

Kathryn David (2006) emphasises the importance of observing the child with co-ordination difficulties in their natural environment such as the classroom or playground, while they participated in everyday functional activities. She also adds that the following background information is pertinent when in the process of making a diagnosis of DCD: a medical history including pregnancy, delivery and past and current health status; developmental history; previous musculoskeletal and neuromuscular examinations and history of the current functional status from the family and school staff.

Results of the Hamilton review (2002) emphasise that diagnosis of DCD is determined by taking a careful history that includes a review of fine motor, visual, adaptive and gross motor milestones and performing a physical examination.

A neurological assessment may also reveal problems with body functions such as soft neurological signs including muscle weakness (especially of the hands); poor coordination (especially finger-to-nose movement) and finger-thumb opposition. There is also the possibility of choreiform movements seen as small jerky twitches of the upper extremities. However, this is not seen in all children with DCD (David, 2006, Chapter 19 –Physical therapy for children).

David (2006) also adds that children with DCD may have slower response times and have difficulty in the following areas:

1. Identifying the important details of the task
2. Analysing the task to understand is components
3. Using past experience to plan a new strategy (feed forward planning)
4. Executing the task as planned
5. Using feedback to make alterations for the next attempt

An accurate and definitive diagnosis of DCD is difficult, but the literature attempts to list differentiating criteria. One of the diagnostic criteria as described by Hamilton (2002) is poor performance in sports. However, little evidence exists to substantiate why this is so and whether cardiovascular fitness and general exercise endurance may play a role. By comparing the exercise tolerance of physically normal children to that of children diagnosed with DCD, we would gain a better understanding into the disorder and the impact it has on the normal motor development. If discrepancies do exist, it would be easier to address the issue of physical performance, which in turn, would enhance concentration and thus the ability to learn in the classroom environment.

2.2 Endurance in children

Physical fitness can be defined as a set of attributes which people have or achieve that relate to their ability to perform physical activity and included in this definition are characteristics such as cardiorespiratory endurance, muscular strength and endurance, body composition, flexibility, balance and reaction time (Haga M, 2008). Gallahue and Ozmun (2006) add to the definition, the concept of one's genetic make-up and the maintenance of nutritional adequacy. They also describe one's personal level of health-related and performance related fitness influences motor development in many ways. Motor fitness is one's current performance level as influenced by factors such as movement, speed agility, balance, co-ordination and power. One's motor fitness has a definite effect on the performance of any movement activity that requires quick reactions, speed of movement, agility and co-ordination of movement, explosive power and balance.

Children with physical disabilities often exhibit decreased or limited exercise capacity relative to their non-disabled peers. This can result from either their limited participation in exercise, which leads to deconditioning or the specific pathologic factors of their disability that limit exercise related functions. Regardless of the cause, children with disabilities often enter a cycle of decreased activity that precipitates a loss of fitness and further decreases in activity levels (Stout JL, Chapter 8, Physical Therapy for Children, 2006).

Haga (2008) reported that recent studies indicate that children with low motor competence have an increased risk for higher body mass index (BMI) and for being overweight and obese in childhood and early adolescence. This is substantiated by Tsiotra et al (2006). They state that DCD is associated with reduced levels of physical activity, which may contribute to clinical obesity and low cardiorespiratory fitness. Recording of anthropometric data is therefore important when considering a child's level of activity and how it influences general growth and development.

Ensuring physical fitness is one aspect of primary prevention and health promotion upon which the practice of physiotherapy is based (American Physical Therapy Association, 2001) and is a construct that fits appropriately within the ICF model. As clinicians who design exercise programmes and treat children with disabilities, we have a unique responsibility to understand and promote physical fitness as an aspect of those programmes (Stout, 2006).

2.3 The Six Minute Walk Test (6MWT)

2.3.1 Description of the 6MWT

The American Thoracic Society (ATS) (2002) described the 6MWT as a practical, simple test that requires a 100 foot (30, 3 metres) hallway but no exercise equipment or advanced training for technicians. Walking is an activity performed daily by all but the most severely impaired patients. The test measures the distance that a patient can quickly walk on a flat, hard surface in a period of six minutes. In 2002 the ATS endorsed and published guidelines for performing the 6MWT in the clinical setting.

The above description is substantiated by Li and colleagues (2007) in their study to determine reference values for the 6MWT in children. They describe the individual response to exercise as an important assessment tool because it provides a composite assessment of the respiratory, cardiac and metabolic systems. The self-paced 6MWT that was employed in this study allows the patient to choose their own intensity of exercise and are allowed to stop and rest during the test. Since, most activities of daily living are performed at sub-maximal exercise capacity, this test is ideal (Li, et al 2007)

2.3.2 Validity and Reliability of the 6MWT

Excellent test re-test reliability has been observed amongst adults with traumatic brain injuries (van Loo et al, 2004) and multiple sclerosis (Fry and Pfalzer, 2006). It has also been evaluated in healthy children (Li et al, 2005), children with juvenile idiopathic arthritis (Lelieveld et al, 2005 and Paap et al, 2005), in children with cerebral palsy (Thompson et al, 2008) and children awaiting organ transplants (Nixon et al, 1996). In their study involving children with cerebral palsy, Thompson et al (2008) found that the 6MWT had an excellent test re-test reliability with narrow 95 percent confidence intervals.

Sadaria and Bohannon (2001) did a review of a total of 236 articles on the 6MWT and found that it is the most widely used test among patients with lung and heart problems. They established that the 6MWT and other walk tests are useful, reliable and valid as well as responsive for individuals with other conditions or pathologies limiting aerobic functional capacity or endurance.

The results of their review also provide procedural recommendations for the 6MWT and suggest that where reference values are used, one should employ methods as similar as possible to those used to generate the norms.
The suggested procedural recommendations (Sadaria and Bohannon, 2001) are as follows:

1. The course should be circular or rectangular in shape to minimise the time it takes to make turns and maximise the distance walked during the test. If no such course is available, the corridor employed should be as long and wide as possible.
2. Subjects should be instructed before beginning that they are to “walk as far as possible in six minutes” and “take rests if needed but resume walking as soon as possible.
3. A practice trial should be provided whenever possible to familiarise the subjects with the test and to minimise the learning (training) effect.
4. No encouragement should be provided and information as to time remaining should be given only if requested.
5. Subjects should be accompanied with a chair if necessary. However, subjects should set the pace of walking.

Figure 1: Summary of the studies assessing Reliability and Validity of the 6MWT (Sadaria and Bohannon,2001, pg 129)

Study (year)	Subjects investigated	Reliability	Validity
Langenfeld et al, 1990	Pacemaker (97)	-	Correlated with bicycling (r= 0.74) when compared to performance in Watts
Bittner et al, 1993	Congestive cardiac failure and/ or ejection fraction of 0.45 or less (898)	-	Correlated with age (r= -0.34); 3.7-fold high risk of dying in patients walking ≥300m vs. 450m
Mak et al, 1993	COPD (42) and chronic severe asthma (28)	-	Correlated with carbon monoxide transfer capacity (r=0.68), PEF (r=0.55), forced volume in 1s (FEV1) (r=0.53); age (r= -0.49)
Cahalin et al, 1995	End-stage lung disease (60)	Test-retest (ICC = 0.99)	Correlation with VO2 max (r=0.73); R= 0.83 when added age, weight & pulmonary function test results
Fitts and Guthrie, 1995	Chronic renal failure (20)	Test-retest reliability (r= 0.91)	Correlated with HR (r= 0.78)
Cahalin et al, 1996	Heart disease (45)	Test-retest in 20 patients (ICC= 0.96)	Correlated with peak VO2 (r= 0.64)
Nixon et al, 1996	Cardiopulmonary problems (ages 9 -19 yrs) (17)	-	Correlated with physical work capacity (r= 0.64) and VO2 peak (r= 0.70); correlated weakly with peak HR for bike test (r= 0.25)
Kadikar et al, 1997	Lung diseases (145)	-	Distance ≥400m predicted death; sensitivity 0.80, specificity 0.27 positive predictive value 0.91. Distance ≥300m predicted death: sensitivity 0.52, specificity 0.80, positive predictive value 0.38 & negative predictive value 0.88
Montgomery et al, 1998	Peripheral arterial occlusive disease (64)	Test-retest reliability (r= 0.94) and total steps taken (r= 0.90)	Correlated with maximum claudication pain during treadmill test (r= 0.525) & ankle-brachial index (r= 0.552)
O'Keefe et al, 1998	Heart failure (60)	Test-retest (ICC= 0.91)	Correlated with chronic heart failure questionnaire (CHQ- 0.79)
Rikli and Jones, 1998	Volunteers (77)	Test-retest: trials 1 & 2 (ICC= 0.91); trials 2 & 3 (ICC = 0.94)	Correlated with treadmill performance (r= 0.78)
Roul et al, 1998	Heart failure (121)	Test-retest in 40 patients (ICC= 0.82)	Correlated with peak VO2 in patients walking ‹300m (r= 0.64)
Harada et al, 1999	Healthy older adults (51)	Test-retest reliability at 1 week (r = 0.95)	Correlated with chair stand (r= 0.67), tandem balance (r= 0.52) & gait speed (r= -0.73)
King et al, 1999	Fibromyalgia (96)	Test-retest (ICC= 0.73)	Correlated with VO2 peak (r= 0.657)
Troosters et al, 1999	Healthy older adults (51)	-	Correlated with age (r= 0.51) and height (r=0.54)
Pankoff et al, 2000	Fibromyalgia (28)	-	Distance walked correlated with Fibromyalgia Impact Questionnaire (FIQ) (r= -0.494) and pVO2 (r= 0.420)
Rejeski et al, 2000	COPD	Test-retest reliability for 30 patients (r= 0.91)	Correlated with VO2 peak (r= 0.64)
Zugck et al, 2000	Dilated cardiomyopathy (113)	-	Correlated with peak oxygen uptake at initial (r= 0.68) & follow-up visits (r= 0.74 at 263 ± 114 days and r= 0.76 at 528 ± 234 days)

Children with DCD have pre-existing difficulties with co-ordination and perception; more complex testing will be difficult. The 6MWT requires little co-ordination and motor planning or spatial perception skills and thus is ideal to determine the baseline functional endurance capacity of the children with DCD. Solway and colleagues (2001) in their review of the various walk tests found that the 6MWT had better acceptability among participants and provided a better reflection of activities of daily living when compared to other tests. This correlates with the findings of Li et al in their study conducted in 2007.

Since therapeutic interventions are often based on improving motor skills, the 6MWT is an ideal way to test therapeutic outcomes. Its ease of application (requiring few tools and inexpensive testing equipment) makes it user friendly and easily accessible to all therapists, regardless of the clinical setting. This is of particular importance in areas where funds are limited but a measurable outcome tool is needed to monitor progress in therapy or with home programmes.

Previous studies that investigated endurance and /or fitness in children with DCD used the Test of Physical Fitness (Haga, 2008) and fifty metre run test (Hands, 2007). The test of physical fitness, as employed by Haga, contains nine separate items (see appendix VI), of which running a distance of twenty metres is one. The study only had a sample of 24 subjects and selection was purely based on the individual results of the M-ABC, whereby the children with the highest scores were designated to the group with movement difficulties and the children with the lowest scores were allocated to the comparison group. The study did not take into consideration aspects of BMI, weight, height or gender. Also, to complete the Test of Physical Fitness, the individual needs a certain level of motor competence, which children with DCD do not have. They therefore began the test already being at a disadvantage. This has been highlighted by Angilley and Haggas (2009) who also stated that the Test of Physical Fitness was not devised for the DCD population and therefore is more difficult for these children to access.

The study done by Hands (2008) was a done over a period of five years and assessed the changes in levels of motor skill and fitness. The sample consisted of nineteen children with DCD and a control group of nineteen children that were matched by age and gender.

Both these tests, Test of Physical Fitness and fifty metre run test, assess maximal exercise ability, but activities of daily living are performed at a sub-maximal level. Neither one would therefore be an accurate reflection of what the child is able to manage on a day-to-day basis.

In their review of the literature on submaximal exercise testing, Noonan and Dean (2000) describes maximal exercise testing as having a role in the assessment of maximal aerobic capacity or functional work capacity. They add that people are frequently limited by cardiopulmonary, musculoskeletal and neuromuscular impairments and complaints such as exertion, dyspnea, fatigue, weakness and pain during their activities of daily living, maximal exercise testing is often contra-indicated or of limited value.

2.3.3 Application of the 6MWT

Technical aspects as outlined by the American Thoracic Society:

- Location – the 6MWT should be performed indoors, along a flat, straight enclosed corridor with a hard surface. The walking course must be 30 metres in length. The turnaround points should be marked with cones. A starting line, which marks the beginning and end of each lap, using brightly coloured tape

- Required equipment
  - Countdown timer
  - Mechanical lap counter
  - Two small cones to mark turnaround points
  - A chair that can be easily moved along the walking course
  - Worksheets on a clipboard
  - Source of oxygen

- Sphygmomanometer
- Telephone
- Automated electronic defibrillator

- Patient preparation – Comfortable clothing should be worn
  - Appropriate shoes for walking should be worn
  - Patients should use their usual walking aids during the test
  - The patients' usual medication regimen should be continued
  - A light meal is acceptable before early morning or early afternoon tests
  - Patients should not have exercised vigorously within 2 hours of beginning the test

The contra-indications listed by Enright (2003) in his review of the 6MWT literature, includes unstable angina or myocardial episodes in the last month, resting tachycardia or uncontrolled hypertension. As and additional safety measure, training in Cardiopulmonary resuscitation is recommended.

Variables measured – the primary measurement was that of the distance covered in a six minute period. Secondary measures were changes in heart rate, breathing rate (dyspnoea) and peak expiratory flow rate, immediately following the test.
Conducting the test – the patient is required to wear comfortable footwear. The therapist is not allowed to walk the subject being tested as this may alter his/her pace. It is also better to test subjects individually to eliminate the element of competition.

2.4 Endurance and Education

In an editorial on DCD, Mandich and Polatajko (2003) said that participation in typical activities of childhood is essential to a child's healthy development. Early competence in motor-based activities is an important predictor of successful development. Inability to participate leads to marginalisation and social isolation.

A study conducted by Castelli and colleagues (2007) examined 259 public school students in third and fifth grades and found that field tests of physical fitness were positively related to academic achievement. Specifically, aerobic capacity was positively associated with achievement. The study also demonstrated associations between total academic achievement, mathematics achievement and reading achieving, thus suggesting that aspects of physical fitness may be globally related to academic performance in preadolescents. The Castelli study was preceded by a study done by the California Department of Education 2001. This study attempted to identify the relationship between physical fitness and academic achievement. They found that the reading and mathematics scores matched with the fitness scores.

Hand (2008), in her study on motor skill and fitness measures, stated that children with motor difficulties are unable to participate successfully in many physical activities enjoyed by their well-coordinated peers. They also have difficulty with everyday tasks important in home (including self-care activities that involve things like tying shoelaces or doing buttons), school and social life. This results in the children with co-ordination difficulties, withdrawing themselves from participation in physical and at times, social activities. Mandich et al (2001) adds that the impact of children's co-ordination difficulties is influenced by many factors such as culture, family expectations or the child's own activity preferences. These continue into adolescence and early adulthood. David (2006) describes that even though general motor clumsiness is a developmental characteristic for many adolescents as their body proportions change, motor proficiency is valued because competitive sports play an important role in peer interactions and expectations of some families. Academic demands also continue to increase as the child progresses through their school career.

Losse and colleagues (1991) did extensive retesting in their longitudinal study and concluded that children with DCD continue to have significant motor difficulties at 16 years of age, with qualitative differences greater than quantitative measures. These children also demonstrated significantly lower academic scores and handwriting problems and had difficulty organizing materials.

Another implication of the reduced activity is on the fitness components as described by Haga (2008). In addition to this, Cairney et al, 2005 found that low fitness outcomes combined with inefficient patterns of movement can contribute to early fatigue and thereby limit opportunities to develop motor skills. In longitudinal studies, that investigated children into adolescence, it was found that a number of them continue to experience motor problems as well as educational, social and emotional difficulties into adolescence and often into adulthood as well (Losse et al, 1991; Gillberg and Gillberg, 1989; Cantell et al, 1994; Baquet et al, 2006). Missuina et al, 2003 substantiates this factor and emphasised that the increased risk for children with DCD of secondary mental and physical health issues as well as academic failure highlights the importance of early identification of children with DCD and timeous implementation of sufficient or adequate intervention.

Conclusion

The importance of realising the impact that the diagnosis of DCD has on children and their ability to function normally in every day tasks and learn adequately in the school environment is highlighted in the literature. The relevance of adequate submaximal endurance for successful completion of these activities is emphasised.

Chapter 3 – Methods

In this chapter, the methodology used to conduct the research will be described.

3.1 Location

The study was conducted by the researcher in the hall or therapy rooms of the three different schools. The special needs schools that were selected were Muriel Brand and Felicitas schools, respectively. Here children with co-ordination difficulties were selected based on the set inclusion criteria. Only children who were walking independently and without the use of an aid were selected to participate. The mainstream school selected was Môrewag Primary school. One other mainstream school in the area was approached but declined the invitation to participate. The reasons for doing so were not disclosed to the researcher. Invitations to schools were limited to schools in the same catchment area as the two participating special schools. This would ensure learners (participants) would hail from similar socio-economic backgrounds. Typically developing children were selected who met the inclusion criteria as stated.

The schools were selected for their close proximity to each other, ensuring that subjects were from similar socio-economic backgrounds. In the area in which the schools are situated, children generally do not participate in extra-curricular (i.e. club related) sporting activities due to the lower income bracket and limited opportunities.

3.2 Permission to conduct the research

Permission to conduct the research was granted by the Gauteng Department of Education as well as from the principals and governing bodies of the schools involved. Selected individuals were given information sheets with an attached permission letter for the parents (Appendix).

3.3 Ethical clearance

Application for ethical clearance was made to the Human Research Ethics Committee (Medical) of the University of the Witwatersrand and approval was granted. (Clearance number: M080516) (Appendix II)

3.4 Sample selection

The sample size was determined in consultation with a statistician and was based on the primary objective. It was determined that a sample of 13 subjects per group would have 90% power to detect a clinically relevant difference in distance covered by the two groups of 45 metres, where the standard deviation was assumed to be a conservative 33 metres (Elloumi et al, 2007).

The first group consisted of 17 normally developing subjects, attending a mainstream school and the second group consisted of 31 subjects with a diagnosis of DCD.

3.4.1 Inclusion criteria

Both groups – children between the ages seven and ten years (unspecified gender)
Group 1:

- Normally developing children attending a mainstream school
- No history of birth trauma or major injuries
- No co-ordination difficulties

Group 2:

- Children screened and having a diagnosis of DCD, as determined by physio- or occupational therapists based at the schools. The Movement ABC was used to assess the learners. Those learners that had scores below the 5% cut-off score were included in the study (Henderson and Sugden, 1992).
- An adequate walking ability (i.e. they are able to walk independently and without the help of a walking aid). The scores below 5% of the cut-off score of the Movement- ABC, indicate that the learners are able to walk and/or run without difficulty, However, they have difficulty with movements requiring complex motor planning and co-ordination of limbs and movements.

3.4.2 Exclusion criteria

- Pre-existing syndromes or diseases which may affect endurance.
- Previous injuries or trauma that may influence results of the test.
- Current illness that require medical intervention (such as influenza or bronchitis).
- No active and continuous participation in club sports, which would be more than the average sport participation and that, would influence general endurance levels.

3.5 Assessment Tool

Exercise tolerance was evaluated by using the Six Minute Walk Test (6MWT). Exercise tolerance tests are highly effort dependent and rely on the willingness of the subject to endure breathlessness and leg muscle fatigue (Rogers, et al 2003). This method of evaluation was specifically selected for its ease of use and application. It was particularly important in this study as children with DCD present with difficulties of co-ordination. More

complex evaluations (which require running, rapid changes in direction or co-ordination of movements) may have led to difficulties in performing the tasks and thus the overall results.

The 6MWT is a reliable and valid measure of walking endurance in children (Li, et al 2005; Lammers et al, 2008). During the 6MWT, the total distance walked in a period of six minutes, was measured. The children were encouraged to walk without running, but to work to the maximum of their ability.

3.6 Procedure

3.6.1 Recruitment

Candidates for the DCD group were screened and selected at the special needs schools by the therapists, based on their initial admission diagnosis of low muscle tone (the choice of terminology used at the schools). Candidates for the normal group were selected with the help of the class teacher, who reported no difficulties with learning, achievement or gross and fine motor skills. As far as possible the groups were matched for age and gender. Informed consent was obtained from parents or guardians of the participants. Prior to beginning the 6MWT, the procedure was explained to the subject and verbal assent obtained. (Appendix IV)

3.6.2 Age and gender

The age range used in this study, seven – 10 years of age was wider than the study done by Haga (2008) but smaller than the studies conducted to validate the use of the 6MWT (Morinder et al 2008; Lelieveldt et al 2005; Olsson et al 2005; Elloumi et al 2007). The sample group used to determine normative reference values for children had a sample size of over one thousand healthy subjects (Li et al 2007). The present study used a once-off assessment format and the age-range was chosen to ensure that enough subjects could be recruited for the study.

3.6.3 Measurement

All measures and data collection were undertaken by the researcher and conducted individually, with no spectators present (this was done to exclude the element of competition between the participants). All data collection took place between 08H00 and 11H00 on school days, over a period of five weeks. Times and dates were arranged per school to ensure that the participants did not engage in any other physically demanding activities prior to the test.

Measurements began with height by using a standard stature metre (Panamedic), mounted to the wall. Weight was measured using a digital scale (Home Use Personal Scale – micro 2002A2) which was calibrated by the suppliers. These measures were used to calculate the individual BMI scores of each of the participants [body weight in kg / (height in m)^2]. Measures of head circumference, using a standard tape measure in centimetres, were taken and recorded.

Blood pressure was measured using a standard digital sphygmomanometer (Hartmann Tensoval® Comfort 89522 – with a paediatric cuff) also calibrated by the suppliers prior to use.
Heart rate and breathing rate were measured manually using a timer and observing the pulse and breathing rate for thirty seconds and multiplying the figure by two (to obtain the number of breaths or heart beats per minute).

Peak Flow was measured using a standard Sibelmed® Datospir-10 peak flow meter and disposable paediatric mouth pieces. Use of the peak flow meter was demonstrated and the subject was allowed three measures to obtain the best results.

These measurements were taken before (10 minutes prior to testing) and after the 6MWT with the subject sitting on a chair, feet supported and in an upright position. Post-test measures were taken immediately after the test and once only as per American Thoracic Association Guidelines (Crapo et al, 2002 as well as other studies using the 6MWT – Morinder et al, 2008; Cunha et al 2006; Lammers et al, 2008 and Li et al, 2007).

An oval track was laid out, using a standard balance beam (of the same length) and markings were made on the floor using tape to demarcate the area within which they had to walk as well as the starting point and the direction in which they needed to walk in. The distance of one complete round was measured, using a standard measuring wheel, as being 8, 7 metres in length.

At the start of the assessment, baseline breathing rate, pulse rate, blood pressure and peak flow were measured and captured on individual data sheets which utilised a numeric system. The six minutes were timed using a standard digital sport timer and an alarm to indicate when the subject needed to stop. During the 6MWT the subject was encouraged to walk to the best of their ability and the number of completed rounds were counted and recorded. Terms used to encourage the participants were: 'you are doing well, keep going' and 'remember to walk as much as possible'. The end-point for each individual was marked at the end of the six minutes and the additional distance measured and added to the overall distance they managed to cover.

Breathing rate, pulse rate, blood pressure and peak flow was again measured immediately following completion of the six minutes. Each subject was given some fruit juice following the test to aid recovery.

3.7 Statistical Considerations

The primary objective was to compare normally developing children and DCD children between the ages of seven and 10 years with respect to submaximal endurance levels as measured by the distance covered during the six minute walk test.

3.7.1 Data analysis

The data for both the primary and secondary parameters were summarized by group by using mean, standard deviation and 95% confidence interval or median, range and interval, based on percentiles where the data was not normally distributed.

The DCD and normal groups were compared with respect to the mean distance covered in six minutes using the students' two- sample t-test. Where the observed data not have a normal (Gaussian) distribution the non-parametric Mann-Whitney U-test was employed. The secondary parameters i.e. heart rate, breathing rate, blood pressure, etc were analysed in a similar way.

The results obtained in this study are presented in the following chapter.

Chapter Four – Results

The following chapter describes the results obtained during the study:

The variation in number of participants for the two groups (DCD n=31 and normally developing n=17) is attributed to the poor response of the participants' parents when the researcher requested parental permission as well as a high rate of absenteeism and illness of some participants at the time of data collection.

4.1 Demographics

The table describes the children in terms of their age and gender for each of the two groups in the study. The selected participants were recruited from two neighbouring schools. The schools are fed from the same area and the children therefore have similar socio-economic and cultural backgrounds.

Table 4.1.1: A comparison of the DCD group and normal comparative group with respect to age.

Gender	***Mean Age (SD) DCD (n=31)***	***Mean Age (SD) Normal (n=17)***	***p-Value****
Female	11(n) 9.4 years (SD ± 1.23)	6 (n) 8.9 years (SD ± 0.65)	0.03
Male	20(n) 9.5 years (SD ± 0.93)	11(n) 8.9 years (SD ± 0.67)	0.03

***p ≤ 0.05** denotes a significant difference between the groups*

As depicted by the p-value the groups varied significantly with regard to age. The DCD group had more subjects for both gender groups and the mean age was 9.4 years for females and 9.5 years for the males. The normal group had an average age of 8.9 years for both male and female participants.

The DCD group had a larger age range from 7.1 years to 10.11 years whereas the normal group had a smaller range, from 8.0 years to 10.0 years.

The following table shows the distribution of gender for each age group

Table 4.1.2 Table representing number of female and male participants for each age group

Age	***DCD Group (n = 31)***		***Normal Group (n = 17)***	
	Female	***Male***	***Female***	***Male***
7	1	1	-	-
8	3	4	3	5
9	2	7	2	5
10	5	8	1	1
Total	11	20	6	11

The above table shows why the two groups differed so significantly. There were no subjects for the age band of seven years for the normal comparative group and substantially less subjects in the age band of 10 years as well. For the eight and nine year age band, they were fairly evenly matched.

The table below is a summary of the anthropometric data collected prior to commencement of the 6MWT

Table 4.1.3 Anthropometric data collected prior to the 6MWT

Parameter measured	**DCD group (n=31) Mean (SD)**	**Normal group (n=17) Mean (SD)**	**p-Value***
Height (m)	1.34 (±0.09)	1.36 (±0.08)	0.43
Weight (kg)	37.71 (±10.03)	32.15 (±7.75)	0.83
Body mass Index	18.08 (±3.99)	17.28 (±2.66)	0.41
Head circumference (cm)	52.68 (±1.89)	52.79 (±1.30)	0.80

***p ≤ 0.05** denotes a significant difference between the groups*

The measurements were taken to establish anthropometric data and to determine whether there were any differences between the two groups, which may have had an influence on the outcome of the 6MWT. No significant differences between the two groups with respect to the parameters measured were found, indicating that the two groups were well matched for comparison. As in the studies conducted by Li et al (2007) and Lammers et al (2008) these measures are important for submaximal endurance levels as it indicates their development. This is particularly important when the results are compared between the groups as well as when comparing the results of the present study to that of internationally determined standards. It gives a clearer understanding of how the two groups may vary and the factors that may influence these differences.

A comparison of the anthropometric data to international standards of development is important for the study findings, to determine whether the subjects can be compared to pre-determined, normal walking distance standards.

When the height results of the present study are compared to the standardised CDC stature-for-age charts, it is summarised as follows:

Table 4.1.4 Comparison of the DCD group height results to the CDC growth charts

DCD group	***Females***		***Males***	
Age(yrs)	***Height (m)***	***Percentile***	***Height (m)***	***Percentile***
7	1.13	Btw 3^{rd} & 10^{th}	1.32	97^{th}
8	1.33	75^{th} – 90^{th}	1.28	50^{th} – 75^{th}
9	1.36	50^{th} – 75^{th}	1.31	50^{th}
10	1.40	50^{th} – 75^{th}	1.37	Below 50^{th}

As seen in the above table, only the eight year old male and the eight year old females in this group fell within the normal standardised limits as determined by the World Health Organization. The single female in the seven year age group as well as the nine and ten year old children tend to be shorter than the international norms. This could be indicative of cultural variations as well as the fact that height varies with genetics.

Table 4.1.5 Comparison of the normal comparative group height results to the CDC growth charts

Normal group	***Females***		***Males***	
Age(yrs)	***Height (m)***	***Percentile***	***Height (m)***	***Percentile***
7	-	-	-	-
8	1.33	75^{th} – 90^{th}	1.31	75^{th}
9	1.31	25^{th} – 50^{th}	1.42	90^{th}
10	1.47	90^{th}	1.34	25^{th} – 50^{th}

In the comparative group, both genders of the eight year band fell within relatively normal limits. In the nine year age band the females were relatively below par, but the males fell within the determined 90^{th} percentile bracket. In the ten year age band, these results are reversed, with the females being in the 90^{th} percentile bracket and the males falling below the 50^{th} percentile mark.

When compared to the standardised CDC weight-for-age charts, the results are summarised as follows:

Table 4.1.6 Comparison of the DCD group weight results to the CDC weight-for-age growth charts

DCD group	***Females***		***Males***	
Age(yrs)	***Weight (kg)***	***Percentile***	***Weight (kg)***	***Percentile***
7	13.7	Below 3rd	41.0	Above 97th
8	26.7	25th - 50th	27.2	50th - 75th
9	29.9	50th – 75th	33.5	50th
10	35.9	Below 75th	37.1	75th

As seen in the above results, only the seven year old male fell within the normal limits of the WHO standards and the remaining subjects fall between the 50th and 75th percentiles. The single seven year old female participant fell grossly below the 3rd percentile.

Table 4.1.7 Comparison of the normal comparative group weight results to the CDC growth charts

Normal group	***Females***		***Males***	
Age(yrs)	***Weight (kg)***	***Percentile***	***Weight (kg)***	***Percentile***
7	-	-	-	-
8	32.0	75th – 90th	34.7	97th
9	26.9	50th	36.9	90th
10	46.3	90th	27.5	25th

The subjects of the normally developing group fell within the normal limits of the WHO charts, except for the ten year old males who were within the 25th percentile only.

When compared to the standardised CDC head circumference-for-age charts, the results are summarised as follows:

Table 4.1.8 Comparison of the DCD group head circumference results to the CDC growth charts

DCD group	***Females***		***Males***	
Age(yrs)	***Head circ. (cm)***	***Percentile***	***Head circ. (cm)***	***Percentile***
7	47	10^{th}	54	97^{th}
8	51	97^{th}	52.9	97^{th}
9	52	97^{th}	54	97^{th}
10	52.4	97^{th}	53.1	97^{th}

In the above results it is noted that all, except the seven year old female participant, fall within the normal range for their head circumference values.

Table 4.1.9 Comparison of the normal group head circumference results to the CDC growth charts

Normal group	***Females***		***Males***	
Age(yrs)	***Head circ. (cm)***	***Percentile***	***Head circ. (cm)***	***Percentile***
7	-	-	-	-
8	52.5	97^{th}	52.8	97^{th}
9	51.5	97^{th}	53.5	97^{th}
10	52.5	97^{th}	54	97^{th}

Head circumference is clinically measured until the age of three years, but it was interesting to note that the seven year old girl in the DCD group still fell significantly below the normal percentile value

4.2 Submaximal -Endurance Levels

The overall results of the 6MWT is depicted in the table below for each group, with the standard deviation The table below depicts the baseline data collected for both groups.

Table 4.2.1: Baseline data collected prior to the 6MWT

Parameter measured	**DCD Group (n=31) Mean (SD)**	**Normal group (n=17) Mean (SD)**	**p-Value***
Heart rate (bpm)	83.26 (±14.73)	76.47 (±12.11)	0.09
Respiratory rate (bpm)	24.52 (±4.82)	26.59 (±6.16)	0.24
Peak Flow(ℓ/min)	178.71 (±47.17)	199.41 (±44.65)	0.14
Blood pressure (mmHg) -Systolic	100.87 (±14.07)	99 (±8.58)	0.10
Blood pressure (mmHg) -Diastolic	67.52 (±13.08)	68.7 (±8.51)	0.37

***p ≤ 0.05** denotes a significant difference between the groups*

As depicted by the above chart, it can be seen that the two groups did not vary significantly with regard to their baseline measurements of heart rate, respiratory rate and peak flow. This is important as it indicates whether the two groups started in comparative physiological conditions.

The study by Wallis and Maconochie (2006) compared measured heart rate and respiratory rate to the reference ranges for four to sixteen year old UK children. They found that South African children have a higher respiratory rate when compared to the UK reference ranges. This difference is statistically but not clinically significant.

In 2006 a similar study was conducted by Wallis and Machonochie in South Africa (results depicted in Appendix). The South African children had similar heart rates to the British sample but had slightly higher resting respiratory rates. This difference was not felt to be clinically significant (Wallis and Maconochie, 2006).

The following is a summary of the post-test measurements

Table 4.2.2: Comparison of post-test measured parameters of DCD and normal groups after the 6MWT, mean (Standard deviation - SD) and p-values

Parameter	***DCD group (N=31) Mean (SD)***	***Normal Group (N=17) Mean (SD)***	***p- Value* Student t-test***
Heart rate (bpm)	90.52 (± 18.24)	86.06 (± 9.67)	0.27
Breathing rate (bpm)	29.81(± 5.52)	34.82 (± 6.60)	0.01
Peak flow (L/min)	170.65 (± 48.85)	190.588 (± 44.79)	0.16
Blood pressure (mmHg) -Systolic	108.35 (±16.22)	97.24 (±10.49)	-0.01
Blood pressure - Diastolic	71.74 (±14.19)	70.35 (±9.87)	-0.34

****p ≤ 0.05*** *denotes a significant difference between the groups*

As depicted above, the only parameter that varied significantly between the two groups after the 6MWT, were the breathing rate and systolic blood pressures.

4.3 Six Minute Walk Distance (6MWD)

Results of the distances covered by each group and the differences between the groups are depicted in the following tables

Table 4.3.1: Comparison of DCD group to normal group with respect to results of the 6MWT using the Student t-test

Group	***No of subjects***	***Mean distance (m)***	***Standard deviation***	***95% Confidence Interval***
DCD	31	375.89	± 73.33	339.96 – 411.82
Normal	17	430.48	± 60.85	400.66 – 460.30

***p= 0.0086** ($p \leq 0.05$ denotes a significant difference between the groups)

In six minutes, the DCD group covered a significantly shorter mean distance than the normally developing group [376 metres ± 73.33 (SD) versus 430 metres ± 60.85 (SD)]

The following table summarises the results of the 6MWT depicting the differences between the groups for each age band.

Table 4.3.2: Summary of the mean distance covered, for each age band and gender.

Age	***DCD Group (n = 31)***		***Normal Group (n = 17)***	
	Female	***Male***	***Female***	***Male***
7	266.8 m	276.3 m	-	-
8	420.6 m	361.2 m	457.3 m	489 m
9	404 m	374.5 m	365.5 m	404.2 m
10	371 m	390 m	342 m	409 m

As depicted by the graph, in the eight year band, the normal group covered more distance, but the females did much better than the boys in the DCD group of the same age band. The same result is seen in the nine year age band, with the females of the DCD group again performing better than the boys. However, in the 10 year age band the DCD girls performed better than their normal peers, but the results is a comparison of one normal girl to that of five girls with DCD. On the contrary, the one boy of the comparison group in the 10 year age band did significantly better than the eight boys from the DCD group.

Conclusion

The Six Minute Walk Test was effective in determining that there are significant differences in the mean distance covered by children with DCD when being compared to normally developing children. The significant difference in the post-test breathing rate is also indicative of differences in levels of fitness and effort taken to do the test, between the two groups.

Chapter Five – Discussion

In this chapter, the results obtained in the study are discussed in relation to existing literature on the subject. The implications and limitations of the study are highlighted and recommendations are made.

5.1 Anthropometric Data

All anthropometric data were compared to the charts developed by the National Centre for Health Statistics in collaboration with the National Centre for Chronic Disease Prevention and Health Promotion or the CDC as it is more commonly known (2000). The comparisons were done to assist in comparing the DCD and normally developing groups to each other and then to the normative standards to establish the extent of the differences when looking at international standards.

The growth charts are constructed for boys and girls separately, using large populations of normal children living under near-optimal conditions and therefore representing the range of normal growth achievement for children at different ages. Standards produced for North American children in the form of charts for length and height (stature), weight and head circumference are preferred. It should be noted that these charts were compiled in an area and time where nutrition was good and obesity probably more common that under-nutrition (Coovadia and Wittenberg, 2007).

Coovadia and Wittenberg further explain the use of the percentile- there is a wide variation between children for all growth parameters and this variation is expressed conventionally by comparison of the individual child's measurements to centiles or percentiles, that is 3^{rd} (or 5^{th}), 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 97^{th} (or 95^{th}). It is important to understand the meaning of a

percentile. If the height or weight percentiles were constructed from a population of 100 healthy children at a given time, the smallest three percent would have height or weight measurements less than the 3rd percentile, 10 percent under the 10th etc. At the end of the scale, 97 of 100 children would have measurements below the 97th percentile and only the three biggest have measurements above it. Height has a normal (Gaussian) distribution and the 50th percentile measurement corresponds to the mean and median height of the population measured.

As described, the growth charts are internationally determined standards; it is of concern to note that the DCD group fell below par in most age bands for measures of height. The comparative group faired better, even though no statistically significant differences were measured between the two groups. However, Coovadia and Wittenberg (2006) reminds us that the height of an individual child bears a significant relationship to the genetic background as exemplified by the height of the parents. They mention that developing countries, in contrast to developed countries, growth takes place over a longer period and final height attained may be reached at a later stage.

Weight

Weight measures for the DCD group was 32.7 kg ± 10 (SD) and the comparative group was 32.2 kg ± 7.8 (SD). In relation to each other, the two groups did not vary significantly. When compared to the weight for age percentile charts of the CDC (2000), both genders for both groups fall within the 90th to 97th percentile for their age range. This indicates that although the children are not overweight, they are on the top end of the normal range and their weight should be monitored carefully. There is a growing concern globally that children are becoming obese and South African children appear to be following this trend (Morinder G et al, 2009; Cantell et al, 2008; Gutin and Owens, 1999). The children in this study may not be eating a balanced diet and exercising enough, these factors warrant further investigation.

Body Mass Index

Body composition (percent body fat) is a major marker of health-related fitness. To accurately assess one's body composition, the percentage body fatness needs to be separated from the other components of one's total body weight. Skinfold callipers and calculating one's Body Mass Index are the preferred methods of estimating percent body fat in the field. Regular vigorous physical activity can alter body composition. The extent to which body composition can be altered depends on the degree and length of training. As activity levels decrease, body fat percentages increase (Gallahue and Ozman, 2006).

BMI results for the study were 18.1 ± 3.9 (SD) for the DCD group and 17.3 ± 2.7 (SD) for the normal comparative group. There were no significant differences between the two ($p = 0.41$). These results concur with both the normative range as determined by Bini et al (2000). Bini and colleagues conducted a study in an Italian population and determined a normal range for this age group as being 16.9 – 19.3 which is in agreement with the CDC standardized charts (2000).

Children are considered underweight if the calculated BMI-for-age is below the 5^{th} percentile, in the normal range if between the 5^{th} and 85^{th} percentile; at risk for overweight if between the 85^{th} and 95^{th} percentile and overweight if BMI-for-age is over the 95^{th} percentile (CDC, 2004). Since all the subjects who participated in the study fell within the normal limits, it can be deduced that none were either over-or underweight.

Head circumference

In the normal child, values for height, weight and head circumference tend to conform and follow the same percentiles before puberty. Accurate longitudinal measurements plotted on a standard percentile chart are much more informative than single measurements. A gross difference between values, such as head circumference below the third percentile, with a weight and height in the region of the 75^{th} percentile, may well be significant. Similarly, several measurements which deviate from a centile line require investigation to ascertain the cause (Coovadia and Wittenberg, 2007).

Head circumference measures were 52.7 cm ± 1.9 (SD) for the DCD group and 52.8 ± 1.3 (SD) for the normal group. When compared to the CDC standardised charts (2000), both groups fall within the normal range for their age groups.

The anthropometric measurements for the children in the control and experimental groups fell within the normal ranges for their age groups. It can therefore be assumed that the endurance levels of these children would not be adversely influenced by their growth status.

5.2 Baseline Data

Heart rate and breathing rate

Heart rate and breathing rate measures were also taken prior to and following the SMWT. These are clinically important measures as they generally affect clinical decision-making, giving an indication of the individual response to exercise. Wallis and colleagues (2005) undertook a study in Plymouth, UK to investigate and produce reference ranges of heart rate and respiration rate in healthy resting children, aged four to sixteen years. As depicted by figure, these ranges vary quite widely. The study sample utilised a large sample of 1153 children that was fairly representative of children in the UK.

In 2006 a similar study was conducted by Wallis and Machonochie in South Africa (results depicted in Appendix). The South African children had similar heart rates to the British sample but had slightly higher resting respiratory rates. This difference was not felt to be clinically significant (Wallis and Maconochie, 2006)

The heart rates for the children in this study are similar to those in Wallis and Machonochie's study on South African children (2006). No cardiac abnormalities were suspected in the study group and the heart rate and blood pressure responded appropriately to the submaximal exercise provided by the six minute walk test.

The respiratory rates for both the control and experimental groups was slightly higher than the values found by Wallis and Maconochie (2006). Although somewhat elevated these values are not high enough to indicate respiratory distress and were not considered clinically relevant. The slightly higher resting breathing rates for the normally developing group, prior to the 6MWT (when compared to the DCD group) can be attributed to excitement about participating in the research as well as being in the presence of someone who was unfamiliar to the subjects, within a 'testing' environment. This group also walked at a faster pace and covered a greater distance during the test, than the DCD group did, and therefore had a higher breathing rate after the 6MWT.

Peak Expiratory Flow Rate

The response of a child to exercise (a single event or repeated exercise) includes physiologic changes in the cardiovascular and pulmonary systems as well as metabolic effects. In children, however, differences in physiologic changes are seen as growth and development occur. Physiologic capacities depend on growth of myocardium, skeleton and skeletal muscle. Any exercise increases the energy expenditure of the body. As a child grows, the cardiopulmonary and musculoskeletal systems are integrated so that oxygen flow during exercise optimally meets the energy demands of the muscle cells, regardless of body size (Stout, 2006)

The values for the peak expiratory flow rates, in this study, are given table 4.1.3.
These averaged values are not consistent with the results of the study conducted by Mohammadzadeh and colleagues (2006) who determined normative peak flow values for each age band in an Iranian population. Their findings for the same age band as for the present study are shown in the table in Appendix VIII. No normative data for the South African paediatric population could be found

Minor dysfunction which is not apparent at rest may come to light on exercise. It also gives an indication of the level of effort taken to complete the exercise test. The differences between

the groups were not significant for both pre-and post tests, but both groups had a lower rate after the 6MWT. This indicates that both groups used adequate effort to complete the test.

Peak flow charts generally use height as a measure for determining normal values of peak flow, but in study conducted by Barcala et al (2008) they state that lung function prediction equations based on height alone can result in under- or overestimated spirometry for the ages analysed, particularly in the case of boys and the in the youngest and oldest individuals. When the results of the Barcala et al (2008) are compared to that of the present study, all the individuals fall into the normal ascertained limits of the previous study. This again highlights the importance of considering the variations between populations.

When the results for the genders are combined for an average value a total of 246.5 ℓ/min is obtained. These values are baseline determinants and when it is compared to our pre-test results, the discrepancy is once again highlighted, in which both groups of the present study fall below the normal values as determined by Mohammadzadeh et al (2006). The authors suggested a formula for predicting of PEFR in females {(age × 4/8) + (height × 0/6) – 25)} and males {(age × 1/7) + (height ×2/1) – 208)}. They also highlighted that there are many biologic sources of variation in pulmonary function. Intra-individual variability may be due to a variety of host factors, including size (height and weight), age, race, past and present health. Geographic factors, exposure to environmental and occupational pollution and socio-economic status may also influence intra-individual variation (Mohammadzadeh et al, 2006). When taking all this into consideration, it is important that each country establish independent normal reference values.

The peak flow values dropped slightly in both groups after the 6MWT. This drop was not significant and represents a normal response to exercise. As the respiratory rate and tidal volume increase with exercise so the expiratory reserve decreases, this implies that the peak expiratory flow will decrease (Cech and Martin, 2002). This decrease is transient and is not clinically significant.

5.3 Submaximal Endurance Levels

The normally developing group in this study completed an average distance of 54 metres more than the DCD group, which is indicative of the significant submaximal endurance difference between the two groups.

When reflecting on table 4.2.2, the distances covered are depicted per age band and gender, the eight year old subjects in the normal group covered more distance, but the females did much better than the boys in the DCD group of the same age band. The same result was seen in the nine year age band, with the females of the DCD group again performing better than the boys. However, in the 10 year age band the DCD girls performed better than their normal peers, but the results are comparisons of one normally developing girl to that of five girls with DCD. On the contrary, the one boy of the normally developing group in the 10 year age band did significantly better than the eight boys from the DCD group. Aerobic capacity is slightly higher in boys than in girls throughout childhood but gender has not been found to greatly affect fitness in pre-pubertal children (Cech and Martin, 2002). The differences noted in this study are most likely due to individual factors and not due to group characteristics. Further studies with larger sample sizes are required.

When the results of the present study is compared to the graph of Li et al (Appendix IX) it is noted that both groups fall below the value of the shortest distance as determined by Li and colleagues (2007). They valuated 580 metres to be the reference for the 25^{th} percentile for girls and 600 metres to be the reference percentile for boys with the shortest measured height in their study being 1.20m. Hence, all the subjects that participated in the present study fall below the 25^{th} percentile which is indicative of a significant shortfall in submaximal endurance levels.

A more recent study conducted by Lammers and colleagues (2008) in the United Kingdom, used both height and age as the reference to determine normal values (Appendix X).In contrast to Li

et al (2007), they used a smaller sample size and preferred to use age. When the results of the present study are compared to that of Lammers and colleagues, only the children of the eight year age band falls into the normal predicted values of the Lammers study. Once again, the other age groups fall below the average values.

However, when the values for the age groups determined by Lammers et al (2008) are compared to that of Li et al (2007), the results for the UK study also fall below the 25th percentile (as determined by Li et al (2007). This indicates that the UK study would be a better predictor for comparison in the present study.

Since there are no other studies that provide normative values, it is difficult to ascertain the exact cause of the discrepancy. Factors that could come into play are cultural differences, social and ethnic background as well as socio-economic variations between the study populations. Another issue of concern is the increasing sedentary lifestyle of the western world that is impacting on global health. Our current education system, which does not advocate compulsory physical education, may further exacerbate the problem. It again highlights the importance of determining normal reference values for South African children, so that research based in our country can have more inherent value for our professionals and society as a whole.

It is clear that the difference in the submaximal endurance places the children diagnosed with DCD at a disadvantage when doing daily tasks and learning. It is also important to note that when one considers the literature as discussed in chapter two, children with DCD have difficulty planning and executing tasks. Therefore, it not only takes them longer to do, it requires a lot more energy and time to complete successfully. This would further limit their submaximal endurance levels. The importance of this finding, suggests that the children with DCD in general already have limited endurance when compared to their peers and this correlates with the literature (Hands, 2007 and Haga 2008).

The current management of children with DCD has not taken cognisance of decreased endurance levels. Most therapy programmes for these children focus on balance, motor

planning and possible strengthening but not on endurance. Children with DCD may avoid physical activity due to their coordination problems and therefore have little opportunity to challenge and improve their endurance levels through day to day activities. The results of this study support the inclusion of endurance and fitness programmes into the management plans for children with DCD. This could be done through structured physiotherapy intervention and could be enhanced by encouraging the children to participate in school and recreational sporting activities.

There is a need for physiotherapists to create awareness of the importance of physical activity in the lives of all children, not just those with DCD.

5.4 Post test results

The only post-test parameter that yielded a significant result was the breathing rate which was 29.8 bpm ± 5.5 (SD) for the DCD group and 34.8 bpm ± 6.6 (SD) for the comparative group, with a p-value of 0.01. Normal baseline values of breathing rate at rest, for children between the age of eight and 15 are 20 breaths per minute (Coovadia and Wittenberg, 2007; Harrison et al, 1999). The DCD group showed a 17.7% increase in breathing rate in comparison to the 23, 6% increase of the normal group indicating the significant difference of respiratory effort between the two groups. This finding is not surprising considering the greater distance walked by the normal group.

The heart rate recorded in this study shows that the 6MWT represents submaximal effort in both groups. The estimated peak heart rate during maximal exercise of children between four and 11 years of age would be approximately 210 bpm (220 minus the age)[Astrand, 1960]. Thus peak heart rate in this study was approximately 43% (DCD group) and 41% (normal group) of the normal predicted heart rate.

5.5 Limitations of the study

The limitations of this study are the following:

- One of the limitations of the study was the use of a small sample size and a wider age band than most studies on DCD.
- An additional limitation was that the numbers were not equally distributed between the two groups (i.e. the DCD group had 31 subjects and the normally developing group only had 17 subjects)
- The true definition of DCD and its diagnostic criteria are still poorly understood and is a relatively new concept in the South African realm of practice. Therefore, it is difficult to ascertain whether the DCD group of children had a true diagnosis of DCD.

5.6 Suggestions for further research

Based on the results of this study the following recommendations can be made:

- It is important for us to establish how many practitioners use the DSM IV criteria for diagnosing DCD and how widely the concept or definition is used in practice, be it public or private.
- It would be of great value to establish baseline values for South African children. These important values need to include parameters such as height-for-age, weight-for-age, BMI, lung function reference values and levels of fitness. The information gained from these studies would prove invaluable to South African research and would shed light on many aspects of health and the general well-being of the South African population.
- There is a need to further investigate endurance in DCD, maybe using other tests such as The Modified Bruce Treadmill Test, Single- Stage Submaximal Treadmill Walking Test, Canadian Aerobic Fitness Test, Twelve-minute Run Test or the Twenty metre shuttle run test (Noonan and Dean, 2000). The use of the cycle ergometer endurance test would be useful for subjects who present with walking difficulties.

The conclusions drawn from this study will be presented in chapter six.

Chapter 6 – Conclusion

The purpose of this study was to determine the submaximal endurance levels of children diagnosed with developmental co-ordination disorder and compare the results to that of normally developing children. All subjects were between the ages of seven and ten years. The children involved in the study were of similar socio-economic backgrounds and attend Felicitas, Muriel Brand and Môrewag schools. The assessment tool used was the Six Minute Walk Test.

Performing a 6MWT is practical and feasible in young children, but it depends on their motivation and co-ordination (Lammers et al, 2008). The findings of this study support previous research which has shown that children with DCD have significant impairment of their submaximal endurance levels when compared to their normally developing peers.

It is apparent that there are significant discrepancies between the children involved in this study when compared to internationally determined reference standards. It has highlighted the lack of local data for determining the extent to which South African children are affected by DCD. There is also a gap in accurate diagnosis of the disorder and thus we are unable to determine accurate statistics.

Implications for clinical practice

- Children with DCD are potentially at risk of having decreased endurance levels. The assessment and management of these children should therefore address endurance in addition to conventional management.
- Use of the 6MWT in clinical practice will enable practitioners to objectively measure change in submaximal endurance in children affected by DCD.
- Creating a holistic picture of the individual will enable practitioners to refer for further investigations, if required. This ensures effective and comprehensive management of patients.

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APPENDIX I

Research Protocol

Name: Natalie Benjamin

Supervisor: Joanne Potterton

Title

A comparison of exercise endurance levels between children diagnosed with developmental co-ordination disorder (DCD) and endurance levels of normal children between the ages of seven and ten years.

Introduction

Definition:

Developmental co-ordination disorder is defined as being motor co-ordination markedly below expected levels for the child's chronological age and intelligence, which significantly interferes with academic achievement or activities of daily living, is not due to a medical condition, does not meet criteria for pervasive developmental disorder, and if mental retardation is present, the motor difficulties are in excess of those usually associated with mental retardation. *Diagnostic and Statistical Manual of Mental Disorders (DSM IV, 2000).*

Background

DCD can occur on its own or in combination with mental retardation, genetic disorders (e.g. Down's syndrome), neurologic disorders (cerebral palsy), brain tumours or loss of sensory function. Some may even present with attention deficit disorder (ADD) and attention deficit hyperactivity disorder (ADHD). Campbell S, et al (2006)

Hamilton (2002) described developmental co-ordination disorder (DCD) as a delay in the development of motor co-ordination in otherwise healthy children of normal intelligence. Parush et al (1998) further added that it is a condition in which the low muscle tone affects gross and fine motor skills in a developing child. These impair the development of the child as a whole and his/her participation in normal functional and school activities. This is particularly important as it has an impact on the child's ability to concentrate long enough to learn. It is also

strongly associated to behaviour problems such as fearfulness and clumsiness (Campbell et al, 2006) this implicates socio-emotional development and thus peer interaction.

It has, in previous years, also been referred to as low muscle tone (LMT), Benign Congenital Hypotonia (BCH), the Floppy Infant Syndrome (FIS), Clumsy Child Disorder and Idiopathic Hypotonia. Signs of motor developmental delay is generally only noted when the children are of school going age and display signs of difficulty with fine motor activities, handwriting, co-ordination and being generally clumsy.

Pathophysiology

The aetiology and pathophysiology of DCD is still unknown, affected children appear to have underlying difficulties in motor planning, the timing and the amount of force needed during movement and the integration of information from sensory and motor systems (Missiuna et al, 2006). By definition, DCD is not related to muscle pathology, peripheral sensory abnormality or central nervous system damage (that causes symptoms such as spasticity, athetosis or ataxia). (Campbell S. et al, 2006)

Castrodale and Carlson (2003) described DCD as children who present with hypotonia since birth, diminished active movement with preserved tendon reflexes, mild motor retardation or normal development, normal investigations, muscle enzymes, Electromygraphs, nerve conduction studies and muscle biopsies.
According to Prasad and Prasad (2003) the children may have joint laxity or hypermobility. In general they have a good prognosis.
Wilson (2005) describes children with DCD as having difficulty with motor planning, the timing and amount of force needed during movement and the integration of information from sensory and motor systems. Hamilton (2002) adds that children display poor balance, slow reaction times and difficulty executing fine motor skills.

Epidemiology

The incidence of DCD in countries such as Britain, United States of America and Australia has been recorded but local data is still vague. Dawson and Puckree (2006) found in their study in KwaZulu Natal, that males are more affected. Also, almost 58% of children testing positive for DCD were from rural areas. The study revealed that there is a high prevalence of DCD in KwaZulu Natal. It was also associated with the low levels of activity. The study also revealed a much higher prevalence of DCD as compared to westernised countries.
However, they also state that accurate diagnosis of DCD is difficult and that the reported prevalence rates may be misleading.

Diagnosis

An accurate and definitive diagnosis of DCD is difficult but some of the literature attempts to list differentiating criteria.
One of the diagnostic criteria as described by Hamilton (2002) is poor performance in sports. However, little evidence exists to substantiate why this is so and whether cardiovascular fitness and general exercise endurance may play a role. By comparing the exercise tolerance of physically normal children to that of children diagnosed with DCD, we would gain a better understanding into the disorder and the impact it has on the normal motor development. If discrepancies do exist, it would be easier to address the issue of physical performance, which in turn, would enhance concentration and thus the ability to learn in the classroom environment.

Current management

At present, therapeutic intervention focuses on improvement of balance and motor co-ordination. It also includes sensorimotor training combined with Bobath techniques of neurodevelopmental therapy.
Some of the interventions described by Campbell et al (2006) are perceptual motor training, sensory integration therapy (done by occupational therapists trained in the field) and kinaesthetic training.

They (Campbell et al, 2006) further discuss other intervention approaches currently in use in the management of DCD.

4. Guided imagery which is based on the efference-copy-deficit hypothesis
5. Cognitive approaches based on the hypothesis that children with DCD have poor problem-solving skills
6. Task-specific interventions based on motor learning principles

Significance of study

By determining endurance levels of children with DCD and comparing it to normal developing children, we can establish an objective measure of improvement during therapy intervention. It is a measure requiring few tools and some space. This makes it cost effective, but simultaneously invaluable in providing the therapist with some indication of how the disorder affects the child's performance

Problem statement

Current research reveals little with regard to the aetiology of developmental co-ordination disorder. Diagnostic criteria are based on the observation of the motor development and behaviour of the child. However, the measure of endurance is not included in the assessment. This objective measure may be useful in determining the successful outcome of therapeutic intervention.

Research question

Are there differences in exercise endurance levels of normal children aged between 7 and 10 years of age when compared to children diagnosed with developmental co-ordination disorder (DCD), of the same age?

Aim

A cross-sectional (comparative) study aimed at establishing whether there are differences in exercise endurance levels between normal children and children diagnosed with developmental co-ordination disorder (DCD), investigating children between the ages of 7 and 10 years

Objectives

1. To determine exercise endurance values of normal children and compare it to the endurance levels of children diagnosed with DCD.
2. To establish whether differences do exist and if so, it could be used as an objective measure of progress during and after physiotherapy intervention.

Methodology

Study type

A cross-sectional (comparative) study using two groups, one of which will be children diagnosed as having DCD and attending Muriel Brand School. A second group of children will be selected from a primary school in the same area. As far as possible, I will attempt to select children from a similar socio-economic group.

Inclusion criteria:

The target groups will be: two groups of children, of mixed gender, between the ages of 7 and10 years.
The first group will consist of normally developing children attending a mainstream school, who have no history of birth trauma or major injuries.
The second group will consist of children diagnosed with developmental co-ordination disorder and attending (either a mainstream or) special school such as Muriel Brand School. The screening for DCD will be done using the Movement ABC checklist (or would have been) by the physiotherapists/ occupational therapists working at the school that the children attend.
The size of the sample groups would be determined by further research and in consultation with a statistician.

Exclusion criteria:

Pre-existing syndromes and/or diseases, which would affect development, previous injuries that would affect endurance, medical intervention in the children diagnosed with DCD.
Current illness (such as the flu or bronchitis that would affect test results).

Measurement tools and techniques

Exercise tolerance would be evaluated by using the Six Minute Walk Test (6MWT) and the Energy Expenditure Index (EEI). Exercise tolerance tests are highly effort dependent and rely on the willingness of the patient to endure breathlessness and leg muscle fatigue (Rogers et al, 2003). This method of evaluation has been selected for its ease of use and application. This is particularly important in this study as the children often present with difficulties of co-ordination. More complex evaluations may lead to difficulties in performing the tasks and thus the overall score.

The SMWT is a reliable and valid measure of walking endurance in children (Li, et al 2005). During the six-minute walk test, the total distance walked in a period of six minutes, is measured. The children will be encouraged to walk without running, but to work to the maximum of their ability. Cones will be used to designate the measured distance and the number of times they complete one measure will be documented. The overall distance covered after the six minutes will then be measured in metres, using a measuring wheel or tape measure.

The measurements undertaken include:

- Baseline and Highest breathing rates (in breaths per minute)
- Continuous heart rate (in beats per minute)
- Distance walked in six minutes
- Baseline and highest respiratory capacity (in litres per minute)

The EEI is a means of using the heart rate response to assess the amount of energy used during ambulation. It is expressed as the number of beats per metre and is the ratio of change in the heart rate to the walking velocity.
Formula: EEI= (walking heart rate– resting heart rate)/walking velocity)

Also included would be:

Measurements of body height (measured in metres) and weight (measured in kilograms) to determine the Body Mass Index (BMI). The height will me measured using a standard tape measure fixed to a wall and the weight will be measured using a digital scale that has been calibrated before use. That is, the body weight in kilogram divided by the square of the body height in metres.

Heart rate will be measured at the beginning and throughout the 6MWT using continuous heart rate monitors. Respiratory capacity will be measured using a standardized peak flow meter, at the beginning and one minute after completion of the test.

Statistical considerations

The primary objective is to compare normal and DCD children between the ages of 7 and 10 years with respect to endurance as measured by the distance covered during the six minute walk test.

Sample size

The sample size will be based on the primary objective. A sample of 13 subjects per group will have 90% power to detect a clinically relevant difference in distance covered by the two groups of 45 metres, where the standard deviation is assumed to be a conservative 33 metres (Elloumi et al, 2007)

Data analysis

The data for both the primary and secondary parameters will be summarized by group by using mean, standard deviation and 95% confidence interval or median, range and interval, based on percentiles should the data not be normally distributed.

The DCD and normal groups will be compared with respect to the mean distance covered in six minutes using the students' two- sample t-test. Should the observed data not have a normal (Gaussian) distribution the non-parametric Mann-Whitney U-test will be employed. The secondary parameters i.e. heart rate, breathing rate, blood pressure, etc will be analysed in a similar way.

To facilitate interpretation of the significance tests the 95% confidence intervals for the difference between the two groups will be reported along with p-values.

Ethical considerations

Permission would be obtained from the University Ethics Committee to conduct the research. The Gauteng Department of Education will also be approached for permission to enter the selected schools and to involve the learners in the study. The principals and governing bodies of participating schools will be approached for permission to conduct the research following a briefing on the aims of the study.

Written consent would be obtained from the parents of the children selected to participate and verbal assent from the individuals participating, following a full description of the research and its purpose. Where possible they will be asked to sign an assent form if they agree to participate and understand the purpose of the research. It will briefly describe what they will be required to do during the study as well as that they reserve the right to withdraw if they want to.

All information will be held in confidence and a coding system will be used to record the data being collected. Parents and or guardians will be reassured and informed of the confidentiality of all information disclosed to the researcher.

APPENDIX II

Ethics clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Benjamin

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER M080516**
PROJECT	A comparison of exercise endurance levels between children diagnosed with developmental co-ordination disorder and endurance levels of normal children.....
INVESTIGATORS	Miss N Benjamin
DEPARTMENT	Physiotherapy
DATE CONSIDERED	08.05.30
DECISION OF THE COMMITTEE*	Approved unconditionally

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

DATE 08.06.11 **CHAIRPERSON** .....
(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Dr V Potterton

DECLARATION OF INVESTIGATOR(S)

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

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX III

Permission from the Department of Education

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries : Shadrack Phele MIRMSA

Tel. no. : [+2711] 355 0285

Tuesday, 03 June 2008

Miss Benjamin Natalie Alice
Private Bag x30
Brakpan
1540

Dear Miss Benjamin Natalie Alice

PERMISSION TO CONDUCT RESEARCH: PROJECT

The Gauteng Department of Education hereby grants permission to conduct research in its institutions as per application.

Topic of research	: "A comparison of exercise endurance levels between children diagnosed with developmental co-ordination disorder and endurance levels of normal children between the ages of seven and ten years."
Nature of project	: B.Sc. Physiology
Name of university	: University of Witwatersrand

Upon completion of the research project the researcher is obliged to furnish the Department with copy of the research report (electronic or hard copy).

The Department wishes you success in your academic pursuit.

Yours in Tirisano,

p.p. Shadrack Phele [MIRMSA]
TOM WASPE
CHIEF INFORMATION OFFICER
Gauteng Department of Education

Office of the DDG: IS & KM (CIO)
Room 1807, 111 Commissioner Street, Johannesburg, 2001 P.O.Box 7710, Johannesburg, 2000
Tel: (011) 355-1514/1507 Fax: (011) 355-0734/0833 E-mail: tomw@gpg.gov.za or elridar@gpg.gov.za

APPENDIX IV

Informed consent

Information Document

Study title: A comparison of exercise endurance levels between children diagnosed with developmental co-ordination disorder (DCD) and endurance levels of normal children between the ages of seven and ten years.

Hello

I, Natalie Benjamin, am a student at the University of the Witwatersrand and I am doing research for my Masters degree in Physiotherapy, on endurance levels of children between the ages of seven and ten years. Research is just the process to learn the answer to a question. In this study we want to learn if there are differences in the endurance levels of children with co-ordination difficulties when they are compared to normally developing children. Conducting the research will enable us to institute programs at primary schools that can improve the endurance of children with co-ordination difficulties and thus help them to learn better.

I am asking your permission for your child to participate in the study

During the research I will be looking at your childs' ability to walk a given distance over a period of six minutes. I will also measure his/her heart rate and breathing rate (before and after the test), height and weight.

Risks

There are no risks involved unless your child has any medical condition that would exclude him/her from participating in the study.

Benefits

The study will help us to determine whether more regular exercise will benefit children in the school environment. In other words, improve their ability to learn

Participation is voluntary and your child may withdraw at any time should he/she wish to do so.

Confidentiality: Efforts will be made to keep personal information confidential. Absolute confidentiality cannot be guaranteed. Personal information may be disclosed if required by law.

Contact details of researcher/s

Natalie Benjamin, Physiotherapist

Muriel Brand School 011 817 9320

Consent statement

I, the undersigned, _____, acknowledge that I read

(Full name and Surname of parent/ guardian)

the information sheet and hereby give permission that my son/ daughter,

_____, may participate in the study as described

(Full name and Surname)

above.

YES	NO

Signatures:

Parent or Guardian: _____

Researcher: _____

Witness: _____

Verbal assent form

Hi, my name is Natalie. I am busy with a project for the university. Please can I look at how fit you are?

Before we begin, I will look at how tall you are, how much your body weighs, how fast your heart is beating and how fast you breathe.

I will then ask you to walk as far as you possibly can, for six minutes. I will be talking to you and encouraging you all the time. If you feel that you do not want to, or cannot carry on, you can stop. When we are finished I will again look at how fast your heart is beating and how fast you are breathing. We will also measure just how far you were able to walk.

This letter says that I explained what you will be doing and that you either agree or may refuse to help me.

Thank you for your help.

YES	NO

Signatures:

Participants' signature _____

Researcher's signature _____

Witness _____

Inligtingsdokument

Studie opskrif: ‘n Vergelyking van uithouvermoë tussen normal ontwikkelende kinders en kinders met ontwikkelings-koördinasie probleme, tussen die ouderdomme van sewe en tien jaar.

Hallo
Ek is Natalie Benjamin, ‘n student aan die Universiteit van die Witwatersrand. Ek doen tans navorsing vir my meestersgraad in Fisioterapie, oor die uithouvermoë van kinders tussen die ouderdomme van sewe en tien jaar oud. Navorsing is die proses waardeur daar na ‘n antwoord op ‘n sekere vraag gesoek word. Met hierdie studie wil ons bepaal of daar verskille in die uithouvermoë van kinders met koördinasieprobleme en dié van normaal ontwikkelende kinders is.
Deur die navorsing te volbring, beoog ons om programme in laerskole daar te stel wat kinders se uithouvermoë sal bevorder. Die program kan hul vermoë om langer te konsentreer, asook hul leervermoë verbeter.

Hiermee vra ek u toestemming dat u kind aan hierdie navorsingsprojek mag deelneem.

Tydens die navorsing gaan ek kyk na u kind se vermoë om ‘n afgemete afstand binne ses minute te voltooi. Ek sal ook metings van harklopspoed, asemhalingsspoed, lengte en gewig neem.

Risiko’s
Daar is geen risiko’s aan verbonde nie, tensy u kind enige mediese toestand het wat hom of haar van deelname sal uitsluit.

Voordele
Die navorsing sal ons in staat stel om te bepaal of meer gereelde oefening kinders in die skoolomgewing sal bevoordeel, met ander woorde, om hul vermoë om te leer, te verbeter.

Deelname is vrywillig en u kind mag ten enige tyd onttrek as hy/sy sou wou. Die toets word eenmalig gedoen en neem slegs tien minute.

Vertroulikheid: Maatreëls sal aangewend word om die vertroulikheid van alle inligting te verseker. Absolute vertroulikheid kan nie gewaarborg word nie, aangesien persoonlike inligting geopenbaar mag word, sou dit vir Wetsdoeleindes benodig word.

Kontakbesonderhede van navorser:

Natalie Benjamin, Fisioterapeut
Muriel Brand Skool 011 817 9320

Toestemmingsbrief

Ek, _____, verklaar hiermee dat ek die voorafgaande brief
Volle naam en van (ouer/voog)

deurgelees en verstaan het. Hiermee gee ek toestemming dat my kind,

_____, aan die studie mag deelneem.
Volle naam en van (kind)

JA	NEE

Handtekeninge

Ouer of Voog: _____

Navorser: _____

Getuie: _____

Mondelingse toestemmingsvorm

Hallo, my naam is Natalie. Ek is tans besig met ‘n projek vir die universiteit. Mag ek asseblief kyk hoe fiks jy is?

Voordat ons begin, gaan ek meet hoe lank jy is, hoeveel jy weeg, hoe vinnig jou hart klop en hoe vinnig jy asemhaal. Daarna gaan ek jou vra om so ver as moontlik vir ses minute te loop. Ek sal die hele tyd met jou praat en jou aanmoedig. As jy voel dat jy dit nie wil doen nie of dat jy nie kan aangaan nie, mag jy vir my so sê. Wanneer jy klaar geloop het, gaan ek weer kyk hoe vinnig jou hart klop en hoe vinnig jy asemhaal. Ek sal ook die afstand wat jy geloop het meet.

Hierdie brief sê dat ek alles wat ons gaan doen, aan jou verduidelik het en dat jy óf instem om saam te werk óf nie graag wil nie.

Dankie vir jou tyd en hulp.

JA	NEE

Handtekeninge

Deelnemer: _____

Navorser: _____

Getuie: _____

November 2008

Dear Principal and Student Governing Body

RE: Permission to conduct research

I, the undersigned, am currently registered at the University of the Witwatersrand for a Masters degree in Physiotherapy. I am conducting research, comparing endurance levels of children with co-ordination difficulties to endurance levels of normally developing children. Subjects needed for the research must be between the ages of seven and ten years.
I would appreciate it, if I may include learners attending your school. The procedure is non-invasive and measures the distance covered, by walking, within six minutes. The research will assist therapists in determining whether improving endurance will improve a learners' ability to concentrate for longer.

Each learner will be issued with a copy of the attached letter, explaining the procedure and its purpose. Participation in the study remains voluntary and all information collected will be held in confidence.
Your assistance in this regard will be greatly appreciated. Please do not hesitate to contact me should you require further information in this regard.

Kind regards,

Miss Natalie Benjamin
Physiotherapist, Muriel Brand School

APPENDIX V

Demographic Data Sheet

Name: _____

Surname: _____

Date of birth: _____ Age: _____

Gender: _____

Diagnosis of DCD: Y / N Group: ____

Physical home address: _____

_____

Grade: _____

Height: _____ (m)

Weight: _____ (kg)

BMI: _____

Head circumference: _____ (cm)

Heart rate: _____ (bpm – resting) ____ (bpm -after)

Breathing rate: _____ (bpm - resting) ____ (bpm - after)

Blood pressure _____(mmHg - resting) ____(mmHg –after)

Peak Flow _____ _____ _____ (cmH2o resting)

Peak Flow _____ _____ _____ (cmH2o after)

Total distance covered in 6 minutes: _____ (m)

APPENDIX VI

The test items of the Test of Physical Fitness

1. Standing broad jump. The child stands with two feet parallel behind a starting line, shoulder width apart. On a signal, the child swings his/her arms backwards and forwards and jumps with two feet simultaneously as far forward as possible. Test-items score (best of two attempts) is the distance between starting line and landing position (in centimetres).
2. Jumping a distance of 7m with two feet together as fast as possible. Test item score (best of two attempts) is time needed to cover the distance (in seconds).
3. Jumping a distance of 7m on one foot (child is free to choose which foot) as fast as possible. Test item score (best of two attempts) is time needed to cover the distance (in seconds).
4. Throwing a tennis ball with one hand (child chooses which hand) as for as possible. The child stands with one foot in front of the other. Test item score (best of two attempts) is distance thrown (in centimetres).
5. Pushing a medicine ball (1kg) with two hands simultaneously as for as possible. Starting position with feet parallel to each other, shoulder width apart, and ball held against chest. Test item score (best of two attempts) is distance achieved (in centimetres).
6. Climbing wall bars, crossing over two columns to the right and down the fourth column as fast as possible. Each column of the wall bars was 255cm high and 75cm wide. Test item score (best of two attempts) is time needed for the test item (in seconds).
7. Shuttle run. Test item score is time needed to run 10 x 5m (in seconds). When the child makes a procedural error, performance is interrupted and the test item repeated. Test item score is time needed to run the distance (in seconds).
8. Reduced Cooper test. The child runs/ walks around a volleyball field for 6 minutes. Both running and walking are allowed. Test item score is distance covered in 6 minutes (in metres).

Administration of the test requires masking tape, ruler, stop watch, tennis ball, medicine ball (1kg), wall bars at least four columns wide and gym mats.

APPENDIX VII

Table 5.1.1: Reference values for heart rate and breathing rate in South African children of four to sixteen years (Taken from: Wallis et al, 2005, pg 1118)

Table 2 Respiration rate and heart rate; median and 2½, 97½ centiles by age

	Heart rate (bpm)*			Respiration rate (bpm)†		
Age (y)	2½	50	97½	2½	50	97½
4	81	103	131	20	22	26
5	74	95	121	19	21	25
6	69	89	115	18	21	24
7	66	85	111	17	20	24
8	63	83	109	17	19	23
9	62	82	108	16	19	23
10	61	81	108	15	18	22
11	60	80	108	14	17	21
12	59	80	108	14	17	21
13	58	79	107	13	16	20
14	56	77	106	12	15	20
15	54	74	103	12	14	19
16	51	71	99	11	14	18

*Beats per minute.
†Breaths per minute.

APPENDIX VIII

Table 5.1.2: Summary of results for peak flow measures in relation to age (Taken from: Mohammadzadeh et al, 2006, pg 196)

Age	***Boys*** ***Mean in ℓ/min (SD)***	***Girls*** ***Mean in ℓ/min (SD)***
7	228.5 (± 48.5)	186.4 (± 32.1)
8	246.1 (± 46.9)	212.6 (± 41.3)
9	265.9 (± 45.5)	241.8 (± 36.5)
10	309 (± 56.7)	265.3 (± 64.1)

APPENDIX IX

The following graph is taken from the results of Li and colleagues and it combines centile curves for both genders.

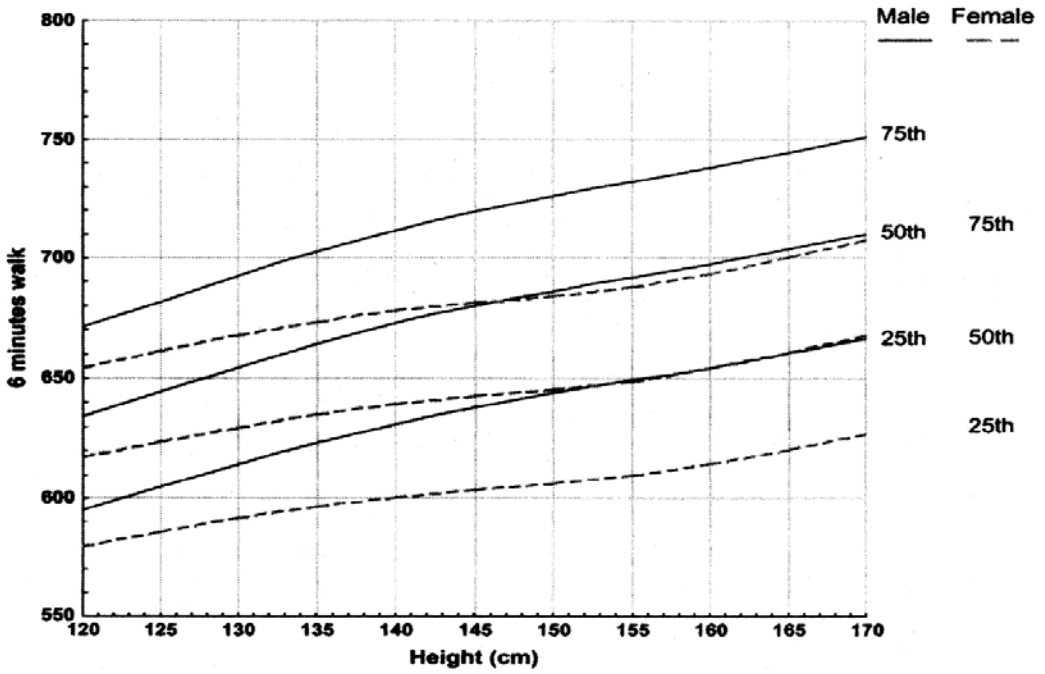


Figure 2: Graph combining male and female percentile curves for the 6MWT in children aged seven – sixteen years (Taken from: Li et al, 2007, pg 179)

APPENDIX X

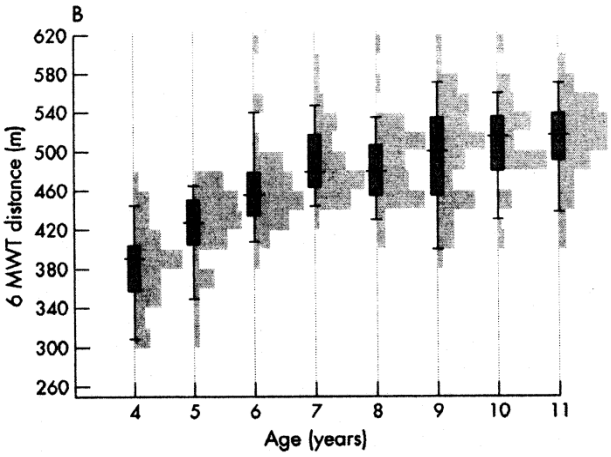


Figure 3: Reference values for the 6MWT in children of four to eleven years of age (Taken from: Lammers et al, 2008, pg 466)