INVESTIGATION INTO THE IMPACT OF COGNITIVE LOAD IN CHILDREN WITH AND WITHOUT IDENTIFIED POSTURAL CONTROL DIFFICULTIES.

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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 Occupational Therapy

Johannesburg, 2011
In loving memory of my father
William James Bennie
1951- 2000
DECLARATION

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

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Signed

27 day of May, 2011
ABSTRACT

This study investigates the effect of cognitive load on children with and without identified postural control difficulties. In addition the study investigates whether this difference, if any, is different between these two groups of participants. The study made use of Modified Chailey Levels of Sitting Ability to compare each child’s sitting postural control in the initial assessment (the baseline) to their sitting posture during the non-cognitive load and cognitive load conditions. The results of the study found that although there was an observable difference between the two groups the modified assessment was not sensitive enough to provide statistically significant results. In addition there was a difference seen clinically in the improvement of postural control while sitting when involved in a cognitively challenging task. The results of this study indicate that the use of cognitively challenging tasks in the treatment of postural control may be warranted, further study is however recommended.
ACKNOWLEDGEMENTS

I would like to thank and acknowledge the following people for the assistance in the completion of this research report:

Denise Franzsen, University Supervisor, Department of Occupational Therapy
Heather Maidens, Research Assistant
Dalene Rostovsky and staff at Dominican Convent
University of the Witwatersrand, Faculty Committee Individual Research Grant (2010)
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DEFINITION OF TERMS

**Postural Control** – the ability to control posture as a result of adequate postural tone, proximal stability and righting and equilibrium reactions [1]

**Co-ordination** – the working together in harmonious action of several muscles or muscle groups in order to execute complicated movements [2]

**Developmental Co-ordination Disorder** – motor co-ordination difficulties that significantly impact on a child’s occupational performance in all areas of daily living including academic performance, in relation to the child’s chronological age and measured intelligence. These difficulties are not the result of a general medical condition nor do they meet the DSM IV criteria for a pervasive developmental disorder [3]

**Occupational Performance** – the ability to assemble all prerequisite actions required to carry out any given occupational behaviour appropriately [4]

**Cognitive Load** – the intensity of cognitive task or processing being carried out at any particular point in time [5]
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADHD</td>
<td>Attention Deficit Hyperactive Disorder</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>ATNR</td>
<td>Asymmetrical Tonic Neck Reflex</td>
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<tr>
<td>CL</td>
<td>Cognitive Load</td>
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<tr>
<td>CNS</td>
<td>Central Nervous System</td>
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<tr>
<td>COMPS</td>
<td>Clinical Observations of Motor and Postural Skills [6]</td>
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<tr>
<td>CO-OP</td>
<td>Cognitive Orientation to Occupational Performance</td>
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<tr>
<td>DAMP</td>
<td>Deficits in Attention, Motor Control and Perception</td>
</tr>
<tr>
<td>DCD</td>
<td>Developmental Co-ordination Disorder</td>
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<tr>
<td>GVP</td>
<td>General Visual Perception Quotient [7]</td>
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<td>MPH</td>
<td>Methylphenidate</td>
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<td>NCL</td>
<td>Non-cognitive load</td>
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CHAPTER 1
INTRODUCTION

Developmental co-ordination disorder (DCD) is a term used to describe children with motor co-ordination difficulties [8-11]. Children with DCD are commonly referred to occupational therapy where assessment and treatment focuses on the dysfunction experienced in all the occupational performance areas [12]. Difficulties in achieving educational or academic skills (reading and writing), personal management skills in relation to dressing and feeding and leisure or play skills are commonly seen. As a result the child may have difficulty coping in all environments including home, school and social and thus may not develop a healthy self-esteem [10, 13, 14].

Self esteem is further affected as the academic and sporting demands increase over time and, as a result children with DCD often employ more passive or avoidant coping strategies which in turn can further impact on task performance, particularly at school [8, 11]. In fact occupational dysfunction in terms performance skills in the educational performance area were the most common area of shared concern between children with DCD, their parents and teachers. Dunford, Missiuna, Street & Sibert (2005) found that teachers generally raise concerns regarding a child with co-ordination difficulties presenting with a discrepancy between written work and other academic skills [11].

Since children with motor co-ordination and praxis disturbances often have postural control difficulties, occupational therapists in their treatment of these children need to understand the underlying role of postural control on coordinated movement. There is also a need to address the impact of postural control on cognitive load in order to facilitate the development of performance skills in the classroom [15]. Adequate postural control is a prerequisite for developing coordinated movement patterns. It is essential in maintaining an upright posture against gravity [14, 16-18] when executing motor behaviours [17] which allow participation in activities of daily living [19, 20]. Poor postural control thus has an
affect on functional outcomes at school in terms of fine motor skills such as handwriting and scissor skills and gross motor skills required for sport and play. Prerequisites for achieving postural control are the development of postural musculature that provides proximal stability to the neck and trunk during movement [21]. This includes reflex mechanisms that react when there are changes in balance through the use of tonic postural regulation. Difficulties with postural control are defined as the

‘outward manifestation of vestibular-proprioceptive processing deficits; characterized by difficulty with proximal stability, low extensor muscle tone, poor prone extension, poor neck flexion against gravity and often, poor equilibrium’ (p479) [1].

Cognitive processes are also essential to the postural control system in order to anticipate postural changes [22] and literature indicates there is a definite link between the intensity of concurrent cognitive activities and postural control performance [5, 23-25]. The role of cognition in postural control was originally identified when considering feed forward control in adaptation to motor goals. This is associated with prior knowledge affecting the timing of anticipatory control of posture which is not a purely automatic spinal or subcortical process as initially thought [5, 23-26]. It has been shown that both the instructions given regarding the motor task as well as the alertness of the participant may result in varied postural control abilities [14, 27].

Thus although postural adjustments are largely automatic and controlled unconsciously a number of theories [5, 26] indicate that increased cognitive load affects postural control. Cognitive load relates to the cognitive requirements of a task. The impact of cognitive load on postural control has been studied with conflicting results. Some researchers showed a decline in postural control [24, 26, 28, 29] with an increase in the cognitive ability an activity demands while others have shown a decrease in postural sway, indicating an improvement in postural control [5, 24, 29, 30].
Thus it is important to consider the role of cognitive load on postural control when treating children with co-ordination difficulties in occupational therapy. This is in line with a relatively new treatment approach called ‘Cognitive Orientation to Occupational Performance’ (CO-OP) which has been shown to be effective for children with DCD. The CO-OP approach is based on traditional cognitive and cognitive/behavioural theory [31-33] and addresses the treatment of children with DCD disputing the use of neuromaturational (bottom up) approaches. The focus has changed to activity performance as the result of interactions between the person, environment and task [32, 34, 35]. This shift in focus supports current thinking concerning the role of cognition in postural control and the interactions between person, task and environment which have been clearly defined in the literature dealing with models of occupation, such as the Model of Human Occupation, that form the basis of occupational therapy theory [36-38].

1.1 Statement of the Problem

Occupational therapists commonly treat children diagnosed with DCD or other conditions that result in poor postural control. When planning occupational therapy intervention, goals and objectives need to be set that are specific to the child’s needs and which allow for the achievement of occupational performance goals such as school based tasks. [39]. Although various studies have shown a relationship between cognitive load and postural control [24, 25, 40, 41] controversy exists in terms of what the effect is. In addition there is a lack of evidence to show that the impact of cognitive load on children with poor postural control is the same as those with typical postural control. Thus the consideration of the cognitive load of a given activity on the postural control of children seems to be neglected when planning, implementing and evaluating therapy and the implications of this factor in the classroom environment are not considered.

1.2 Purpose of the Study

The treatment of postural control is a primary concern in children with DCD and a link between performance of school tasks, which represent a variety of different cognitive loads and postural control has been described [11, 42]. This study
therefore aims to compare the effect of cognitive load on the postural control of children with and without identified motor co-ordination difficulties and therefore related postural control difficulties. Their postural control in sitting at a desk will be measured during the execution of various cognitive activities, presenting differing levels of cognitive demand. This information will provide greater insight into the effect of cognitive load on postural control that can be applied to both the therapy and classroom situation.

1.3 Aim of Study

The aim of the study is to compare the postural control in sitting of children identified with poor postural control and those with typical postural control as well as the impact of cognitive load on their postural control.

1.4 Objectives of the Study

To establish

- The differences in postural control, in children with and without identified postural control difficulties, when sitting at a desk
- the effect of high and low cognitive load on the postural control of children with and without identified postural control difficulties

1.5 Null Hypotheses

There will be no difference in the postural control of children with and without identified postural control difficulties when sitting at a desk.

There will be no difference in the effect of cognitive load in children with and without identified postural control difficulties when sitting at a desk.

1.6 Justification for the Study

Considering the need for adequate postural control to maintain upright postures, in order to carry out activities of daily living, the impact of cognitive load is one of importance for occupational therapists. Thus a study into the impact of age
appropriate cognitive tasks of varied levels of difficulty while sitting for an extended period, as is required of children in the classroom situation, is warranted.

Current knowledge regarding the impact of cognitive load on postural control has primarily been established through studies of adults in standing using non-purposeful cognitive tasks such as rote counting [24, 26]. Studies in children have also been conducted in standing and little information is available on the effect of cognitive load in sitting while carrying out a purposeful cognitive activity [23, 43]. For this reason this study is required to add to the current knowledge base of occupational therapists working with children both in therapy and when providing guidance for performance of activities especially within the classroom.

The impact of cognitive load on postural control, whether positive or negative, will therefore have an impact on the choice of activity and potentially influence the frame of reference or occupational therapy approach for a particular child. In addition an impact on cognitive load on postural control will occur in the classroom situation and this could result in interference or improvement in the child’s ability to learn. However before these links can be made it is important to establish whether or not the impact of cognitive load affects children with postural control difficulties differently to children without postural control difficulties or not. It is also important to establish what this impact, if any, is when the child is sitting and carrying out various prolonged cognitive load activities.
CHAPTER 2
LITERATURE REVIEW

The literature review will consider motor co-ordination disorders and the components of postural control. The relationship of dysfunction in co-ordination and postural control as well as the relationship of postural control and cognitive activity including the effect of cognitive load (concurrent cognitive activities) will be presented. The overall effect of postural control and cognitive load on occupational performance, especially at school is also considered.

2.1 Motor Co-ordination Disorders

Poor motor co-ordination is a significant problem in approximately 6% of children aged 5 - 11 years [20] and it has been well established that children with DCD and other motor co-ordination difficulties, have poor postural control [31, 32, 34, 42, 44, 45]. Although the term developmental co-ordination disorder (DCD) is an umbrella term for children with motor co-ordination difficulties [8-11] not all children with poor co-ordination meet all the criteria for this diagnosis [11]. The Diagnostic Statistical Manual (DSM IV) does not have provisions for those children with other types of motor co-ordination difficulties [3]. In this study motor co-ordination difficulties will be referred to using the term developmental co-ordination disorder (DCD) although other terms are used to describe children with motor co-ordination difficulties. These include developmental dyspraxia, sensory integrative dysfunction, perceptual motor dysfunction, clumsy child syndrome [16, 17] as well as ‘deficits in attention, motor control and perception’ otherwise referred to as DAMP [15].

The literature indicates that there is a definite difficulty with postural control in children with motor co-ordination difficulties such as DCD [31, 32, 34, 42, 44, 45]. The main characteristics of DCD are cited as being poor postural control (particularly hypotonia, poor distal control and poor static and dynamic balance), difficulty with motor learning and poor sensorimotor co-ordination [42].
This is also true for a high percentage of children who present with co-morbid conditions such as gross motor clumsiness, vestibular processing difficulties as well as poor motor planning (praxis) which are all part of the general presentation of attention deficit hyperactive disorder (ADHD) [30, 46] with or without co-morbid DCD [9, 13, 20, 46]. It has been shown that children with ADHD combined type have definite difficulties with equilibrium reactions and postural control abilities [46] and when ADHD is co-morbid to DCD the effects of the DCD are often amplified [24]. Studies of children with DAMP have shown that this population of children has even greater dysfunction in attention, gross and fine motor skills, visual perception as well as speech and language abilities [47].

The lack of consistency in the terminology used to describe the co-ordination problem experienced by a child is not the important issue in occupational therapy. The concern for the occupational therapist is the occupational performance deficits caused by the co-ordination and motor control difficulties which may have a significant impact on the child’s activities of daily living, particularly school performance, and result in a variety of functional difficulties [9, 10]. Due to their marked impairment in motor co-ordination children with DCD experience a disruption in daily occupational performance. As a result of the child’s poor occupational performance there is often a related difficulty with self-esteem, confidence, academic performance and coping. It is important to realise that DCD persists into adulthood if intervention is not provided resulting in long term occupational dysfunction [31, 32, 34, 44, 45].

2.2 Postural Control

Postural control has been defined as ‘the ability to maintain body alignment while upright in space’ [16] (p 266). Postural control requires the development of postural stability which is the ability to control the centre of gravity in relation to the base of support in order to complete the desired movement and to prevent overbalancing and falling [14, 17, 18, 48].

Developing the ability to maintain stability in upright postures precedes the development of the ability to impose mobility on stability which is an important
aspect of the execution of all goal directed actions [17] such as walking [48] and reaching [19]. Mobility on stability provides a stable reference point from which accurate movements can be produced [17]. Postural control is thus required to orientate and stabilise the body in space in relation to the task in the context of the environment which then allows for adequate task execution [14]. Postural control is however also dependent on the ability of the central nervous system to correctly perceive the external environment through the somatosensory and visual system. Processing of proprioceptive and vestibular information regarding the body’s position in space in relation to gravity allows for the selection of appropriate muscle synergies to maintain equilibrium [14, 15, 42, 49, 50].

The development of postural control follows a predictable sequence of developing antigravity control and stability using both reactive and anticipatory postural control responses [16]. Three processes are essential to the development of each of these postural mechanisms.

- Firstly motor processes need to develop in order to allow for the maintenance of stability.
- Secondly sensory processes involving sensory systems and central processing strategies need to be matured and integrated.
- Finally the musculoskeletal components involving changing structure and morphology of soft tissue and muscle strength needs to support the postures required [14].

These processes are non linear and postural control only emerges when each system reaches a threshold of development to allow specific motor behaviours [14]. Thus postural control is a complex process that requires sensory integration, perception and cognitive processes to be able to control both static and dynamic postures [28, 43, 51]. Although reactive and anticipatory postural adjustments are largely automatic and controlled unconsciously the more demanding the situation the more conscious monitoring of balance and attention to posture is required [27, 29, 30, 41, 52].
2.2.1 Reactive Postural Control

Postural control is affected by the integration of the sensory systems namely the vestibular, proprioceptive and visual systems [15, 42, 49, 50, 52, 53] and enhanced vestibular and proprioceptive inputs can have a profound impact on motor and postural skills [47]. Figure 2.1 represents a summary of the literature presented by the researcher.

2.2.1.1 The vestibular system

The vestibular system is situated in the inner ear and consists of the otolith organs (the utricle and saccule) and the semicircular canals [53-55]. The VIIIth cranial nerve carries the vestibular afferent information to the vestibular nuclear complex.
in the brainstem [54, 56]. The vestibular nuclei function in conjunction with the cerebellum to modify muscle tone, maintain equilibrium and orientate the person to position in space [57].

The motor output of the vestibular system that is involved in postural control is primarily through vestibular reflexes namely

1. The **vestibulo-ocular reflex** – ensures that eye movements are equal and opposite to the movement of the head to stabilise gaze [58] resulting in the maintenance of visual clarity during movement of the head [48, 59]. This reflex system is present at birth but the immature visual system of the newborn infant results in differences in the properties of the function of this reflex in older children or adults [48, 59]. The cerebellum is important for the adaptation but not production of the vestibulo-ocular reflex when permanent changes to the input occur [59]. Besides the cerebellum several efferent neurons from the vestibulo-ocular reflex pathway project to the upper cervical spinal cord where the neck motor neurons are located and thus this system plays a role in head stabilisation in space [54].

2. The **vestibulospinal reflex** – a collection of reflexes that receive input from the vestibular labyrinth that stabilise the head and control erect posture relative to gravity [48, 58, 59]. This reflex facilitates postural reactions in the neck, trunk and limbs and it functions to orientate the body to gravity during motion [48] as well as to maintain head alignment [54]. The utricle and saccule, and not the semicircular canals, are involved in the long term stabilisation of the head. They are also responsible for the initiation of flexion and extension movement patterns that will return the head into neutral alignment (i.e. a stable vertical position) in response to acceleration of the head in any direction with or without the presence of vision [54]. The lateral and medial vestibulospinal tracts synapse on alpha and gamma lower motor neurons to facilitate postural control and tone [60]. During early childhood this system is the primary postural control mechanism [48] due to the immaturity of the visual system at birth [48, 59].

3. The **vestibulocollic reflex** – stabilises the head through the excitation of the neck muscles in opposition to head and body movements[54, 58].
In addition to the vestibulo-ocular reflex vision also contributes to the control of posture through the secondary visual pathway that projects to the superior colliculus. This pathway responds to horizontal movement within the visual field rather than interpreting the specifics of the visual image, which is the role of the primary visual pathway. The superior colliculus also receives afferents from the visual cortex and the spinotectal pathways and in turn sends efferent signals to the thalamus, spinal cord and occulomotor nuclei. Thus this system plays a role in the visual co-ordination of posture and the control of eye movements [55]. It has also been shown that augmented visual feedback improves postural control through decreasing postural sway [28] thereby confirming the role that the visual system has on the control of posture.

Vestibular afferents however have limited direct control over maintenance of upright stance on a stable surface when eyes are open due to the vestibular ocular reflex. However once visual and proprioceptive inputs are impaired or ambiguous (for example standing on an unstable surface with eyes closed), vestibular system function is essential [52].

Both the cerebellum and the reticular formation have reciprocal connections with the vestibular nuclear complex and are therefore implicated in postural control [54]. The cerebellum plays a role in movement control, locomotion and balance especially the timing, error correction and precision of movements [42, 54]. The reticular formation on the other hand receives input from various sources such as the cerebellum, cerebral cortex, somatosensory and vestibular systems in order to influence postural control through the reticulospinal tract that has connections with the flexor and extensor motor neurons of the neck, trunk and limbs [54].

2.2.1.2 The proprioceptive system

Proprioceptive input is vital to good postural control and the central nervous system (CNS) may indeed weight this information over the information received from the visual and vestibular systems [51]. Proprioception is defined by Bundy as:

'Sensations derived from movement (i.e. speed, rate, sequencing, timing and force) and joint position. Derived from stimulation to muscle and, to a
Proprioceptive information is transmitted to the CNS via the Medial Lemniscus System along with sensations of discriminative touch and vibration. Proprioception is specifically carried in the dorso-medial pathway of this system and provides precise information regarding the position of a body segment, range and direction of movement as well as the size, shape and weight of objects held in hands [53, 60].

The receptor sites for proprioception are found in muscle spindles and free nerve endings in or near joint capsules and ligaments. This provides the CNS with important information needed for the proper co-ordination of movements through both reflexive action and conscious proprioception, otherwise referred to as kinaesthesia [53, 60]. The central neurons for proprioceptive information are found in the dorsal root ganglion and the nerve fibres are large and have thick myelin sheaths allowing for rapid transportation of information from the receptor sites to the CNS. The nerve fibres of the medial lemniscal system ascend the spinal cord through the ipsilateral dorsal, gracile and cuneate funiculus and cross in the caudal half of the medulla [53].

An accessory pathway occurs for proprioceptive information from the lower limb and this is transmitted to the nucleus dorsalis where the caudal neurons give rise to axons that ascend to the cerebellum ipsilaterally through the dorsal spinocerebellar tract. As these axons enter the inferior cerebellar peduncle some neurons bifurcate and then synapse on nucleus Z to give rise to arcuate fibres that cross to join the medial lemniscus after crossing the midline. The medial lemniscal fibres synapse on the ventral posterior nucleus of the thalamus, fibres are then projected via the internal capsule to the post central gyrus (the somatosensory cortex) [53, 60].

Bundy (2002) has defined postural control dysfunction as the ‘outward manifestation of vestibular-proprioceptive processing deficits’ [1] (pg 479). If there
is any difficulty in processing vestibular and proprioceptive information anywhere along the neuroanatomic pathways, difficulty with maintaining upright postures can result as these systems have been shown on numerous occasions to be vital to postural control [15, 42, 49, 50, 52, 53]. It is proposed that this is what occurs in children with DCD and other sensory integrative dyspraxias.

2.2.2 Anticipatory Postural Control

Anticipatory postural control allows the maintenance of stability during dynamic tasks [14, 49] and this process requires feed forward mechanisms to make postural adjustments before planned movements [16, 49, 61]. Children use different feed forward control to adults when navigating obstacles in their path and this indicates that there is a difference in the cognitive interpretation of the visual information received [61].

The ability to use feed forward mechanisms depends on the ability of the body to maintain antigravity control and to move the head independently of the trunk and this typically develops between the ages of 6 – 10 years [49]. Although the development of anticipatory postural control begins to emerge from approximately 10 months of age feedback control predominates [16, 18, 49]. Development of anticipatory control is task specific and is the result of interaction between motor development, age and experience within the specific environment [16, 18, 49]. Poor anticipatory postural control, in relation to the age, can negatively impact on a child’s occupational performance, including school tasks.

2.2.3 Postural Control - Systems Theory

Previously it had been thought that postural control was hierarchical [16] and based on an ontogenetic perspective meaning that motor responses were pre-programmed [61] and reliant on spatial organisation. Gradual mastery was obtained through balance reactions from a stable frame of reference [17]. More recent literature however proposes otherwise. Postural control is now viewed using systems theory which is dependent on interplay between higher and lower nervous centres rather than as the pure maturation of the nervous system. Muscle
strength and body mass, as well as sensory and behavioural development interact with the environmental constraints to affect postural and motor development [16].

The systems theory indicates that postural control relies on feedback from the sensory systems [14, 61] and feed forward to and from the CNS as well as integration of this information within the CNS. This allows the generation of new sensory input and completing the postural control system which is necessary for motor skills and therefore occupational performance [17, 61].

![Image](image.png)

*Figure 2.2 Summary of Closed and Open Loop Feedback*

There are two feedback loops that are important in the postural control system. The first is closed loop feedback which is primarily used in the control of static postures while the second is open loop feedback which is used in the control of dynamic postures [17, 43, 61]. These have been summarised by the researcher in Figure 2.2.

Feed forward is based on the experience of planning movements before the movement or balance disturbance occurs [61]. In addition to the systems theory it has been shown that cognition plays an important role in postural control [5, 23-25]. This role will however be discussed in detail in a later section.

Evidence to support this newer systems theory is the overlap between proximal and distal control, as well as trunk and head control, that contradicts the hierarchical theory [16] which denotes linear development of postural control. The
systems theory allows for mobility to develop on stability and it has been shown that postural control is dynamic and the system is constantly changed and modified as the body grows and develops [61]. Children tend to experience and test the limits of their postural control system but this allows for the improvement and development in their postural control abilities further evidencing the use of feedback and feed forward control [61]. The complex nature of the postural control system in humans explains why postural control is developed throughout infancy, childhood and adolescence [18].

2.2.4 Development of Postural Control

The development of postural control in terms of antigravity control has been described by authors such as Margaret Rood and Pountney, Mulcahy, Clarke & Green (2004) [16]. When infants are placed in a novel position they use whole body fixation in order to achieve stability in this position resulting in minimal movement or rotation. Once the child becomes more familiar with and practiced in the posture he begins to use rotation and movement within that position. Finally through experience and practice he begins to develop more mature rotation within the position and this allows increased movement opportunities and transitions between postures [16]. Antigravity control development is however not linear and coincides with the development of higher-level balance and motor skills [16, 17]. The ability to maintain antigravity control is dependant on the challenge of the task. For example 3 – 6 year olds are only able to adequately stabilise their heads when walking if there is no challenge to their equilibrium. Children between 7 and 8 years on the other hand are able to maintain head stabilisation during more challenging tasks, while adults make use of head stabilisation most of the time [17].

Postural reactions develop sequentially and success in one position may be a prerequisite for the development of postural reactions [16]. Periods of disorganisation and regression can be noted as the child progresses to the next level of postural control. This may be due to the reduction of the degrees of freedom to ensure that the child has sufficient control of the posture. The child can
then practice and experience the co-contraction required in that posture while reactive and anticipatory postural reactions are being developed [14].

Late development of postural reactions may lead to delayed or altered achievement of gross motor milestones such as rolling, sitting and walking. Children with delayed postural reactions may also present with decreased coordination which has an impact on balance and antigravity control as a result of poor muscle tone as well as neck, trunk and limb reflexes [48]. This in turn affects the ability to maintain upright postures which allows for the development of the ability to combine mobility on stability which is required for the hand function components of reach, grasp and manipulation needed for adequate handwriting and cutting with scissors. A lack of these skills will impact on occupational performance at school [16, 18, 19, 62].

2.3 Postural Control and Developmental Co-ordination Disorder

The postural control and motor skills of children with DCD have been shown to be significantly lower in terms of age expectations. It is proposed that this discrepancy in motor skills is due to these children having greater difficulty in regulating muscle activity as well as immaturity of their nervous systems [3, 51] Older children with DCD have been shown to have postural control reactions similar to younger typically developing children, further highlighting the immaturity and delayed development of their postural control system. In addition children with DCD have greater difficulty with balancing when increased task constraints are presented and the difficulties experienced with balance do not decrease as significantly with age as in typically developing children [42].

Children with DCD have been shown to have disorganised sensory systems, which results in greater postural sway, and their performance of many complex motor tasks is more compromised in comparison with children with pure proprioceptive difficulties [14, 42]. Postural sway in children with DCD occurs primarily in the lateral plane rather than the anterior-posterior plane and studies have shown that children with DCD activate co-contraction in the ankles more frequently in a balance task than their typically developing peers [42]. This group
of children have also been shown to have slower responses to visual stimuli and goal directed movement completion [42] with greater dependence on visual feedback in postural control and balance tasks.

As skilled limb movement is dependent on a stable postural base altered postural muscle activity is likely to result in poor proximal stability, affecting upper limb coordination and thus selective control of movement. Studies show that children with DCD also have altered timing of muscle activity during voluntary goal directed movements, such as reaching, and they make use of less trunk muscle activation in the anticipatory period for the movement [42].

Poor development of anticipatory control results in many difficulties in activities of daily living as reach to grasp is one of the most frequently performed movements in daily life [20, 42]. As most classroom based occupational performance tasks take place seated at a table for extended periods of time, and require reach to grasp, it is therefore important to look at postural control in sitting.

### 2.4 Postural Control and Sitting Posture

Sitting is a more relaxing posture than that of standing as a greater surface area is supported and this allows for the relaxation of the lower limb muscles. When seated the centre of gravity should be aligned over the base of support so that the centre of mass extends through the ischial tuberosities and just anterior of the 11th thoracic vertebra. When sitting on a chair that does not have sufficient thigh support or a back rest, sitting can be an unstable posture due to the position of the centre of gravity [63]. In order to obtain the ‘ideal sitting posture’ several factors need to occur, firstly the pelvis should be in a slight anterior tilt to allow the ischial tuberosities to provide the main base of support [63, 64]. Secondly the thighs should increase the base of support without adding additional pressure to the back of the knees (in other words the seat length should be correct). The lumbar spine should be in mid flexion while the entire spine is supported by a back rest with a slight posterior inclination and the weight of the legs should be carried through the feet onto the supporting surface of the floor [63, 64].
In addition to the maintenance of a good sitting posture it is important to be able to move in and out of sitting independently as well as be able to transfer weight in and out of the base of support without falling and to recover an upright sitting posture when displaced. In order for this posture to be a functional one and to allow the participation in purposeful activity, it is important that the arms are able to move above shoulder height [64]. Therefore there should be no reduction of the degrees of freedom to allow for adequate reach [18] and the hands should be able to move freely and be brought to the midline [64].

When a child sits with a posterior pelvic tilt, which is common in children with postural control difficulties [64], the centre of gravity is shifted from through the ischial tuberosities to behind them. This shift of the centre of gravity results in the loss of the lumbar lordosis, thus strain is placed on the posterior spinal ligaments, and a concave curvature of the thoracic spine results [63]. As this position is less comfortable, and can lead to decreased reach at the shoulder due to the lumbar kyphosis, performance in academic tasks such as writing as well as concentrating on cognitive tasks can be negatively affected.

2.5 Assessment of Postural Control in Developmental Co-ordination Disorder

In order to understand the effect of postural control and motor skills on performance the occupational therapist needs to observe the child while they are involved in activity in order to establish the difficulties with which they present. This occurs through assessment of postural control.

The purpose of assessing postural control is to identify specific difficulties experienced by a child in order to plan appropriate intervention. The assessment of postural control is multifaceted and age dependant. It includes interviews with parents or caregivers as well as formal and informal observations of the child’s performance during testing [65, 66].
Interviews provide the occupational therapist with information regarding the child’s gross and fine motor skills in various environments and tasks. This provides information regarding the child’s postural control ability in tasks that may not be elicited in the assessment environment [66].

There are no standardised tests for postural control for children presenting with soft neurological signs and conditions like DCD and ADHD. The assessments like the Chailey Levels of Postural Ability [64], that are available for postural control have been designed and are non-norm referenced assessments for children with overt neurological conditions like cerebral palsy. Formal assessment of postural control for children with motor co-ordination difficulties therefore take the form of clinical observations of postural movements [65] based on the original work of Ayres (1976) and Johnson (1977) [6].

Although these assessments provide a guide to standard observation for the occupational therapist, these have not been standardised and lack normative data [65]. Occupational therapists therefore commonly use the Clinical Observations of Motor and Postural Skills’ (COMPS) assessment, which provides adjustment of scores according to ages [6], when assessing children with motor co-ordination difficulties. This allows for the assessment of performance components known to be associated with motor co-ordination and postural control difficulties and allows the therapist to interpret the possible effect of these components on motor co-ordination and postural control. The COMPS includes the following test items:

- **Slow Movements** – this item appears in both the COMPS as well as the original clinical observations and it measures the child’s ability to move slowly and symmetrically [6, 67]. Children with poor postural control have difficulty stabilising proximal muscle joints as well as controlling movements due to the lack of a stable base from which to move [41, 48]
- **Diadokokinesis (Rapid Forearm Rotation)** – this test item is a test of cerebellar-vestibular integrity [6]. Observations during the performance of this test item can provide information regarding proprioceptive processing, through the pressure used while carrying out the task, as well as proximal stability of the shoulders and elbows.
• **Finger Nose Touching** – this item did not appear in the clinical observations protocol and it measures cerebellar function [6] which is involved in the control of posture through the timing of movements [48]. By the age of 7 this task should be completed without missing more than once [6].

• **Prone Extension Posture** – the prone extension posture assesses antigravity control and tonic postural extension. Several observations regarding postural control are included in this test item such as the non-segmental attaining of the posture and the ability to maintain posture without excess effort or background movements [6, 65, 67].

• **Asymmetrical Tonic Neck Reflex (ATNR)** – the presence of the ATNR indicates immaturity of the postural control system [67]. This is assessed in a quadruped position and observations of the child’s ability to assume and maintain this posture without locking of the elbows or employing a wide base of support indicates adequate postural control [6].

• **Supine Flexion Posture** – this test item measures the child’s ability to non-segmentally assume and maintain a flexed posture against gravity assessing the strength of the tonic flexors [6]. Difficulty with neck flexion against gravity may indicate poor vestibular input to the neck flexors [65] thereby indicating poor postural control [1].

The COMPS is not the only method of assessing postural control. Other informal test items, many of which were part of the original clinical observations protocol are used within the clinical setting:

• **Low Muscle Tone** – involves palpating the child’s triceps and biceps as well as looking for elbow hyperextension [67]. Indication of low muscle tone often indicates poor postural control abilities but before low tone can be diagnosed it is necessary to ensure that there are no other explanations such as joint hypermobility [65]. Muscle tone is further assessed making use of clinical judgements such as the child’s posture, gait as well as mouth position and drooling on entering the assessment room [65].
• **Co-contraction** – the ability to maintain an upright posture while arms are passively moved. This indicates proximal stability and the presence of restriction of the degrees of freedom is easily noticeable [67].

• **Equilibrium reactions** – an important aspect in the development of postural control [16] and are a good indicator of vestibular-proprioceptive function and therefore a good indicator of postural control [65]. Equilibrium reactions are assessed through the passive movement of the child in the lateral, anterior-posterior and diagonal planes while on an unstable surface [16, 65]. In addition to equilibrium reactions protective extension is assessed through sufficient displacement of the child to provoke a protective response in the form of active limb extension to prevent a fall [16, 65].

• **Postural Background Movements** – are normal adjustments of posture during maintenance of static and dynamic positions. Exaggerated, inappropriate or diminished postural background movements are typically the result of low postural tone and hence poor postural control can be assumed [65].

• **Gross Motor Skills** – observations of tasks such as running, jumping, skipping and ball skills are important in the context of a postural control assessment [16, 67]. Difficulty with gross motor skills may indicate difficulty with anticipatory postural control due to the difficulty activating postural muscle tone to allow adequate control of posture in order to successfully complete the gross motor task [16].

The COMPS assessment allows for the identification of a number of performance components and skills in which difficulties are experienced by the child. A significant cluster of difficulties [65] related to the child’s age must however be found before a diagnosis of poor motor co-ordination and postural control can be confirmed.

Therapists should be aware of the environmental conditions during the assessment of motor co-ordination and postural control and take the effect of this into account. Obvious changes in the environment, such as to the surface on
which the assessment takes place or external support offered, as well as factors like the demand of the cognitive tasks engaged in have been identified as affecting postural control [27, 30].

2.6 Cognitive Influences on Postural Control

Postural control is not an automatic process but rather demands attention and is thus affected when a child is asked to perform demanding cognitive tasks while maintaining adequate postural control. During a complex cognitive task, cognitive resources are used and are competed for by both conscious and unconscious processes which are directed at goal achievement. In addition learning is more efficient when given instructions regarding what to do rather than what not to as cognitive processes are designed to process positive information or commands more effectively than negative ones [27, 30]. Thus both the harnessing of the cognitive processes that are required in the control of posture and the use of positive instructions play a role in influencing postural control.

The cognitive processes that affect postural control are attention, arousal, motivation and judgment [22, 43]. These processes all the central nervous system to assess body position in space related to gravitational forces, the environment and body segments [22]. The executive processes of activation and inhibition of attention allow a person to focus on information relevant to posture as well as the task thus managing attention sharing between the posture and task/s. [22]. Van Zomeren and Brouwer (1994) further divide attention into focused attention and divided attention. The ability to divide attention matures most between the ages of 5 and 10 years with the allocation of attention between two tasks maturing in adulthood. Thus children with and without DCD and other conditions like cerebral palsy may have problems when being challenged by a task requiring postural control, balance and cognitive activity (dual task condition) [68].

In addition it has been shown consistently that motor tasks secondary to postural control increase the need for (a) balance control and stability or (b) the movement of the centre of gravity within the base of support. This requires attention sharing and therefore may negatively influence postural control [28]. Thus the role of
cognitive control of posture is an important aspect to consider when looking at the impact of other cognitive tasks (i.e. cognitive load) on postural control.

2.6.1 Cognitive Load

Cognitive load is not formally defined in the literature but is a term that is used to describe tasks that require the use of complex or multiple cognitive functions. The term ‘cognitive’ is derivative of the Latin word meaning ‘to know’ or ‘to be conscious of’ [69] and the term ‘cognitive processes’ generally refers to thought (both intelligent and creative), learning, memory, problem solving and reasoning [70].

There are several important processes that are involved in cognition and these include the receiving, processing and storing of information as well as the organisation of purposeful behaviour and conscious activity [71]. The frontal lobes of the cerebrum, specifically the prefrontal cortex, are highly involved in cognitive processes such as forming intentions and plans of action and converting these into purposeful, voluntary behaviour. The interactions that the prefrontal area has with the reticular formation, thalamus, hypothalamus, limbic system and other cortical areas are important to the prefrontal area’s ability to carry out these cognitive processes [71]. The cerebellum, an area of the brain affected in DCD, is also crucial for tasks requiring divided attention and attention allocation. Thus it is possible that deficits in these areas could cause decreased postural performance in dual-task situations in children with DCD.

While load theory states that the processing of information that is irrelevant or unrelated to the task requires some attentional capacity, this in turn depends on the attentional demands of the task at hand [26]. In addition attentional demands of dual activities is not simply the sum of the component tasks but rather requires the development of a co-ordinated action plan [41]. Combining this information a definition of cognitive load can be said to be the degree to which a cognitive task fills available attentional load.
2.6.2 The Impact of Concurrent Cognitive Tasks on Postural Control

The impact of cognitive load on postural control has been studied through the use of dual task paradigms [5, 23, 26] in which participants maintain a static posture on a force platform which is used to monitor balance control and the movement of the centre of gravity within the base of support [5, 14, 23-26].

A dual task paradigm has been proven to be a sensitive measure of the effect of concurrent tasks on postural or cognitive performance. This technique involves the participant performing the postural and cognitive tasks individually and then concurrently and any changes in performance are measured [5, 23, 26]. In order for a dual task effect to be considered relevant there needs to be a comparable difference between the task performance on its own and the performance on the both tasks together. Scores below the baseline level of performance can be considered to be a dual task effect with the implication that competition for central processing resources has taken place [29, 41].

Two possible outcomes could be expected when studying the dual task effect of cognitive load on balance and postural control:

- the first is that balance requirements impact on the ability to perform the cognitive task. This has been referred to as the ‘Posture First Principle’ in which a decrease in cognitive performance takes place during dual task conditions as the primary resources are used to maintain posture. This principle is highlighted by Pountney (2004):
  ‘a child with a low level of postural ability may appear to be distractible, unable or unwilling to concentrate on the task or unable to follow instructions. His concentration will go into the gross motor task of maintaining his position rather than the fine motor task being presented’ (p 43)[64].

- the second possible outcome of dual task studies is that cognitive task performance impacts on balance function [41].

The types of cognitive tasks that have been used in studies on the effect of cognitive load on postural control to date include sentence completion, visual
perceptual matching, word colour identification, short term memory tasks and comprehension of video sequences [5, 24, 26]. These all require the use of cognitive skills, such problem solving, reasoning, thought, learning and memory, to varied degrees. The results obtained by various researchers have been contradictory, with some researchers showing a decline in postural control [24, 26, 28, 29] while others have shown a decrease in postural sway, indicating an improvement in postural control [5, 24, 29, 30].

2.6.2.1 Hypotheses regarding impact of cognitive load on postural control

The inconsistent results of studies have lead to various hypotheses regarding the impact of cognitive load on postural control. Pellecchia (2003) described the ‘Action Orientated Hypothesis’ in which a combined action plan is used to coordinate postural control and cognitive processing and therefore changes will occur in postural control if the complexity of either task increases [5, 26]. Coordination of skills is developed and integrated through practice and experience. Prior to this integration of skills and the development of a combined action plan, through the use of higher order skills, one of the conflicting processes is given priority over the other [26, 30, 43].

The ‘Limited Capacity Theory’, on the other hand, views the brains processing abilities as limited to available resources and thus postural control is unaffected if the concurrent cognitive task can be performed with available capacity. Dual task interference only occurs if task requirements exceed this capacity [26, 30, 41, 43]. This theory, although recently shown to be inadequate [43], can provide a possible explanation for improved postural control, measured through decreased postural sway, in that the body overcompensates and restricts the degrees of freedom of movement to free the brain’s resources to perform the cognitive task [5, 24, 29]. The alternate explanation for the decreased postural sway is the ‘Posture First Principle’ [29]. This is consistent with the knowledge regarding the development of antigravity control in that when placed in new, or in this case cognitively challenging positions, the trunk is fixated allowing for minimal movement or rotation within the posture. As the child practices a position rotation
within the base of support emerges followed by the ability to increase movements within and out of the base of support [16].

Finally the ‘Constrained Action Hypothesis’ presented by McNevin & Wulf, (2002) as cited in Riley (2005) is based on evidence from movement science and sport psychology [24]. This hypothesis views the positive changes in postural control under dual task conditions as due to the change of focus of attention from postural control to the cognitive task thus improving postural control as attention on motor performance may interfere with the desired motor output [5, 24]. It has also been hypothesised that cognitive load dual tasks that are free from external information result in a degradation of postural control while those dual tasks that include external information such as auditory instructions bring about an improvement in postural control [22].

All of the above mentioned theories could be applied to what is seen in the impact of motor co-ordination difficulties on postural control.

2.6.2.2 Impact of cognitive load on postural control – Position

The current knowledge regarding the impact of cognitive load on postural control has been gained through studies using either adults [24-26] or children [5, 23] standing on a force platform with or without compliant surfaces for trial periods ranging from 22 – 60 seconds [5, 23-26]. This makes it difficult to generalise the findings into sitting postures. The only study found in which cognitive performance is measured in sitting versus standing, as a control measure, was by Dault, Geurts, Mulder & Duysens’ (2001) study on 24 adults. This study required the participants to stand as still as possible with hands behind their backs while on a force platform for 4 trials of 22 seconds each, one single task and three dual task conditions. The dual task conditions were word and colour identification as well as word-colour reading. The dual task activities were also completed in sitting to identify the impact of balance on cognitive task performance. The interference of cognitive load on postural control was found to be related to the novelty and difficulty of postural tasks and cognitive performance was better in sitting than
standing [25]. This study did not however consider the impact of cognitive performance in a sitting posture directly.

2.6.2.3 Impact of cognitive load on postural control – Children

In the studies that were conducted on children aged 10 years or younger the results and procedures have varied.

Blanchard et al (2005) in their study of typically developing children aged 8 - 10 years found that there is a definite link between postural control and the attentional demands of concurrent cognitive tasks. This study involved each participant standing on a force platform for three trials; the first was standing still, the second standing while counting backwards and the third standing while reading from the wall. 15 out of the 35 participants were excluded due to their difficulty standing still during the trials and this negatively impacts on the strength of the study results. These results differed from those for adults and the authors felt that this was because children restrict their freedom of movement initially and are only comfortable to move freely once they are familiar with the task requirements and therefore show the impact of the practice effect [43].

The conclusion of Blanchard et al’s (2005) study is that as children are developing motor skills they respond differently to adults in dual task situations. Although the children’s initial response was in line with that of adults, i.e. decreased postural sway through the restriction of degrees of freedom of movement, through practice children’s postural sway increases as their postural strategies change. [43].

In a later study Schmid et al (2007) looked at 50 healthy 9 year old children and found that concurrent cognitive activity (backwards counting in 2s) while standing on a force platform influenced their postural control. Results lend support to the link established between postural control, cerebellar function and the increase in the distance of postural sway. This is consistent with the theory that the postural control system is unable to maintain stability as successfully when there is interference of a concurrent cognitive task. This study employed a fixed experimental order to ease the familiarisation with the experimental procedure but
this could have impacted on the results due to the practice effect as described in previous studies. In this study noise and lighting were controlled and no articulation of the participants was allowed [5], making the results difficult to apply to a classroom or therapy environment where none of these aspects are realistic.

2.6.2.4 Impact of cognitive load on postural control – Diagnosis

Laufer et al (2008) studied the impact of cognitive load on 4 – 6 year old children with and without DCD (26 children with DCD, 25 children without) and their results showed that the effect of the cognitive load on the standing posture of these children depended on the attentional demands of the cognitive activity. The study involved children standing on a compliant surface for five testing conditions presented in a random testing order with centre of pressure measures taken during two single task and two dual task conditions.

The cognitive load activities in these studies involved the children identifying simple coloured objects. This could be thought to be more relevant to daily cognitive load activities as more cognitive processes are employed such as visual perception, attention, memory and recall in comparison to the rote learnt counting tasks used in previous studies. The authors found that the DCD group was more affected by the presence of the concurrent activities than the non DCD group. The researchers explained that the difference found between the groups was due to the DCD group taking longer to respond to visual signals and to complete goal directed movements, due to their difficulty with motor co-ordination [23].

Jacobi-Polishook et al in a 2009 study compared the effect of methylphenidate (MPH) on postural control in single and dual task conditions in children with ADHD. They found that MPH significantly improved the children’s postural control during memory and attention demanding tasks. 24 children, aged 7 – 16 years with ADHD who had been on MPH treatment for a minimum of three months, with good results according to the DSM-IV ADHD Rating Scale, were included in the study. Participants were randomly assigned to either the control or experimental group. The control group received placebo treatment while the experimental group continued with treatment of 5mg short acting MPH. There was an hour and a half
break following the administration of the drug and baseline assessment before the experimental procedure was carried out again based on the time during which the MPH has maximum effect. The study required the participants to stand upright, as still as possible with hands behind their backs, on a force platform for 3 task conditions. The first condition was a single task and the second a dual task that was memory and attention demanding, the third condition was listening to relaxing music.

The dual task condition had a smaller impact on the postural sway in children with ADHD, who often have co-morbid DCD, than that reported in children without ADHD in other studies. The authors believe that this was due to the fact that children with ADHD are already operating nearer their stability boundaries when engaged in single task conditions and that they were unable to afford themselves any additional sway during the dual task. They were therefore more focused on balance than on the cognitive task at hand. The presence of the MPH may however have impacted on their ability to perform the concurrent task more efficiently.

These findings are consistent with the ‘Posture First Principle’. Since children with ADHD have difficulty maintaining attention it is logical to assume that they have difficulty attending to the demands of correctly changing their centre of gravity over their base of support in single and dual task conditions [30].

The cognitive load tasks used in the dual task trials were however not functional activities that would typically be performed in daily living. Therefore the effects of the dual task performance cannot be easily applied to the occupational therapy context. To achieve the goal of therapy, therapeutic activity needs to provide the just right challenge, which implies that the child is stretched beyond their current level of ability but not so challenged that they are unable to succeed [72].

In addition these studies were carried out in standing and the instruction was often to stand as still as possible which is not a functional posture during daily life and this can impact on the application of the results to occupational performance.
2.7 Summary

Postural control is essential to daily occupational performance as it allows the maintenance of upright postures against gravity and provides a stable base from which dynamic movements such as walking and reaching can occur [16, 18, 48]. Poor postural control may impact on a child's ability to perform academically which will further negatively impact on their development of self-esteem [31, 32, 34, 45].

Current evidence has shown that there is a link between postural control and cognitive performance although it has not been confirmed whether or not this effect is a positive or negative one. However, studies to date have only focused on standing postures for short trial periods of a maximum of 60 seconds each and the cognitive task has not been a functional one [5, 23-26] that would impact on occupational performance.

The literature cites that there is a definite difficulty with postural control in children with motor co-ordination difficulties such as DCD [31, 32, 34, 42, 44, 45] as well as there being a high percentage of children who present with co-morbid ADHD [9, 13, 20, 46]. Children with DCD and/or ADHD are often seen by occupational therapists and there is a continuing debate in the literature regarding the best approach of treatment as efficacy of therapy has been difficult to establish [73-77].
CHAPTER 3
METODOLOGY

3.1 Study Design

The study employed a descriptive design in which two pre-existing conditions were compared. These conditions were children with postural control difficulties and children with typically developing postural control and participants were selected according to this criterion. The study aimed to determine (a) the difference in postural control and (b) the effect of cognitive load on postural control between and within the two groups of participants. As such the study employed a cross sectional analytical study design [78]. The study design was appropriate as descriptive research is commonly used in the occupational therapy context as this type of study is generally exploratory and therefore looks into naturally occurring events [79], in this case the difference between children with and without postural control difficulties.

A longitudinal approach was added to the research design to decrease the bias in a once off assessment, in an attempt to generate new knowledge [79]. Participants were assessed over two sessions and the effect of cognitive load was evaluated using a time series of 1, 5 and 10 minutes. The two sessions were one week apart and this allowed for assessment of changes in postural control over time compared to a cross sectional baseline value. The study also included a non randomised group comparison design as the assignment of participants into groups was determined by a pre-existing condition (i.e. postural control difficulties or the lack thereof) [80] and matched selection was not used. The independent variable of cognitive load was adjusted within each trial to ascertain if there was an effect on the dependant variable of postural control.
Figure 3.1 Study Design

Population

Children aged 6yrs 0mths – 9years 11mths

Sample Selection

Group A

Inclusion Criteria:
- Identified postural control difficulties
- Attending occupational therapy
- With or without visual perceptual difficulties

Group B

Inclusion Criteria:
- Typically developing postural control
- No current or previous occupational therapy or physiotherapy for postural control difficulties
- Average or above average visual perceptual skills

Session 1
(Week 1)

Assessment:
- Clinical Observations of Motor and Postural Skills (COMPS)
- Developmental Test of Visual Perception (DTVP-2)
- Modified Chailey Levels of Sitting Ability (Baseline)

Video recorded

Session 2
(Week 2)

Random selection of starting activity
(Both activities completed by all participants)

Non-Cognitive Load Activity
- Listening to story on tape of child’s choice, follows pictures in story book

Cognitive Load Activity
- Playing Go-Getter (Prince and Dragon) starting at level specified by perceptual assessment scores

Modified Chailey Levels of Sitting Ability
1 min, 5 mins, 10 mins

Population

Random selection of starting activity
(Both activities completed by all participants)
3.2 Population:

The population that was used in this study consists of two naturally occurring groups. Group A consisted of participants with identified postural control difficulties who are currently receiving occupational therapy. Group B consisted of typically developing children without identified postural control difficulties, and who have not received previous intervention for motor or postural control difficulties. When children recruited for Group B were identified as having postural control difficulties, through the assessments involved in this study, they were excluded from the study and a full occupational therapy assessment was recommended and their parents were provided with a list of occupational therapists within the local area.

3.3 Sample Selection:

3.3.1 Group A

Group A was obtained from private occupational therapy practices in the Northern Johannesburg region. Therapists in the area were contacted via email and telephone but unfortunately the response was very poor and no participants were obtained from practices other than the ones the researcher is affiliated with. The parents of children who fell in the correct age group who were being treated by the researcher or colleagues where verbally informed about the study and invited to participate. They were given the information sheet and informed consent form as well as the participant demographic and participant assent form to sign and the first appointment was scheduled outside of the child’s regular occupational therapy time (Appendix B-1, C & D).

Inclusion criteria for Group A

- children aged 6 years 0 months to 9 years 11 months,
- identified postural control difficulties and currently receiving occupational therapy or physiotherapy intervention.

Exclusion criteria for Group A

- children with weighted score on the COMPS above 0,
- children with neurological, musculoskeletal, visual (unless corrected), hearing or vestibular limitations (such as Labyrinthitis or Meniere’s Disease)

Children with ADHD were included in the study regardless of whether or not they were on medication; the reason for this inclusion is that ADHD is often co morbid in children with postural control difficulties as discussed in the literature review [9, 13, 20, 46].

3.3.2 Group B

The principals of the Independent Schools in the area were contacted by email and a letter was sent (Appendix A) to request permission to send home an information sheet and consent form to those children who were not having difficulty at school in order to recruit a sample for Group B.

Two school principals agreed initially after several follow up calls and emails and forms were sent out with self addressed and stamped envelopes for the parents to respond. No responses were received. A second round of emails and phone calls to schools were made and at this time one other school agreed to send out letters and a research invitation flyer was sent home to all grade 0 to grade 4 children in the school. Several call backs were received from which three participants were recruited for the study, of which one scored below 0 in the COMPS and was excluded. At a parent information day at the start of the 2010 school year the researcher was given the opportunity to invite parents to agree to allow their children to participate in the study during the school day. Many parents signed up for this but only five completed consent forms were received of which two participants presented with postural control difficulties.

After a number of attempts to recruit more children at schools and preschools in the area, the remainder of the sample for Group B was recruited by convenience and snowball sampling by word of mouth. As a result siblings or friends of those children receiving therapy by the researcher were included in the study.
Inclusion criteria for Group B
- children aged 6 years 0 months to 9 years 11 months,
- children who were typically developing and had not previously received occupational or physiotherapy intervention for postural control or motor co-ordination difficulties.

Exclusion criteria for Group B
- children with neurological, musculoskeletal, visual (unless corrected), hearing or vestibular limitations,
- children with weighted score on the COMPS is below zero,
- children with a General Visual Perception Quotient (GVP) on the DTVP-2 of 85 (which equates to a Z score of -1 which is considered below average) or less. This differs from Group A to ensure that only typically developing children are included in Group B.

3.3.3. Sample Size

When planning the research study a sample of 45 per Group was required when it was assumed that
- 90% of typically developing children (Group B) would maintain a consistent sitting ability between baseline assessment and cognitive load trials.
- 40% of children with poor postural control (Group A) would be able to maintain their sitting ability.

A 5% significance level at 80% power was used for the sample size calculation. This was also based on the assumption that children in the Group B would achieve a level 7 sitting ability using the Modified Chailey Level of Sitting Ability and that those in Group A would achieve a level 4 or 5, considering the naturally occurring difference between the two groups. A 30% difference between the postural control abilities during the cognitive load trials between the two groups was also assumed. This sample size and the assumption regarding difference between the 2 groups was discussed with and approved by Tobias Chirwa a biostatistician in the Faculty of Health Sciences.
Participants were recruited according to the inclusion criteria for approximately 15 months but due to the difficulty in finding participants for the study, recruitment of participants were stopped after this time even though the sample size did not reach the numbers suggested by the sample size calculation for this study. Therefore the sample groups were considerably smaller than originally planned; 21 in Group A and 14 in Group B.

3.4 Ethical Considerations

Parents or legal guardians were invited to allow their children to participate in the study. All parents received information sheets regarding the purpose of the study. Informed consent was signed by the participants’ parents who also gave permission for them to be videoed (Appendix B-1 & B-2). The children themselves were asked for assent to take part and be videoed and signed the participant assent form (Appendix C). Parents and children were made aware that their participation in the study was voluntary and that they could withdraw at any stage without consequence, there were however no drop outs from this study.

Confidentiality of the participants was ensured throughout the study as the researcher kept all identifying information separate from the data and only codes were used on the assessment forms. All videos will be destroyed in accordance with HPCSA guidelines for research data.

Feedback on the results of the study was provided to all participants. Those who were excluded from Group B due to baseline assessments that fell below the average range on the COMPS or DTVP-2 were provided with the test results as well as a list of occupational therapists in the area that could further assess and treat the identified difficulties.

3.5 Measurement tools

The measurement tools that were used in this study were the:

- Participant Demographic Form – Compiled for this study to provide the researcher with demographic information regarding the participants as well as
information regarding previous occupational therapy or physiotherapy intervention (Appendix D)

- Clinical Observations of Motor and Postural Skills – used to assess children for difficulties with motor co-ordination and postural control. This test was used to determine inclusion or exclusion in to either Group A or B based on postural control problems. (Appendix E)

- The Developmental Test of Visual Perception (2nd Edition) – used to determine the participant’s visual perceptual level so that cognitive activities of a suitable level could be presented to them. (Appendix F-1 and F-2)

- The Chailey Levels of Postural Ability – used with children with more severe neurological deficits like cerebral palsy. The section on Chailey Levels of Sitting Ability was adapted and used in this study as it is considered a valid and reliable assessment of postural ability. Since there is no other standardised assessment for postural control available for the population to be studied, this existing assessment which the researcher has found useful in clinical practice was selected (Appendix G and H). The validity of this assessment was however affected by the modifications and therefore required piloting.

These assessments were chosen as they are assessments that were designed for use with children of the age group of this study and provide standardised scores that can easily be used for interpretation of the study results.

3.5.1 Clinical Observations of Motor and Postural Skills (COMPS) [6]

The COMPS (Appendix E) is a valid and reliable tool that was used in the initial assessment of both groups and provided a baseline measure of the participant’s postural control. The COMPS assessment consists of six test items namely slow movements, rapid forearm rotation, finger-nose touching, prone extension posture, ATNR and the supine flexion posture. All of these test items, except the finger-nose touching, were part of the original clinical observation protocol of 19 test items.

Each test item is rated according to various criteria, each of which is scored from 0 – 3 with 0 indicating poor performance of the skill and 3 being typical performance.
Definitions are provided with each score to guide the assessor during the assessment. Scoring of each item is not age specific, however after the test items are scored an adjustment is subtracted to allow for a cut off score of 0 for all ages [6] A weighted score of 0 or above is indicative of normal postural motor skills [6].

This assessment was designed to help occupational therapists with the assessment of children with suspected DCD within the age range of 5 – 9 years. The assessment is primarily based on the work of Jean Ayres (1976) namely the Clinical Observation protocol and as such is not a new assessment but rather a revision of an assessment that is commonly used by occupational therapists. The COMPS was designed as a screening tool for the identification and monitoring of change in motor problems although the evaluative use of this assessment has not been fully established [6].

The assessment was chosen for this study as it only takes 15-20 minutes to administer and score and it is a simple enough test to learn to use, especially with paediatric experience in making clinical observations, which the researcher has. The limitation of the test however is the small sample size on which it was standardised [6].

3.5.1.1 Reliability and Validity of the Clinical Observations of Motor and Postural Skills Assessment

The test-retest reliability of the COMPS was above 0.75 for a retest period of two weeks with both the DCD and non DCD group. The co-efficient for each age group (5 year olds, 6-7 year olds and 8-9 year olds) also exceeded 0.75. Interrater reliability was established at greater than 0.75 for therapists experienced in paediatrics. Internal consistency using Cronbach’s Coefficient Alpha was 0.77 for the total test indicating that the internal consistency was moderate although acceptable [6].

Multivariate Analysis of Variance (MANOVAs) were calculated between the DCD and non DCD groups and it was shown that the two groups differed significantly on the COMPS total score in each age band [6]. Further discriminant analysis was
performed to ascertain the contribution of each test item to the ability of the COMPS assessment to discriminate between the DCD and non-DCD groups. This analysis allowed the authors to weigh each test item in the gaining of the overall total weighted score in order to maximise the difference between the two groups of children in each age band [6].

The COMPS total score sensitivity was 100% for both the 5 year old and 8-9 year old age band and 82% for the 6-7 year old age band, indicating that the assessment is able to detect motor dysfunction when it is actually present. The specificity ranged from 62-90% for all ages showing that the assessment accurately identified children without motor problems as functioning normally. [6]

When comparing the results of the COMPS with other assessments particularly the Sensory Integration and Praxis Test (SIPT) it was found that the Low Average Bilateral Integration and Sequencing diagnostic group strongly correlated with the COMPS total weighted score (rpb=0.70; p=0.03) while the diagnostic group Low Average Sensory Integration and Praxis was weakly associated (rpb=0.53; p=0.09) and negatively associated with the slow motion (rpb=-0.67; p=0.04) and rapid forearm rotation test items (rpb=-0.61; p=0.06). All test items of the COMPS were negatively associated with the diagnostic group Generalised Sensory Integration Dysfunction except the supine flexion posture test which was correlated at a significant level (rpb=-0.93; p=0.001). Interpretation of these correlations is however non-conclusive due to the small sample size (n=8) however the lack of association between the praxis profiles and performance on the COMPS is understandable due to the test’s design to separate motor planning skills from the underlying postural and motor skills through the use of demonstration and verbal instruction as well as physical cues in some instances such as the finger-nose touching test item. Despite the small sample size the analysis of the validity of the COMPS indicates that the postural test items are related to other tests of vestibular-related functions and balance such as the Test of Visual Motor Integration (Berry 1982), Motor Accuracy Test – Revised (Ayres 1980) and the SIPT [6].
3.5.2 Developmental Test of Visual Perception, 2nd Edition (DTVP-2) [7]

The DTVP-2 (Appendix F) assessment is a test of visual perceptual skills for the use with children aged 4 – 10 years. The assessment tests both motor reduced visual perceptual skills as well as visual motor integration. The test consists of eight subtests each with a mean of 10 and a standard deviation of 5. These subtests are Eye-Hand Co-ordination, Position in Space, Copying, Figure-Ground, Spatial Relations, Visual Closure, Visual-Motor Speed and Form Constancy. From the scores for the subtests the assessment allows the calculation of a General Visual Perceptual Quotient (GVP), Motor Reduced Visual Perception Quotient (MRP) and a Visual Motor Integration Quotient (VMI). These quotients each have a mean of 100 and a standard deviation of 15 [7].

The GVP scores and the child’s age was used in this study to ascertain the starting point for the cognitive load activity for each participant. The use of the GVP scores was based on the report that there is a relationship between the DTVP-2 assessment and cognitive ability. This relationship was established using the three measures of intelligence and in both cases the coefficients for the subtests and composite scores were related in statistically significant although low degree to cognitive and intellectual ability, which was consistent with the consensus the authors found in literature [7].

3.5.2.1 Reliability and Validity of the Developmental Test of Visual Perception

The reliability of the DTVP-2 assessment was studied looking at the three aspects that most commonly affect assessment reliability – internal consistency, test-retest reliability and interrater reliability. The internal consistency (Cronbach’s coefficient alpha) of the assessment for the subtests ranged between 0.83 and 0.95 while the alpha values for all three composites were above 0.90 showing that the test is reliable. With regards to test-retest reliability the DTVP-2 subtests are minimally reliable with coefficients of 0.80 in two of the subtests and a ‘rounded’ 0.80 in five while the Copying subtest was well below the acceptable level. Despite this the composite values are 0.89 for the Motor Reduced Visual Perception and Visual Motor Integration and 0.93 for General Visual Perception and these scores ensure
confidence in the quotients. Interrater reliability coefficients for the DTVP-2 subtests and quotients ranged from 0.92 to 0.99 giving evidence of the tests reliability.

Content validity of the DTVP-2 was assessed by the authors of the test using both qualitative and quantitative methods. The qualitative rationale behind each subtest was evaluated in detail and found to be satisfactory. The quantitative evidence for the validity of the DTVP-2 test was done in the form of item analysis using biserial correlation techniques and criterion related (concurrent) validity using correlating tests with other assessments. When applying the biserial correlation technique the authors used conservative value of 0.30 to ensure the validity of the assessment (typically a value of 0.2 to 0.3 is considered to be acceptable) and the subtests were found to be valid [7].

Concurrent validity was established by correlating the composite scores and the subtests with the total scores of the Developmental Test of Visual Perception (Berry, 1989) and the Motor Free Visual Perceptual Test (Colarusso & Hammill, 1972) [7]. The computed coefficients were found to be high enough at 0.65 to indicate a high relationship. In addition all three tests (using the composites of the DTVP-2) have a mean of 100 and a standard deviation of 15 and no statistical difference was found between the scores in the assessment of the normative group. These figures conclude that the DTVP-2 has strong concurrent validity [7].

Construct validity of the DTVP-2 shows an increase in performance with age, as is expected as a child’s perceptual skills improve as they mature. The correlation coefficients for all subtests ranged from 0.43 (figure-ground) to 0.65 (spatial relations) and all values were statistically significant with p values of ≤ 0.01. In addition a low relationship correlation between the subtests was found showing that although the subtests are related to each other, they measure different aspects of visual perception [7]. As is expected of a visual perceptual assessment the DTVP-2 has been found to differentiate between children with perceptual difficulties and those without. This was established through averaging the standard scores of a sample of 49 children with neurological impairments and all the scores
were found to be below average (10 for subtests and 100 for composite scores) providing evidence of the assessment’s construct validity [7].

Finally factor analysis results provided a single eigen value of greater than 1. It was concluded that as all subtests are loaded on a single factor it can be presumed that the factor measures overall visual perceptual ability. When employing the Prornax rotation method two factors, motor reduced visual perception and visual motor integration, were generated with eigen values of greater than 1 providing further evidence of the DTVP-2’s construct validity [7].

3.5.3 Chailey Levels of Postural Ability [64]

The levels of sitting ability measured by the Chailey Levels of Postural Ability (Appendix G) are a non norm referenced assessment that is recognised as a ‘reliable and accurate measure for clinical and research purposes’ ([64] pg 21). This assessment was originally designed to assess children with neurological impairment such as cerebral palsy [64, 81] who have a low level of postural ability that is not easily assessable with the use of other assessments [81]. The assessment has been in use for over 20 years and has been gradually refined for clinical use. It is based on observational scales, which have been found to be more reliable than assessments that require handling or specialist equipment [81].

The Chailey Levels of Postural Ability measures nine constructs in the positions of prone and supine lying, floor sitting, box sitting and standing. The constructs measured in these scales are [64, 81]:

- load bearing when still and moving;
- ability to change position in a controlled manner;
- the position of the pelvis, trunk and legs;
- the position of the shoulder girdle and arms;
- the position of the head and chin;
- the lateral profile of the body;
- the effect of movement of the head on the limbs and trunk;
- the ability to perform isolated movements of the limbs;
- the predominant position and alignment of the major girdles and joints;
Each component group is scored in each position with the lowest level of ability correlating with a level 1 while the highest level of performance scores a level 7. Each component needs to be present for the next level to be scored. If a child is still developing an aspect of the component group which is seen through the partial achievement of a skill then the lower level of ability is scored. The overall level of postural ability in each position is equal to the lowest level awarded for the component groups [64, 81].

3.5.3.1 Reliability and Validity of the Chailey Levels of Postural Ability

Reliability of the Chailey levels of lying and standing scales has been established for test-retest reliability as well as interrater reliability by Smithers (1991) and Carpenter (1998) with co-efficients exceeding 0.75. The reliability and validity of the sitting scales has not been formally established but the wide spread use of the scale in clinical settings as well as recommendation in publications implies that it is considered to be a reliable tool [81].

Content validity of this assessment was studied using previously existing pilot data consisting of 38 normal infants and 85 children with cerebral palsy. The comparison of the data showed that both groups of children displayed all the levels defined in the Chailey Levels of Postural Ability when placed in the positions of prone and supine lying, sitting and standing. The content validity study in addition to the assessment’s widespread use and reliability showed that the Chailey Levels are valid to measure postural ability [81].

Criterion Validity was established by Pountney, Cheek & Green (1999) through the comparison of the Chailey Levels of Postural Ability with two previously existing assessments that have established reliability and validity, namely the Alberta Infant Motor Scales (AIMS) and The Gross Motor Function Measure (GMFM) [81]. The study using the Pearson Product Moment Correlations co-efficient in which a result of 0.75 or more is considered good showed that the Chailey Levels of Postural Ability have criterion validity when compared to the above assessments. There were however slight differences found between the assessments as the
assessments purposes varied. The AIMS and GMFM are not specifically designed to measure low level abilities as are the Chailey Levels of Postural Ability and therefore the Chailey was more able to assess lower level skills while the AIMS and GMFM higher level and balance skills [81].

3.3.3.4 Modified Chailey Levels of Postural Ability

Since only sitting was to be assessed in this study the Chailey Level of Sitting Ability, using the Box Sitting assessment scales were used for assessment of the participants. These scales, needed to be modified for use in this study (Appendix H) as the assessment was designed for use with children with neurological impairment with a low level of ability. Participants in this study were children without neurological impairment but with or without postural control difficulties. The modified criterion for measuring sitting ability was designed from the literature regarding postural control and motor co-ordination, for use in this study only. The modifications that were made to the assessment were based on current knowledge regarding the development of postural control within the current occupational therapy knowledge base.

The modifications that were made to the assessment are as follows:

- The first change was to clarify the ‘Pelvic Girdle Position’ item of the assessment according to the Chailey manual and to highlight that children who sacral sit have difficulty with postural control [64, 82].
- The item ‘Chin Position’ was removed and ‘Head Alignment’ added as many children with poor postural control have difficulty with crossing the midline and as a result develop many ways, including holding head away from the midline, to avoid midline crossing [65]. Further those with low muscle tone and difficulty maintaining antigravity positions often support their head on their hands [65].
- The level scoring on the ‘Trunk Position and Movement’ item was slightly altered to differentiate between those children with poor righting and equilibrium reactions, i.e. poor postural control [65], and those without. This modification entailed removing levels from the assessment chart in order for
there to be differentiation between children who are able to move outside of their base and those who are able to recover their balance from outside the base.

- An additional criterion was added to the ‘Hip Position’ item as children with poor antigravity postures make use of hip internal rotation (W sitting) as well as wrapping legs around legs of the chair as a means to compensate. These are common observations made during occupational therapy assessments [65, 83, 84], and this was not accounted for in the original assessment.

- The final modification was to the ‘Activities’ item and this was significantly altered as the original assessment was designed for those with severe motor difficulties. Thus the height to which those children can raise their arms during an activity without disturbing their sitting posture is important [64]. Children with postural control difficulties however do not have difficulty raising their arms but do have difficulty with developing bilateral integration and crossing of the midline [65, 85], therefore these were important aspects to be included in the assessment.

The effects of this modification on the assessments reliability and validity have not been established statistically but the modified assessment was piloted prior to the study. Interrater reliability was not assessed as only one rater assessed the participants in this study.

**Pilot Study 1: Content validity**

The Modified Chailey Level of Sitting Ability was sent in written format to two experienced occupational therapists to validate the content.

**Selection of therapists**

Two occupational therapists that practice in the field of paediatrics with experience in the treatment of learning disabilities and DCD, were approached to participate in the pilot study.

**Inclusion criteria**

- Five years experience and/or post-graduate qualification;
- Experience in the treatment of learning disabilities and DCD;
- International experience in the field.

The therapists felt that the scale and changes made to the Chailey Box sitting levels were appropriate for children with postural control difficulties, therefore content validity was established.

**Pilot Study 2: Construct Validity**

The Modified Chailey Level of Sitting Ability was piloted on children being treated for postural control difficulties to establish if this assessment was sensitive to the presence of dysfunction or not.

If the Modified Chailey Levels of Sitting Ability are to be used to identify postural control difficulties then children with these difficulties should score below a score of 7 which indicates ideal sitting posture. This would indicate that what was being evaluated by this assessment tool was the construct of postural control in sitting at a desk.

**Selection of Children**

The sample was selected using convenience sampling. Fifteen children between the ages of 6 years to 9 years with known postural control difficulties who were attending occupational therapy for these problems were invited.

The pilot study was carried out by the same 2 therapists selected for pilot study 1. They completed the Modified Chailey Levels of Sitting Ability assessment forms while observing the children chair sitting during a single task condition, i.e. no cognitive load as in the baseline measures in the research study.

**Results**

The results of the pilot study showed that 60% of those children assessed scored a level 5 sitting ability, 13% of children obtained a level 6 while 27% obtained a level 4. The lowest scoring component was the ‘Hip Position’ with a mean level 5
indicating external rotation seen through W sitting which is expected in children with postural control difficulties [65].

Table 3.1 Mean Component Scores on Modified Chailey Levels of Sitting Ability Pilot Study.

<table>
<thead>
<tr>
<th>Component</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load-bearing</td>
<td>7.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Shoulder Girdle Position</td>
<td>7.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Pelvic Girdle Position</td>
<td>6.13</td>
<td>0.36</td>
</tr>
<tr>
<td>Spinal Profile</td>
<td>5.80</td>
<td>1.01</td>
</tr>
<tr>
<td>Head Alignment</td>
<td>5.73</td>
<td>1.22</td>
</tr>
<tr>
<td>Trunk Position &amp; Movement</td>
<td>5.67</td>
<td>0.98</td>
</tr>
<tr>
<td>Hip Position</td>
<td>5.27</td>
<td>1.03</td>
</tr>
<tr>
<td>Activities</td>
<td>5.73</td>
<td>0.80</td>
</tr>
<tr>
<td>Overall</td>
<td>4.87</td>
<td>0.64</td>
</tr>
</tbody>
</table>

The highest scoring components were ‘Load-bearing’ and ‘Shoulder Girdle Position’ in which 100% of the children assessed scored a level 7 equivalent to load-bearing through the thighs and buttocks as well as protracted shoulders. The mean scores for each component are shown in Table 3.1. These items were therefore not appropriate for the construct of postural control in sitting at a desk.

The other change that was made after this pilot study was the scoring for posterior pelvic tilt in the ‘Pelvic Girdle Position’ component. The initial normal score for posterior tilt was changed to reflect this as a deviation from ideal sitting posture with a neutral pelvic position at level 7, to a level 5.

3.6 Research Procedure:

3.6.1 Session 1: Baseline Assessments

The assessments described above were carried out using the standardised administration criteria provided in the assessment manuals by the researcher (COMPS and DTVP-2) and research assistant (Modified Chailey Levels of Postural Ability in Sitting).
The COMPS and DTVP-2 assessments were used initially in assessment session 1 in this study to ensure that the participants met the inclusion criteria for the study groups. For the COMPS participants in Group A who were attending occupational therapy for postural control difficulties were required to score a total weighted score of less than 0 to show the presence of postural and motor skill dysfunction. Those participants in Group B however had to score 0 or above on the total weighted score of the COMPS and GVP of 85 or above on the DTVP-2 to be included in the study. Both sessions were conducted by the researcher.

Scores from the DVTP-2 were recorded to set the level for each participant in the “Go Getter” activity.

The Modified Chailey Levels of Postural Ability were used to assess components of posture while sitting the child was sitting at a desk. This analysis was done by the research assistant, to ensure blinding, from the video footage taken during the baseline Session 1 assessment as well as both Session 2 cognitive load trials.

### 3.6.2 Session 1: Establishing cognitive level and cognitive load

In order to ensure the integrity of the study equalised difficulty of cognitive load tasks across the participants [23, 26] had to be determined. Therefore the DTVP-2 results were used to ensure that the cognitive load activity was appropriate and achievable for each participant. The activity used in the cognitive load trials was the Smart Games ‘Go Getter – Prince and the Dragon’ which is a problem solving game with various levels of difficulty suitable for use from the age of 5 years to adult. This problem solving puzzle consists of a puzzle board with 9 pictures around the perimeter. Nine square pieces with different roads are provided and the game requires paths to be made from one picture to another, as set out in the puzzle booklet. The challenge is to avoid creating dead ends as well as to use bridges and corner pieces to avoid going to certain pictures as required by the puzzle. An example puzzle and solution from the puzzle booklet is provided in Appendix I for further clarification.
The starting challenge for each participant was determined by their general visual perceptual skills score on the DTVP-2 and all participants continued progressing through challenges for a 10 minute period. A table indicating how the DTVP-2 score and the level in “Go Getter” were matched is provided in Appendix J. At the start of the cognitive load trials, before the time limit was started each participant was shown how to play the game using puzzle number 1. The 9 puzzle pieces were set out on the table on either side of the puzzle board at the start of the cognitive load condition as well as between each puzzle level completed.

3.6.3 Assessment Venue

The research room design was planned before the study commenced and remained consistent throughout the study to control for lighting, sound and other distracting variables [5] this was however not possible due to the various locations used in the data collection. When carrying out the study several rooms were used at a private occupational therapy practice in Highlands North. Three rooms were used depending on their availability at the time, however all three rooms were similarly lit and had the same furniture and equipment available. These rooms allowed for privacy and no interruptions were made during the assessment or cognitive load trials. Two options of table and chair were available, the first was a plastic table and chair and the second a higher table and adult sized chair. The choice of table and chair used was determined by the child’s height. If necessary a block was placed under the participants’ feet at the larger table to ensure that they were able to achieve a good sitting position. Both chairs used had a back rest with no arm rests and were stable chairs that did not have wheels or the ability to spin. Through the use of the two table options an acceptable sitting position was achievable in all participants.

The secondary research venue was at Dominican Convent, where several rooms were made available for the study, again depending on availability at the time. The lighting and noise could not be controlled to the same extent as in the practice rooms. The ergonomics of the table and chair height were a problem but again compensation through the use of a block under the feet was used to ensure that correct sitting posture was possible.
Regardless of the venue the COMPS assessment was carried out on a mat with the child initially sitting on a block opposite the researcher and the camera facing the child. After the first three test items (namely slow movements, diadokokinesis and finger nose touching) the blocks were removed and the mat was used for the remaining test items. When setting up the room it was essential to ensure that the camera, although facing the child, could record the full mat area and that when carrying out the assessment the researcher did not obstruct the view of the camera at any given moment, particularly during the prone extension posture, ATNR and supine flexion posture test items.

For the DTVP-2 and Modified Chailey Levels of Sitting Ability, when the child was seated at the table, the camera was situated towards the back left hand side of the child, to give a view of the child’s spinal profile and hip position. Due to the use of a single camera it was often difficult to ascertain the child’s head alignment. The researcher sat to the left of the child but again had to be aware at all times not to obstruct the camera’s view. This was not corrected during the course of the study due to the analysis of the video’s only commenced once the data collection process had been completed. The baseline score for the Modified Chailey Levels of Sitting Ability were taken when the child was sitting at the table waiting for the DTVP-2 assessment to start, they were sitting still and were not involved in any activity at the time to ensure that the non-cognitive load and cognitive load comparisons were able to be made to a sitting posture with no dual task interference.

3.6.4 Data Collection

Demographic values such as age, gender and grade were collected through the participant demographic sheet that parents were asked to complete once they had given permission for the child to participate in the study. Data for each participant was collected over a two week period.

The first session was an assessment session in order to establish inclusion criteria for the group using COMPS and DTVP-2 as well as baseline scores, using the
Modified Chailey Levels of Sitting Ability. This session took up to one hour due to the length of the DTVP-2 assessment and a second session was used to introduce cognitive load conditions. The one week between the first and second session was to allow the researcher time to score the COMPS and the DTVP-2 assessment so as to be able to select the appropriate level of cognitive activity for each participant. In addition due to the nature of children’s concentration and attention span, the participants required a rest period before the dual task conditions were introduced.

As the child arrived at the first session the researcher introduced herself and thanked the child for being willing to participate. The child was then shown around the research venue and taken into the allocated room for the research assessment. Accompanying parents were requested to wait in the waiting area. Once in the research venue the researcher explained the process of the first and second session to the child. As the camera needed to be moved between completing the COMPS and starting the DTVP-2 assessment the child was made aware of the camera. The selection of appropriate table and chair was carried out before the start of the first session to avoid disruption to the assessment process. The first session was standard across the participants with the COMPS being carried out first followed by the DTVP-2 assessment.

The second session took place on an average of one week following the initial assessment. The second session involved Modified Chailey Levels of Sitting Ability during the conditions of cognitive and non-cognitive loads with the administration of the two cognitive load trials. Previous studies limited movement of the limbs to limit interfering body movements on postural control [5]. Due to the fact that the cognitive load activity in this study required arm movements, through the reach for and placing of puzzle pieces on the board, the non-cognitive load task was structured to include arm movements through turning the pages of a book, in order to control for this interfering factor. The reach involved in the cognitive load task was restricted to movement of the arms within the base of support and movement of the arms did not extend more than shoulder height. In-
hand manipulation of the puzzle pieces was also required in the cognitive load activity.

The experimental order of the dual task conditions (non-cognitive load and cognitive load) were randomised to counterbalance the dependant variable to control for effect of fatigue, boredom or familiarisation [23, 24, 26, 80]. Each child only participated in one trial of each condition. The randomisation was done through the child picking a hand with token in it to determine whether to play the game or listen to the story first.

The first condition was a non-cognitive load condition in which the child was seated with their eyes open for a period of 10 minutes while listening to a recorded story while following along in a picture book. The stories used were age appropriate and each child was given the choice of which story they would like to listen to out of a selection. The selection of stories included ‘Lady and the Tramp’, ‘Scrooges’ Treasure Hunt’, ‘The Rescuers Down Under’, ‘Pinocchio’, ‘Snow White and Rose Red’ and ‘Winne the Pooh and the Honey Tree’. In the context of this study this was considered a single task as the cognitive processing required was significantly lower than the cognitive load task.

A one minute rest period between each condition was provided. The cognitive load activity was presented to the all participants prior to the commencement of the cognitive load trial to ensure the child was familiar with the requirements of the task [23, 26]. The experimental procedure is outlined in Appendix K.

The second condition was a cognitive load condition in which the child was again seated with their eyes open for a period of 10 minutes while engaging in a cognitively challenging activity. The activity presented was the Smart Games ‘Go-Getter Prince and the Dragon’ puzzle and the participant worked through puzzle levels until the time limit of 10 minutes had been reached. Minimal assistance was provided by the researcher when solving the puzzles to ensure that the child was fully participating in the activity. Help was only given when it was clear to the researcher that the participant’s concentration would waver due to their inability to
solve a puzzle and this help was in the form of guidance and prompting rather than giving the solution. This activity was equivalent to a dual task in the context of this study.

Both conditions were video recorded and the participants’ postural control analysed according to the Modified Chailey Levels of Sitting Ability. This analysis was done by a research assistant, a qualified occupational therapist who was trained, by the researcher, in the use of the measurement tool. The research assistant was blinded to the participants’ group to prevent bias.

Analysis of postural control during cognitive load conditions was carried out using the video of the participants’ sessions at 1, 5 and 10 minutes. All analyses of the videos was completed at the conclusion of the data collection. All data was captured on the Research Record Sheet for easy analysis of results (Appendix L). In addition the scores on the Chailey Levels of Sitting Ability for the component groups were entered onto an excel spreadsheet as it was decided during the data analysis process that it would be valuable to look at the component groups as well as the overall Chailey Level of Sitting Ability.

3.7 Data Analysis

Data was analysed using the XLSTAT add in software to Microsoft Excel in addition to Graphpad Prism 5. The following analyses were carried out:

The raw scores were used to generate means, ranges and standard deviations for the various variables using an Excel spread sheet. This data was used in further analysis.

Groups were compared at baseline and over the three trials for cognitive and non-cognitive conditions using the Mann Whitney U test. This non parametric test was used as the sample was small and the data was not normally distributed. These results were also confirmed using a Student’s non paired t-test. Testing was done at the 0.05 level of significance.
The Mann Whitney U test was carried out to establish significant differences between the two groups as well as within the groups to establish any significant difference between the baseline sitting ability during the cognitive and non-cognitive load trials for each group.

Table 3.2 and 3.3 below indicate the different comparisons that were carried out using these statistical measures.

**Table 3.2 Between Group Comparisons**

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Non-Cognitive Load 1</th>
<th>Non-Cognitive Load 2</th>
<th>Non-Cognitive Load 3</th>
<th>Cognitive Load 1</th>
<th>Cognitive Load 2</th>
<th>Cognitive Load 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 2</strong></td>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive Load 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Non-Cognitive Load 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive Load 3</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Load 1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Load 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Load 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Table 3.3 Within Group Comparisons**

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Non-Cognitive Load 1</th>
<th>Non-Cognitive Load 2</th>
<th>Non-Cognitive Load 3</th>
<th>Cognitive Load 1</th>
<th>Cognitive Load 2</th>
<th>Cognitive Load 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive Load 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive Load 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive Load 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Load 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Load 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Load 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The non parametric one way analysis of variance (ANOVA), using Graphpad, was carried out to compare the baseline score with all 6 measurements during the dual task conditions with a significance level of p=0.05.
CHAPTER 4
RESULTS

4.1 Introduction
The Modified Chailey Levels of Sitting Ability were analysed for participants with identified postural control problems (Group A: n=21) and those without (Group B: n =14). The posture of participants in both groups was assessed during activities presenting cognitive loads (CL) and non-cognitive loads (NCL) at 1, 5 and 10 minutes. Between group comparisons were made to establish the sensitivity of the Modified Chailey Levels of Sitting Ability in identifying difference in posture between participants with and without postural control problems and within group comparisons were made to establish the effect of cognitive load on sitting posture at a desk.

4.2 Demographics
4.2.2 Gender
The gender distribution of the participants within both groups was relatively even with no statistical difference evident when comparing the male to female ratio between the two groups (p≤0.60). The distribution of male versus female participants was more evenly distributed in Group A than Group B (Figure 4.1).

Figure 4.1 Gender distribution in Groups A and B
4.2.3 Age and Grade

Participants in this study ranged in age from 6 years 0 months to 9 years 11 months coinciding with grades 0 through to 4. Group A’s average age was 7.1 years while Group B’s average age was 8.0. A Mann Whitney U test indicated a statistically significant difference in the ages in the two Groups (p=0.04) (Figure 4.2).

![Figure 4.2 Mean age distribution in Groups A and B](image)

The overall difference in the grade distribution (Figure 4.3) was however not statistically significant using the same statistical measure (p=0.06) with the average grade for Group A being grade 1 and Group B grade 2 (rounded up).

![Figure 4.3 Grade distribution in Groups A and B](image)
4.3 Developmental Test of Visual Perception

The use of the DTVP-2 assessment in the study was twofold. Firstly during the selection of participants for Group B a below average GVP was an exclusion criterion. This was not an exclusion criteria for Group A as children with postural control as children with postural control difficulties often have co-morbid visual perceptual problems [47]. Secondly the GVP was used to determine what starting level would be used during the cognitive load condition.

The GVP for the overall sample averaged 98.71 (z=0.09) which is within the normal range. Group A and Group B participants average quotient was 97.00 (z= -0.02) and 101.29 (z=0.09) respectively both of which are within the normal range. Six Group A participants scored below average (z ≤ -1.00) while 1 participant’s score was borderline (-0.9 ≤ z ≥ -0.8) and one score was above average (z ≥ 1.00). The remainder of the participants scored within average (0.9 ≤ z ≥ -0.7). All except 1 participant in Group B scored within average range (0.9 ≤ z ≥ -0.7). (Figure 4.4)
4.4 Modified Chailey Levels of Sitting Ability

When analysing the Modified Chailey Levels of Sitting Ability three of the component test items were excluded for several reasons. Firstly ‘Load-bearing’ and ‘Shoulder Girdle Position’ were not analysed using the Mann Whitney U Test, Student’s t-test or One Way ANOVA due to all results for all participants and trials scoring a level 7. These constructs were identified in the pilot study as items that would not differentiate postural control in children with postural control difficulties using the Modified Chailey levels of Sitting Ability. Further ‘Hip Position’ was not analysed due to the difficulty scoring this component item with the position of the camera during the trials. The remainder of the component items (‘Pelvic Girdle Position’, ‘Spinal Profile’, ‘Head Alignment’, ‘Trunk Position and Movement’, ‘Activities’ and overall Modified Chailey level) were analysed.

4.4.1 Comparison of the Scores between Groups A and B

Scores between Groups A and B were compared to establish the ability of the Modified Chailey Levels of Sitting Ability to differentiate between participants with and without postural control problems.

4.4.1.1 Pelvic Girdle Position

The results obtained when assessing the participants’ ‘Pelvic Girdle Position’ were not statistically significant between groups. The level scoring of this component was altered at the evaluation stage of the study as a error was found resulting in a posterior pelvic tilt scoring higher than a neutral pelvis. As a neutral pelvis is a more mature sitting posture this was amended to score a level 6 and the posterior pelvic tilt a level 5.
Table 4.1 Comparison of Pelvic Girdle Position between Group A and B

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=21)</th>
<th>Group B (n=14)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5.86</td>
<td>5.93</td>
<td>0.85</td>
</tr>
<tr>
<td>NCL1 (1 minute)</td>
<td>5.71</td>
<td>5.71</td>
<td>0.81</td>
</tr>
<tr>
<td>NCL2 (5 minutes)</td>
<td>5.71</td>
<td>5.42</td>
<td>0.23</td>
</tr>
<tr>
<td>NCL3 (10 minutes)</td>
<td>5.57</td>
<td>5.54</td>
<td>0.80</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>5.67 (0.08)</td>
<td>5.60 (0.15)</td>
<td></td>
</tr>
<tr>
<td>CL1 (1 minute)</td>
<td>5.76</td>
<td>5.78</td>
<td>0.99</td>
</tr>
<tr>
<td>CL2 (5 minutes)</td>
<td>5.81</td>
<td>5.86</td>
<td>0.93</td>
</tr>
<tr>
<td>CL3 (10 minutes)</td>
<td>6</td>
<td>5.86</td>
<td>0.63</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>5.86 (0.13)</td>
<td>5.83 (0.04)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant p ≤ 0.05

Table 4.1 shows the mean raw scores for this component test with all results falling within level 5 indicating that the average ‘Pelvic Girdle Position’ was tilted posteriorly rather than in the neutral position (level 6).

4.4.1.2 Spinal Profile

No significant differences were evident when comparing the spinal profile scores between Group A and Group B. The mean raw scores are represented in the table below (Table 4.2) with level 5 indicating a rounded spinal profile while level 6 and 7 indicate an upright spine.

Table 4.2 Comparison of Spinal Profile between Group A and B

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=21)</th>
<th>Group B (n=14)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>6.05</td>
<td>6.00</td>
<td>0.91</td>
</tr>
<tr>
<td>NCL1 (1 minute)</td>
<td>5.48</td>
<td>6.00</td>
<td>0.12</td>
</tr>
<tr>
<td>NCL2 (5 minutes)</td>
<td>5.76</td>
<td>5.36</td>
<td>0.24</td>
</tr>
<tr>
<td>NCL3 (10 minutes)</td>
<td>5.48</td>
<td>5.71</td>
<td>0.46</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>5.57 (0.16)</td>
<td>5.69 (0.32)</td>
<td></td>
</tr>
<tr>
<td>CL1 (1 minute)</td>
<td>6.24</td>
<td>6.29</td>
<td>0.90</td>
</tr>
<tr>
<td>CL2 (5 minutes)</td>
<td>6.24</td>
<td>6.43</td>
<td>0.58</td>
</tr>
<tr>
<td>CL3 (10 minutes)</td>
<td>6.05</td>
<td>6.14</td>
<td>0.80</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>6.17 (0.11)</td>
<td>6.26 (0.14)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant p ≤ 0.05
4.4.1.3 Head Alignment

No statistical or clinical differences were obtained when analysing head alignment. Both Group A and Group B scored an average level 5 and 6 (using rounding) indicating that the participants had difficulty maintaining head in the midline (Table 4.3).

Table 4.3 Comparison of Head Alignment between Group A and B

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=21)</th>
<th>Group B (n=14)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>6.60</td>
<td>6.77</td>
<td>0.63</td>
</tr>
<tr>
<td>NCL1 (1 minute)</td>
<td>6.25</td>
<td>6.71</td>
<td>0.48</td>
</tr>
<tr>
<td>NCL2 (5 minutes)</td>
<td>6.58</td>
<td>6.36</td>
<td>1.00</td>
</tr>
<tr>
<td>NCL3 (10 minutes)</td>
<td>5.95</td>
<td>6.00</td>
<td>0.97</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>6.26 (0.31)</td>
<td>6.36 (0.36)</td>
<td></td>
</tr>
<tr>
<td>CL1 (1 minute)</td>
<td>6.53</td>
<td>6.86</td>
<td>0.37</td>
</tr>
<tr>
<td>CL2 (5 minutes)</td>
<td>6.58</td>
<td>6.77</td>
<td>0.57</td>
</tr>
<tr>
<td>CL3 (10 minutes)</td>
<td>6.70</td>
<td>6.92</td>
<td>0.14</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>6.60 (0.09)</td>
<td>6.85 (0.08)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant p ≤ 0.05

4.4.1.4 Trunk Position and Movement

Trunk position and movement was not a sensitive enough test item to use in this study.

Table 4.4 Comparison of Trunk Position and Movement between Group A and B

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=21)</th>
<th>Group B (n=14)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2.57</td>
<td>2.50</td>
<td>0.91</td>
</tr>
<tr>
<td>NCL1 (1 minute)</td>
<td>2.00</td>
<td>2.50</td>
<td>0.34</td>
</tr>
<tr>
<td>NCL2 (5 minutes)</td>
<td>2.29</td>
<td>1.86</td>
<td>0.41</td>
</tr>
<tr>
<td>NCL3 (10 minutes)</td>
<td>1.71</td>
<td>2.29</td>
<td>0.25</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.00 (0.29)</td>
<td>2.21 (0.33)</td>
<td></td>
</tr>
<tr>
<td>CL1 (1 minute)</td>
<td>2.71</td>
<td>2.93</td>
<td>0.83</td>
</tr>
<tr>
<td>CL2 (5 minutes)</td>
<td>2.86</td>
<td>2.71</td>
<td>0.80</td>
</tr>
<tr>
<td>CL3 (10 minutes)</td>
<td>2.57</td>
<td>2.50</td>
<td>0.91</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.71 (0.14)</td>
<td>2.71 (0.21)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant p ≤ 0.05
The participants were seated at a desk resulting in mean raw scores in both groups of a level 1 (trunk behind base) due to the child leaning into the back of the chair or level 2 (trunk forward over base) as the child leant forward to read the book or solve the puzzle. There were no statistical differences between the two groups (Table 4.4)

4.4.1.5 Activities

Statistical differences were found between Group A and B in the first non-cognitive load trial at 1 minute with Group A presenting with lower scores. The participants in Group A used less bilateral integration and midline crossing, despite the cognitive load activity being set up with puzzle pieces placed on both sides of the board, and they were observed to allow their non preferred hand to hang down to the side or prop their head during the non-cognitive load condition. In addition this group tended to make use of more postural background movements than their peers with typical postural control.

The mean raw scores for both Groups ranged between a level 4 (excess postural background movements) and level 5 (poor bilateral integration) in both Groups (Table 4.5).

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=21)</th>
<th>Group B (n=14)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5.25</td>
<td>5.09</td>
<td>0.54</td>
</tr>
<tr>
<td>NCL1 (1 minute)</td>
<td>4.71</td>
<td>5.57</td>
<td>0.03*</td>
</tr>
<tr>
<td>NCL2 (5 minutes)</td>
<td>4.85</td>
<td>4.93</td>
<td>0.95</td>
</tr>
<tr>
<td>NCL3 (10 minutes)</td>
<td>4.55</td>
<td>4.86</td>
<td>0.36</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>4.70 (0.15)</td>
<td>5.12 (0.39)</td>
<td></td>
</tr>
<tr>
<td>CL1 (1 minute)</td>
<td>5.38</td>
<td>5.43</td>
<td>0.90</td>
</tr>
<tr>
<td>CL2 (5 minutes)</td>
<td>5.52</td>
<td>5.50</td>
<td>0.34</td>
</tr>
<tr>
<td>CL3 (10 minutes)</td>
<td>5.43</td>
<td>5.50</td>
<td>0.70</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>5.44 (0.07)</td>
<td>5.48 (0.04)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant p≤ 0.05
4.4.1.6 Overall Modified Chailey Level of Sitting Ability

The overall Modified Chailey Level of Sitting Ability is an indication of the lowest score obtained from all the component scores. As such the low scores seen in the ‘Trunk Position and Movement’ component have greatly reduced the overall level of ability in both Group A and Group B. When removing the ‘Trunk Position and Movement’ component from the overall scores the overall Modified Chailey Level of Sitting Ability is increased from an average of Level 2 for Group A and level 3 for Group B to a level 4 in Group A and level 5 (rounded up) in Group B (Table 4.6).

Table 4.6 Comparison of Overall Chailey Level of Sitting Ability between Group A and B (trunk position excluded)

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=21)</th>
<th>Group B (n=14)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>4.48</td>
<td>5.00</td>
<td>0.13</td>
</tr>
<tr>
<td>NCL1 (1 minute)</td>
<td>4.10</td>
<td>4.86</td>
<td>0.02*</td>
</tr>
<tr>
<td>NCL2 (5 minutes)</td>
<td>4.29</td>
<td>4.50</td>
<td>0.40</td>
</tr>
<tr>
<td>NCL3 (10 minutes)</td>
<td>4.33</td>
<td>4.43</td>
<td>0.71</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>4.24 (0.13)</td>
<td>4.60 (0.23)</td>
<td></td>
</tr>
<tr>
<td>CL1 (1 minute)</td>
<td>4.81</td>
<td>4.64</td>
<td>0.59</td>
</tr>
<tr>
<td>CL2 (5 minutes)</td>
<td>4.71</td>
<td>5.00</td>
<td>0.47</td>
</tr>
<tr>
<td>CL3 (10 minutes)</td>
<td>4.86</td>
<td>5.00</td>
<td>0.66</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>4.79 (0.07)</td>
<td>4.88 (0.21)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant p ≤ 0.05

Group A had lower scores for overall sitting posture than Group B indicating a clinical difference even if there was only one score that demonstrated a statistically significant difference for non-cognitive load trial 1.

4.4.2 Comparison of Scores within Groups A and B

In order to establish the effect of cognitive load within Group A and B the baseline, non-cognitive load and cognitive load scores for the Modified Chailey Level of Sitting Ability were all compared to each other within Group A and within Group B.
4.4.2.1 Pelvic Girdle Position

The majority of results obtained when assessing the participants' ‘Pelvic Girdle Position’ were not statistically significant when comparisons of cognitive and non-cognitive loads were analysed within each Group (Figure 4.5). There was however a clinical difference in Group A when comparing baseline to the cognitive load trial 3 at 10 minutes. The participants’ pelvic position improved during the cognitive load trial from a posterior pelvic tilt to a neutral position as the participants leant forward over their base to complete the problem solving activity at the desk.

![Figure 4.5 Effect of non-cognitive load and cognitive load on Pelvic Girdle Position](image)

Group B presented with a clinical difference in the non-cognitive load trial 2 and cognitive load trial 2 at 5 minutes (p≤0.05). The posterior pelvic tilt was therefore significantly reduced in the cognitive load trial at 5 minutes compared to the non-cognitive trial.

The one way ANOVA on both groups was not statistically significant either with p=0.75 for Group A and p=0.81 for Group B showing that there was no overall effect of cognitive load on the ‘Pelvic Girdle Position’.
### 4.4.2.2 Spinal Profile

The mean results for the ‘Spinal Profile’ component scores ranged between level 5 and 6 showing the greatest difference in terms of effect of cognitive load in this study.

Within Group A statistically significant differences were found between the baseline and non-cognitive load trial 1 at 1 minute (p=0.03) as well as the non-cognitive load trial 1 and cognitive load trial 1 at 1 minute (p=0.01). In addition there was a clinical difference between the non-cognitive load trial 3 and cognitive load trial 3 at 10 minutes in this group. The one way ANOVA comparing the baseline score with the 6 dual task conditions (non-cognitive load and cognitive load) showed a statistically significant difference (p=0.03).

Group B however only presented with a statistical difference of p=0.01 when comparing non-cognitive load trial 2 and cognitive load trial 2 at 5 minutes. The one way ANOVA showed a clinical difference (p=0.09) between the baseline scores and the non-cognitive load and cognitive load conditions.

Spinal profile of Group A and B at baseline score averaged a level 6 showing an upright spinal profile with no cognitive load dual task interference. This profile altered with the addition of the non-cognitive load task to a more rounded profile as this condition was measured over time.

Group A participants appeared to exhibit an improvement in the mean spinal profile in the second non-cognitive load measurement, however this remained an average level 5 showing an overall rounded spinal profile in this condition.

The mean spinal profile in both groups during the cognitive load conditions was higher than the baseline score showing that during cognitive load dual task conditions spinal profile becomes more upright, however with time there was a slight decrease in this mean score over both Groups (Figure 4.6).
4.4.2.3 Head Alignment

Figure 4.7 displays the mean raw score results for the ‘Head Alignment’ component score.

Group A participants showed a clinical difference in the comparison between baseline and the non-cognitive load trial 3 at 10 minutes as well as between the non-cognitive load trial 3 and the cognitive load trial 3 at 10 minutes ($p \leq 0.09$). Within this group head alignment decreased with time as the children moved their heads away from the midline and in some cases to supporting their heads on their hands.
Changes in head alignment for Group B were similar to those within Group A but were statistically significant. A statistically significant difference ($p \leq 0.02$) was found between the non-cognitive load trial 3 at 10 minutes and the cognitive load trial 3. There was a statistically significant result in this group when comparing the baseline head alignment with the non-cognitive and cognitive load conditions using the one way ANOVA ($p=0.02$). In this group the mean head alignment scores for the non-cognitive load conditions steadily decreased showing a move away from the midline while maintaining a static sitting posture. There was an increase in the mean scores during the cognitive load condition showing that during the dual task condition head alignment becomes more aligned with the midline.

### 4.4.2.4 Trunk Position and Movement

Group A participants showed a clinical difference between baseline and the non-cognitive load trial 3 as well as between the non-cognitive load trial 3 and the cognitive load trial 3 at 10 minutes ($p \leq 0.09$).

This change reflected a decrease in trunk position and movement from an average level 2 (trunk forward over base) to an average level 1 (trunk behind base) during
the non-cognitive load trial corresponding with the clinical differences seen in the ‘Pelvic Girdle Position’ during the third non-cognitive load and cognitive load conditions as sitting with a posterior pelvic tilt results in the centre of mass moving behind the base of support (Figure 4.8).

No statistical or clinical differences were seen within Group B although greater use of trunk rotation within base was seen in the cognitive load trials.

![Graph showing the mean raw score for Group A (n=21) and Group B (n=14) for different conditions](image)

**Figure 4.8 Effect of non-cognitive load and cognitive load on Trunk Position and Movement**

### 4.4.2.5 Activities

Statistically significant (p ≤ 0.01) and clinical differences (p=0.06) were noted when conducting several of the comparisons of the results of the activities component of the Modified Chailey Levels of Sitting Ability.

In Group A there were statistically significant differences between non-cognitive load trial 2 and cognitive load trial 2 at 5 minutes and (p ≤ 0.01) and non-cognitive load trial 3 and cognitive load trial 3 at 10 minutes (p ≤ 0.01).
A clinical difference was found when comparing the baseline to the non-cognitive load 3 at 10 minutes (p=0.06) as well as between the non-cognitive load trial 1 and cognitive load trial 1 at 1 minute (p=0.06) in Group A.

Group B showed a clinical difference in the non-cognitive load 2 and cognitive load 2 measurement at 5 minutes (p=0.07).

The one way ANOVA showed a statistically significant difference in Group A but not Group B when comparing the baseline score to the dual task conditions in this study (p=0.01).

The more significant differences seen during the non-cognitive load conditions are linked to the demands of the activity not requiring bilateral integration and midline crossing and therefore the use of this skill was not employed by the participants. This was particularly true for Group A who tended to neglect the non-preferred hand down to the side or prop the head during the non-cognitive load task. As demands on bilateral integration and midline crossing increased so do the mean scores during the cognitive load task (Figure 4.9).
4.4.2.6 Overall Modified Chailey Level of Sitting Ability

Figure 4.10 below depicts the adjusted overall scores on the Modified Chailey Level of Sitting Ability in children with and without postural control difficulties.

Although overall scores are usually based on the lowest scores obtained in all components, which in this study were for ‘Trunk Position and Movement’, the lowest score second to this component are presented here as the overall score due to the lack of sensitivity found for that particular component item.

Statistically significant results were obtained when comparing Group A non-cognitive load trial 1 and cognitive load trial 1 at 1 minute (p=0.02). The baseline score was clinically different in Group A in comparison to the non-cognitive and cognitive load trials (p=0.07) using the one way ANOVA.

There were no significant differences in Group B for the overall scores when comparing non-cognitive and cognitive load trials. Nor was there a significant difference on the one way ANOVA (p=0.44) comparing baseline to the dual task conditions.

![Figure 4.10 Effect of non-cognitive load and cognitive load on Overall Score – trunk position and movement omitted](image-url)
Clinically it can be observed that Group A has greater difference between the posture scores for non-cognitive load and cognitive load trials when compared to the baseline than Group B.

4.5 Summary of Results

The null hypothesis that states ‘that there is no difference between participants with and without postural control problems, when observed sitting at a desk, engaged in non-cognitive and cognitive load situations’ has been accepted in this study.

No statistically significant differences between the groups were noted except for the activities component in the Modified Chailey Level of Sitting Ability assessment during the non-cognitive load trials 1 and 2 and in the overall non-cognitive load trial 2. Except for the overall scores there was no consistent pattern of lower scores occurring in Group A.

When the effect of cognitive load on posture was analysed the null hypothesis had to be accepted. There were however some statistically significant changes for Group A sitting posture for ‘Spinal Profile’, ‘Head Alignment’, ‘Activities’ and the overall Modified Chailey Level of Sitting Ability scores in Group A.

In Group B statistically significant differences were found in ‘Spinal Profile’ and ‘Head Alignment’ when comparing non-cognitive load and cognitive load trials. Non significant clinical differences were noted however when comparing the effect of cognitive load on sitting ability in comparison to the baseline assessment as well as between non-cognitive load and cognitive load trials in all components.

Clinically it was noted that the Modified Chailey Level of Sitting Ability scores were lower for non-cognitive load trials indicating posture was better during the cognitive
load trials. The changes seen over time at 1, 5 and 10 minutes indicated no set pattern for either Group.
CHAPTER 5
DISCUSSION

This study aimed to determine whether or not cognitive load has an effect on the postural control of children when sitting and further whether this effect, if any, is the same in children identified with postural control difficulties and those typically developing children without postural control difficulties. This study was unlike previous studies [5, 23-26] of its kind in that the participants were assessed in a seated position and the cognitive load activity was more purposeful and over a longer duration than those reported in the literature, thus was relevant to the philosophy of occupational therapy.

5.1 Demographics

The participants in this study were both male and female children, ranging in age from 6 years 0 months (grade 0) to 9 years 11 months (grade 4). The participants in Group A comprised those children currently receiving occupational therapy intervention for poor postural control. These children were either being seen by the researcher or the other therapists in the same practice while those in Group B presented with no postural control difficulties. A limitation of the study was the small number of participants that were recruited for both Group A (n=21) and Group B (n=14). Finding participants for Group B was difficult as these children were not receiving intervention and a limited response was gained from the invitations sent out to the parents through a number of schools. There was therefore a reduction in group size to less than the 45 per group recommended by the statistician.

Although there were no dropouts in the study the small sample size could have resulted in a Type II measurement error, meaning that the null hypothesis may be mistakenly accepted when in fact it should have been rejected [78]. The type of sampling used and the sample size may also have influenced both the external validity of the study and its generality, as well as the internal validity in terms of the significance of the results and emergence of trends.
There were no statistically significant differences in the distribution of gender, and current grade at school between Group A and B although participants in Group B were significantly older than those in Group A. The groups were considered comparable however because the DTVP-2 and COMPS assessments used in the study are adjusted for age [6, 7] and the Modified Chailey Levels of Sitting Ability is performance related not age related [64].

5.2 Assessment of Sitting Posture

The first objective of the study was to establish if there were differences in the postural control, when seated, of children with and without identified postural control problems.

Desk sitting is the posture that is most frequently required in the classroom. As such the assessment of sitting posture was carried out while seated at a desk. This was considered important as the literature shows that children with poor postural control and other motor difficulties such as DCD have poorer academic achievement [3, 11]. The achievement of the skills, required for academia, include writing, cutting and colouring, all of which are desk based, and these fine motor skills are often poorer in children with DCD [9-11, 13]. It has further been shown that children with DCD often present with secondary problems such as low self esteem, poor social competence and behavioural problems linked to their poor motor skills and resultant academic performance difficulties [32]. These secondary problems can further negatively impact on academic performance through decreased motivation to engage in desk bound tasks. In addition education has been found to be the most common area of shared concern in children with DCD, their parents and teachers [11]. It was therefore relevant to assess postural control when sitting at a desk as this posture is important in academic learning and skill development.

Since no standardised assessment for postural control is available for children with DCD the Chailey Levels of Postural Ability Assessment Charts for Box Sitting, from the Chailey Approach to Postural Management, was chosen to be used in this study. These levels of postural ability are a non norm referenced assessment.
that is recognised as a ‘reliable and accurate measure for clinical and research purposes’ ([64] pg 21). These levels were however originally designed to assess children with neurological impairment [64]. The box sitting charts were chosen as they were the closest to chair sitting which was the position used in the study. This assessment was however modified for the use with children with postural control difficulties with the intention that differences between children with and without postural control difficulties would be noticeable in the overall level of sitting ability. The modified criterion for measuring sitting ability was designed from the literature regarding postural control and motor co-ordination, for use in this study only. The modifications that were made to the assessment were based on current knowledge regarding the development of postural control within the neurodevelopmental and sensory integration occupational therapy frameworks.

The Modified Chailey Levels of Sitting Ability assessment was then piloted, to establish content validity, on children with postural control difficulties. The assessment was not piloted on children without postural control difficulties and this resulted in a limitation to the study in that the assessment was not sensitive enough to detect a significant difference between the two groups of children. In addition the pilot study sessions were not videoed and therefore the difficulties with the camera position were not identified. The assumption that children without postural control difficulties would score a Level 7, at the top of the range for all components of posture, was incorrect and they often scored within the same range as children without postural control problems. Clinical differences were noted between the groups however with the majority of scores for the children with postural control problems being slightly lower than those without as was expected.

When considering the various components of posture assessed the majority of the participants achieved a full score of 7 for ‘Load-bearing’ and ‘Shoulder Girdle Position’. These aspects of the Modified Chailey Levels of Sitting Ability assessment indicated there were no differences for these components in children with and without postural control difficulties.
The scores obtained for ‘Load-bearing’ in Group A and Group B were a level 7 for all participants during all conditions. This indicates that children with and without postural control difficulties load weight bearing on their buttocks and posterior aspect of their legs which is expected in chair or box sitting [63, 64]. Similarly most participants, bar 6 out of the 147 measurements for Group A and 3 out of the 98 Group B measurements, presented with protracted shoulders versus neutral or retracted shoulders which is considered necessary for a good sitting posture [63, 64]. Thus it can be concluded that these aspects are not commonly a problem in either group when seated in a chair.

An additional criterion had been added to the original ‘Hip Position’ item as children with poor antigravity postures make use of hip internal rotation (‘W’ sitting)[65, 83, 84]. This was not accounted for in the original Chailey Levels of Postural Ability. This component could not be used in the analysis of differences between groups or cognitive load conditions and was removed from the overall score due to the position of the camera in the setting up of the research venue resulting in difficulty assessing this component item.

When evaluating the pelvic girdle assessment a change was made to clarify the ‘Pelvic Girdle Position’ item. According to the Chailey manual sacral sitting indicates a difficulty with postural control [64, 82]. An error occurred in this modification in that sacral sitting with a posteriorly tilted pelvis ranked higher than a neutral pelvis and this had to be rectified after the pilot study before assessment could take place. The scoring of this component therefore needed to be changed as when sitting in a chair at a desk it is more desirable for a child to have a neutral pelvis than a posteriorly tilted pelvis. When a child sits with a posterior pelvic tilt, which is common in children with postural control difficulties [64], their centre of gravity is shifted from through the ischial tuberosities to behind them and their centre of gravity is often moved to behind the base of support which is common when leaning into the back of the chair. This error was picked up and corrected before the analysis of the assessment and therefore did not influence the outcomes of the study.
The ‘Pelvic Girdle Position’ (Table 4.1) component was not scored in several cases due to difficulty with the camera angle and therefore the results for this component are not as reliable as other results in this study. The overall scores for both groups averaged a level 5 for all conditions assessed indicating a posterior pelvic tilt [82]. A posterior pelvic tilt is frequently seen in children with postural control difficulties due to their difficulty stabilising the pelvic girdle against gravity as a result of low postural tone [16, 65]. This was also present to nearly the same extent in children without postural control difficulties, who scored lower than their baseline in all three measurements but most noticeably at the 5 minute measurement during the non-cognitive load trial than those with postural control difficulties. Analysis of the differences in performance, according to the scores obtained, showed that children with postural control difficulties made use of more postural background movements and therefore had a less stable pelvis than the participants in Group B without postural control difficulties. As a result Group A employed more fixation of the pelvic girdle although this was unsuccessful in correcting the position of the girdle.

The scores found for ‘Spinal Profile’ (Table 4.2) between the groups varied with only the scores in the cognitive load trials being consistently higher for Group B. There was no clinical or statistically significant difference between the groups for this component as both groups sat with rounded spines while doing the activities. The average raw score for both groups ‘Spinal Profile’ baseline and cognitive load measurements was level 6 and above indicating an upright spinal profile which is expected when sitting [63] while the average raw score for both groups non-cognitive load measurements was a level 5, rounded spinal profile, showing that regardless of a child’s postural control ability a child sits with a more upright posture when concentrating on a cognitively demanding activity than when simply listening to a story. The rounded spinal profile in Group A is consistent with the more persistent posterior pelvic tilt with time seen in the same group of children, this is trend consistent with knowledge that a rounded spinal profile and posterior pelvic tilt are commonly seen in children with low postural tone [16, 65] and resultant poor postural control.
The item ‘Chin Position’ was removed and ‘Head Alignment’ added in the Modified Chailey Levels of Sitting Ability assessment as many children with poor postural control have difficulty with crossing the midline and as a result develop many ways, including holding head away from the midline, to avoid midline crossing [65]. Further those with low muscle tone and difficulty maintaining antigravity positions often support their head on their hands [65] indicating poor head stabilisation which is an important aspect of antigravity control. The limitation in the study in this component item occurred in the setting up of the camera in the research venue as often the exact head position could not be ascertained and as a result this item had to be omitted in several of the participants’ assessments.

All participants in Group B scored slightly higher than those in Group A for ‘Head Alignment’ except for the second non-cognitive load measurement (Table 4.3). All scores fell into the range of 6, excluding Group A’s third non-cognitive load score, and there was no significant difference between the groups. Group B participants tended to move their head in and out of the midline voluntarily, particularly during the cognitive load task, whereas Group A participants head was consistently away from the midline. During the non-cognitive load task many of the children in Group A were observed to rest their heads resting on their hands (mainly the non-preferred hand) during the 10 minute non-cognitive load trial further indicating poor head stabilisation. This observed trend was however not reflected in the levels achieved due to the dynamic nature of posture.

The level scoring on the ‘Trunk Position and Movement’ item (Table 4.4) was slightly altered to differentiate between those children with poor righting and equilibrium reactions, i.e. poor postural control [65], and those without. This aspect of the assessment was not appropriate for use in this study as the children were seated at a desk carrying out purposeful activity which is important in the Model of Human Occupation which is important in the field of occupational therapy [4] as well as mimicking the classroom environment. The difficulty with this aspect of the assessment was not the levels of ability but the use of them in this study as no opportunity for trunk rotation, movement or recovery of balance was afforded to the participants, due to the structuring of the activity including the position of the...
puzzle pieces next to the board, and therefore they all scored relatively low on this component and this impacted on the overall score of the assessment.

Again there was no significant difference in the scores between Group A and B with the mean Trunk Position and Movement scores indicating very similar levels with an average score around 1, trunk behind base, and 2, trunk forward over base (Table 4.4).

Thus ‘Pelvic Girdle Position’, ‘Spinal Profile’, ‘Head Alignment’ and ‘Trunk Position and Movement’, are components that do not differentiate between the posture of children with and without postural control problems when measured on the Modified Chailey Levels of Sitting Ability assessment.

The only component which showed some significant difference between group A and B was the ‘Activities’ item (Table 4.5). The final modification to the Chailey Levels of Postural Ability was to the ‘Activities’ component. This component was significantly altered as the original assessment was designed for children with severe motor difficulties and thus the height to which that population of children can raise their arms during activity without disturbing sitting posture is important [64]. Children with postural control difficulties without neurological deficits do not have the same difficulty raising their arms but rather have difficulty with developing bilateral integration and crossing of the midline [65, 85]. Children with postural control difficulties are inclined to move their trunk to the side to accommodate the lack of midline crossing. These were therefore more important aspects to be included in the assessment and as significant differences were obtained the changes to the assessment were effective in measuring postural control.

The set up of the study however, as with ‘Trunk Position and Movement’, did not allow for the full use of this component. In the assessment the puzzle pieces during the cognitive load condition were placed on both the left and right of the puzzle and this did not allow for the accurate assessment of midline crossing and participants in both groups tended to score below level 7 as a result. There was however a significant difference between the groups in the non-cognitive load
condition and the participants in Group A scored lower than those in Group B. Most of the differences seen were due to the children with postural control difficulties either having their non-preferred hand down to the side or propping their head both of which prevent the use of and indicate the delayed development of bilateral integration. Group A exhibited more postural background movements than Group B which further indicates poor postural control. In addition children in Group A had more difficulty concentrating cognitive load tasks, noted in the number of puzzle levels completed, further impacting on their engagement in the task presented. This is consistent with the literature showing the link between ADHD and motor co-ordination difficulties [30].

The overall Modified Chailey Levels of Sitting Ability scores between Group A and B (Table 4.6) were low as the assessment requires that they are based on the lowest scores obtained, in this case for ‘Trunk Position and Movement’. Thus the overall Modified Chailey level of Sitting Ability was greatly influenced by the low scores achieved in the ‘Trunk Position and Movement’ component Group. These scores were low due to the participants’ trunk being forward over their base of support at the time of measurement during both the cognitive load and non-cognitive load trials. This posture is however appropriate, particularly during the cognitive load condition as the children were seated at a desk carrying out a problem solving activity [63, 64]. This component item was therefore removed from the overall score and this resulted in the average overall baseline score of level 4 in Group A and level 5 in Group B. Although these scores remain lower than the anticipated level 5 in Group A and level 7 in Group B they are closer to the expected level of performance than the Level 2 for Group A and level 3 for Group B obtained when ‘Trunk Position and Movement’ was included.

The results indicate that both groups of children had a less than ideal posture with all aspects of the sitting posture assessment, namely sitting with a posterior pelvic tilt; a rounded spinal profile; head not in the midline; and excess postural background movements as well as poor bilateral integration and midline crossing, being evident. The overall score did however indicate a difference of one level between Group A and B with all scores for Group A being lower. This was clinically
indicative of their poor postural control but no component other than ‘Activities’ could be considered to contribute clearly to the difference between the two groups.

Most of Group A scores were lower than Group B scores at baseline in both non-cognitive load and cognitive load conditions. As Group A participants have identified postural control difficulties that are currently being treated by an occupational therapist this lower overall score was consistent with expectations.

It had been assumed that the assessment would allow participants without postural control difficulties to score a level 7 throughout the study. This was affected however by placing the participants in a chair at a desk which restricted certain movements in sitting and required postures that did not reflect a 7 for all components.

The major limitations of this study were a lack of a pilot study on a group of children without postural control difficulties and the scoring of the videos only at the end of the study. These two factors meant that the realisation of the limitations of the items on the Modified Chailey Levels of Sitting Ability in terms of sitting in a chair at a desk were not addressed and the problems with scoring from the video due to the camera position were not realised. It became clear that the participants should have also been observed and an assessment completed in situ when evaluating posture in the study. This could then have been checked against the video recordings and there would have been no missing values in the data.

The Modified Chailey Levels of Sitting Ability also need further evaluation as most components indicate little difference between the posture of Group A and B. Thus the items and scoring on the assessment indicate a lack of discrimination when comparing the sitting posture of participants with and without postural control difficulties. The assessment needs further modification and testing, with clearer more sensitive scoring if it is to be used clinically with children with DCD and other postural control difficulties.
5.3 Effect of Cognitive Load on Postural Control

The second objective of the study was to establish the effect of cognitive load on the sitting posture in children identified with and without postural control problems.

As a dual task paradigm has been proven to be a sensitive measure of the effect of tasks on postural or cognitive performance, this approach was selected for use in this study. This technique involves the participant performing the postural and cognitive tasks concurrently and any changes in performance are measured [5, 23, 26]. Within the context of this study the cognitive load condition was a problem solving activity with several levels of difficulty while the non-cognitive load activity was listening to a story of their choice with a read along book.

A clear trend emerged in this study with the overall scores on the Modified Chailey Levels of Sitting Ability being higher for both groups in the cognitive load conditions than non-cognitive load. In addition the non-cognitive load scores were lower than the baseline and cognitive load scores (Table 4.6). This indicated an overall improvement in postural control ability in sitting when engaged in a cognitively challenging task. This result has also been noted by some researchers in adults and children when standing [24, 43]. As discussed above, Group A had lower overall scores for both the cognitive and non-cognitive conditions than Group B (Table 4.6) indicating slightly worse postural control in both conditions. Clinically there was a difference in Group A’s scores comparing baseline to the dual task conditions indicating a positive impact of cognitive load on postural control in children with identified postural control difficulties.

Group A consistently presented with lower scores for the non-cognitive load trials than their baseline scores – a trend not seen in Group B with the exception of the pelvic girdle scores. Thus for the majority of cognitive load conditions the scores on the Modified Chailey Levels of Sitting Ability were better than or equal to those at baseline for both groups.

When considering the mean overall Modified Chailey Levels of Sitting Ability, scores during the non-cognitive load trials in Group A increased with time, showing
an overall improvement in sitting posture. The opposite was true for Group B. This result while not significant is clinically interesting as participants in Group A presented with low postural tone, as is common in children with postural control difficulties [65], and initially had poorer postural control in sitting. However with time the use of postural background movements allowed them to generate sufficient postural tone [65] to afford a noticeably improved sitting posture although their posture was still minimally worse than the children without postural control difficulties. In addition to the use of postural background movements these children employed progressively more fixation around the pelvic girdle to allow the maintenance of the ‘Pelvic Girdle Position’ for the first 5 minutes (Figure 4.5). With additional time however fatigue of the muscles around the pelvic girdle, through the effort required for fixation, appeared to result in a slight decrease in ‘Pelvic Girdle Position’ although this did not have an overall effect on the level of sitting ability achieved. The improvement in postural control as a result of the observed postural background movements supports current trends in occupational therapy intervention making use of gross motor activities that provide vestibular and proprioceptive stimulation [39, 83], which is provided in a lesser degree through the postural background movements, to improve postural tone and therefore postural control. In addition the fixation seen around the pelvic girdle indicates that provision within therapy to provide stability to the major joints and girdles allows for greater mobility and control of the rest of the body, therefore allowing greater success in the task at hand. This supports the theory of postural control development [16] as well as the current thinking that success in a task is intrinsically motivating particularly for children with DCD who often have low self esteem due to their motor co-ordination difficulties [11, 25].

In Group A the mean overall Modified Chailey Levels of Sitting Ability scores during the cognitive load conditions decreased from the 1st to 5th minutes but showed an overall increase at 10 minutes (Figure 4.10). All the scores for cognitive load were above those assessed at baseline. In Group B scores for the cognitive condition returned to a baseline level and were fairly consistent with only the score at 1 minute being slightly lower. The overall improvement on postural control in sitting with the addition of the cognitive load activity implies that
occupational therapy intervention should include a cognitive activity in the
treatment of postural control in static positions; this is in agreement with the
recommendations and findings by Blanchard et al (2005) [43].

The lower average non-cognitive load condition scores when compared to the
cognitive load condition and baseline scores in both groups is consistent with
knowledge regarding the development of antigravity control. This effect was also
seen in Blanchard’s 2005 study of typically developing children whose postural
sway decreased at the start of the trial but through the practice effect the
participants no longer required the fixating of the degrees of freedom and their
postural sway increased again [43]. Thus the participants in this study were
restricting the degrees of freedom of movement to improve postural control when
placed in a novel or challenging position [5, 24, 29]. This principle can be applied
to this study as the non-cognitive load task was not demanding enough to require
the reduction of the degrees of freedom while the cognitive load task did. In
addition the cognitive load task became progressively more challenging as the
participants moved through the problem solving puzzles and therefore the need to
restrict the degrees of freedom continued.

When considering Group A it is important to note the significant difference in the
performance between the first non-cognitive and cognitive load trials as well as a
fluctuation in postural ability during the cognitive load trials over time (Figure 4.10)
This decrease in performance during the cognitive load trials is consistent with the
limited capacity theory in that posture decreases as the cognitive load increases
[26, 30, 41, 43] as the complexity of the problem solving activity increased with
time as the child progressed through the puzzles. In Group A the Modified Chailey
Levels of Sitting Ability scores increased again after 5 minutes indicating this is not
a consistent state and that they responded by decreasing degrees of freedom at
10 minutes. This fluctuation in posture may indicate problems with postural control
through the use of postural background movements as well as fatigue. Children
with postural control difficulties tend to have inconsistent postural maintenance in
static postures such as sitting, as assessed in this study, due to their difficulties
processing vestibular and proprioceptive input and low postural tone as described in the literature [14, 15, 42, 49, 50].

It is interesting to note that the same level of decrease in the Modified Chailey Levels of Sitting Ability scores with time was not seen in Group B, the typical postural control group. This group showed an increase in postural ability during the cognitive load condition in comparison to the baseline score in the first measurement and the final two measurements were equal to the baseline score (Table 4.6). This shows that a typically developing child’s postural control is not affected by cognitive load in the same way as those children with postural control difficulties. The changes in the performance in Group B can be explained by the ‘Constrained Action Hypothesis’ (McNevin & Wulf, 2002 and Riley et al, 2005) which views the positive changes in postural control under dual task conditions as a result of the change of focus of attention from postural control to the cognitive task. Thus there is an improvement in postural control as attention on motor performance may interfere with the desired motor output [5, 24] as seen in this study. The alternative explanation would be the restriction of the degrees of freedom [43] as previously described.

The effects of cognitive load and dual task interference on postural control have been studied by various authors and the results have been inconsistent. Several authors have found that cognitive load has a positive effect on postural control and a decrease in postural sway [5, 24, 29, 30] while others have reported a decline in postural control as the result of dual task interference [24, 26, 28, 29]. There are several hypothesis set out in the literature to explain the dual task effect on postural control namely the action oriented hypothesis [5, 26], limited capacity theory [26] and the constrained action hypothesis [24]. This study has shown a general improvement in postural control in sitting in children with and without postural control difficulties during the cognitive load condition for all aspects analysed but little difference was found between the two groups. The overall results of this study support the ‘Constrained Action Hypothesis’.
When considering differences in the components of posture assessed by the Modified Chailey Levels of Sitting Ability, results for the ‘Pelvic Girdle Position’ item in the non-cognitive load condition reflected the typical pattern seen in this study with the scores for both groups being lower than their baseline scores (Figure 4.5). Group A slowly developed more posterior pelvic tilt over time. The participants in Group B on the other hand had corrected their posterior pelvic tilt which scored even lower than Group A at 5 minutes, by the last assessment at 10 minutes. The higher Group A scores may be due to restriction of the degrees of freedom in the lower trunk and pelvis due to their poor postural control [17, 18] whereas their peers without postural control difficulties did not make use of this strategy. In addition postural adjustments [16] of the participants, which occur in all children and adults when maintaining a static posture, at the time of recording the score may have impacted on the scoring. Therefore future studies may benefit from assessing participants sitting ability over a period of time rather than at a set freeze frame to allow for these naturally occurring postural movements thereby improving the results.

The significant difference seen in Group B for non-cognitive and cognitive load conditions for ‘Pelvic Girdle Position’ at 5 minutes appears to indicate that the differences in Group A are not as great and that cognitive load may have a different effect on the posture of participants without postural control difficulties than those with. Schmid et al’s 2007 study of typically developing 9 year olds showed that postural sway in standing increased in velocity and distance with the addition of a cognitive activity [5] which is consistent with the results of the ‘Pelvic Girdle Position’ at 5 minutes in Group B. The 2007 study however did not compare the differences in response between typically developing children and those with postural control difficulties and therefore the results need to be interpreted with caution with regards to the current study.

While both groups indicated an improvement in posture with a decrease in pelvic tilt as the cognitive trials progressed (Table 4.1) the score for Group A was better than that achieved at baseline while those for Group B were not. Both groups demonstrated similar findings to those for the overall results with the highest
scores on the Modified Chailey Levels of Sitting Ability occurring at 10 minutes. This finding was also true for the ‘Head Alignment’ (Figure 4.7) component further confirming the ‘Constrained Action Hypothesis’ for the components of ‘Pelvic Girdle Position’ and ‘Head Alignment’. This was particularly true for Group A where posture improved over the three cognitive trials. A possible reason for this finding is the restriction of degrees of freedom due to low postural tone as previously discussed.

The most significant differences were seen when comparing the Modified Chailey Levels of Sitting Ability scores for the ‘Spinal Profile’ within each group. In the non-cognitive load trials (Figure 4.6) Group A started with a rounded spine, straightened up at 5 minutes and then returned to the position seen initially at the 10 minute assessment. This group showed a significant difference between the baseline and non-cognitive load trial 1 showing an overall decrease in postural control during single task conditions. Statistically there was an overall positive effect of cognitive load on Group A’s ‘Spinal Profile’ scores when compared to the baseline while the difference in Group B was only clinical. This once again indicates that the effect of cognitive load on postural control is different between the two groups.

This pattern of higher posture scores at 5 minutes in the non-cognitive load condition was also seen in the ‘Trunk Position and Movement’ (Figure 4.8) ‘Head Alignment’ (Figure 4.7) and ‘Activities’ (Figure 4.9) for Group A. This finding appears to indicate that children with poor postural control are aware of their postural problems and deviation at 1 minute when in non-cognitive load conditions and they attempt to correct these by the 5 minute trial. They however do not achieve their baseline position and by 10 minutes their posture has decreased to worse than the original inadequate posture.

The change for ‘Trunk Position and Movement’ reflected a decrease in trunk position and movement from an average level 2 (trunk forward over base) to an average level 1 (trunk behind base) during the non-cognitive load trial. This corresponds with the clinical differences seen in the ‘Pelvic Girdle Position’ during
the non-cognitive load conditions as sitting with a posterior pelvic tilt results in the centre of mass moving behind the base of support. All these findings may be related to poor postural control where low postural tone results in a problem in maintaining antigravity positions and proximal stability [16].

The opposite pattern was seen in the non-cognitive load condition for Group B, who presented with the same pattern as described for their pelvic girdle component with lower scores at 5 minutes. This indicates a difference in the response between Group A and B in postural control in non-cognitive load activities. Group B had a similar finding for the ‘Trunk Position and Movement’ component, as in the ‘Spinal Profile’ where participants achieved levels the same as the baseline in the 10 minute trial for non-cognitive load conditions. The decrease at 5 minutes indicates movement of the trunk backward behind the base towards a posterior pelvic tilt although the mean scores did not reach a Level 1. Sitting with centre of gravity forward over the base of support while working at a desk is the expected posture [63] however the movement towards the centre of gravity behind the base of support, particularly in the non-cognitive load condition indicates that while listening to the story the participants without postural control difficulties maintained a more upright posture and made less use of the back rest on the chair than those with postural control difficulties.

The results during the cognitive load conditions for ‘Spinal Profile’ (Figure 4.6) and ‘Trunk Position and Movement’ (Figure 4.8) however indicated that both groups achieved the lowest scores in trial 3. Although both groups showed an initial improvement they returned to their baseline level of sitting ability with regards to ‘Trunk Position and Movement’. Group A’s ‘Spinal Profile’ scores also returned to baseline. The trend seen indicates that on these component groups improved by the second measurement in Group A. They were unable to maintain the improvement for the full trial and their poor postural control resulted in a return to the baseline level of sitting ability.

Group B however showed an initial improvement in ‘Trunk Position and Movement’ at the start of the trial but this steadily decreased back to the baseline score. The
trend seen in the ‘Spinal Profile’ for Group B was a gradual improvement in the first 5 minutes of the trial and then a decline resulting in a more rounded spinal profile towards the end of the condition, which is consistent with the pelvic girdle position. This decline was however not as low as the baseline scores, indicating an overall improvement in ‘Spinal Profile’ in children without postural control difficulties.

The results for Group B continue to support the ‘Constrained Action Hypothesis’ because the values for the cognitive load condition were better than for the non-cognitive load condition. The initial response in Group A supports the ‘Constrained Action Hypothesis’, however the progressive increase in complexity of the puzzles in this study may have resulted in the demands of the dual task exceeding their central processing resources with time. The ‘Limited Capacity’ theory which states that posture decreases as the cognitive load increases [26, 30, 41, 43] would then be applicable, towards the end of the trial, resulting in increased used of fixation of the degrees of freedom to release resources from maintaining posture to completing the cognitive task.

Group B showed a consistent decrease in postural control for ‘Head Alignment’ (Figure 4.7) and ‘Activities’ (Figure 4.9) in the non-cognitive load conditions and unlike Group A they made no attempt to correct this posture in the 10 minute trial period.

Even so ‘Head Alignment’ for participants in Group B’s baseline and trial 1 scores were higher than Group A showing that children with postural control difficulties have more difficulty keeping their head in the midline and do not achieve this position even at the onset of activity (1 minute). The decrease in head alignment is clinically relevant even though the results were not statistically significant and this indicates that both groups of children have difficulty with antigravity control [16] during non-cognitive load tasks. This is especially true at 10 minutes after maintaining the static posture for the extended period of time.
‘Head Alignment’ however improved in both groups during the cognitive trials (Figure 4.7). This supports the statement that head stabilisation during more challenging tasks is thought to be developed in 7-8 year olds [16, 17]. Group A started with a lower score for head alignment than Group B in the cognitive load condition but both achieved a similar level by 10 minutes. Group B however presented with a statistical difference when comparing baseline scores to the dual task conditions once again indicating the positive effect that cognitive load has on postural control in this group. This increase in head alignment with time is again consistent with the practice effect found in Blanchard et al’s 2005 study due to the restriction of the degrees of freedom [43]. It appears that Group A needs more time to achieve the upright position.

The ‘Activities’ (Figure 4.9) component of the Modified Chailey Levels of Sitting Ability consisted of the following items: propping to balance (level 3), excess postural background movements (level 4), poor bilateral integration (level 5), bilateral integration with no midline crossing (level 6) and bilateral integration with midline crossing (level 7). Group A scored considerably lower than Group B in the non-cognitive load trials in this component (Table 4.5). This was to be expected as children with postural control difficulties typically have difficulty with bilateral integration and midline crossing [65, 85] and this is seen most profoundly when these skills are not integral to the task at hand. In most cases during the non-cognitive load activity the participants in Group A had their non preferred hand hanging down to the side or propping their head. Those in Group B however had the non preferred hand supporting the book or resting on the table showing greater awareness of both sides of the body and integration between the two hemispheres.

Little difference was found in the cognitive load conditions between the Group A and B for the ‘Activities’ component (Table 4.5, Figure 4.9). This however may be the result of the set up of the activity with puzzle pieces placed on both sides of the board as this may have encouraged increased use of bilateral integration due to the lack of midline crossing in the children with postural control difficulties.
Future studies should address this through placing all pieces at the top centre of the board to ensure that this limitation does not occur.

A general observation that participants in Group A had more difficulty concentrating on the story and following in the book was made during the study. This is consistent with the findings that children with DCD often have co-morbid concentration difficulties and/or ADHD [8, 9, 30]. In addition this group was observed throughout the 10 minute trial to make use of more postural background movements, as seen through the change in level achieved, in an attempt to maintain postural control [16, 65] and this was exacerbated by their poor concentration, which is typical in this population of children [9, 13].

Observations of both groups throughout the cognitive load condition showed that although postural background movements decreased in Group A, likely due to restriction of degrees of freedom [17, 18, 43, 65] which is consistent with the ‘Constrained Action Hypothesis’ [24], their concentration did not waver as obviously as during the non-cognitive load condition. They did not however progress through the puzzles as well as their peers in Group B.

The ‘Activities’ scores for Group B increased from minute 1 to 5 and then plateaued until the 10th minute. This group’s use of bilateral integration and midline crossing increased with time as they progressed through the cognitive load task. They were observed to concentrate adequately and their motivation to engage in the task, seen through their wish to carry on with the task, was greater than their peers in Group A.

The difference found in postural control as measured by the Modified Chailey Levels of Sitting Ability in this study between the non-cognitive load and cognitive load conditions support the ‘Constrained Action Hypothesis’ in the overall findings and those for ‘Pelvic Girdle Position’, ‘Head Alignment’ and ‘Activities’. Only the findings for the components of ‘Spinal Profile’ and ‘Trunk Position and Movement’ indicated a decrease in posture in the 10 minute trial for the cognitive load conditions supporting the ‘Limited Capacity Theory’ as there is a decrease in
posture with an increase in cognitive task. The small sample may have affected these findings and these contradictions must be interpreted with care.

The starting point for the cognitive load activity was determined by the participant’s age and GVP on the DTVP-2 assessment. The literature shows evidence that the impact of cognitive load is related to the challenge presented by the cognitive activity. An activity of too low a cognitive load will not challenge the body’s postural and/or cognitive resources sufficiently to be considered a dual task effect [23, 29]. This is also important in the context of the ages of the participants as the mean age for Group B was older than Group A. By making use of the DTVP-2 scores it was possible to grade the challenge of the puzzle according to the child’s perceptual ability to ensure a just right challenge to allow for a dual task effect [23, 26] as well as being in line with sensory integration and occupational therapy theory [72].

The cognitive challenge presented in this study was considered successful as all participants managed to move through several puzzles with minimal assistance from the researcher to solve the problem. Although not formally assessed, Group B appeared to move through more puzzle levels than Group A within the 10 minute time limit. This is likely due to the difficulty with concentration and academic performance of Group A which is a common feature of DCD [8, 9, 30]. In addition participants in Group A presented with lower GVP’s which further impact their ability to carry out the task (Figure 4.4). This may however also be related to the possible effect of their postural control on their concentration span [30], which is based on the ‘Posture First Principle’ as described by Pellecchia (2003) [26]. She states that a decrease in cognitive performance takes place during dual task conditions as the primary resources are used to maintain posture. This statement does not seem to agree with the ‘Constrained Action Hypothesis’ previously accepted in this study. The reasoning for this is that as participants in Group A became more challenged by the progressively more complex puzzles their focus shifted back to the maintenance of the gross motor condition rather than task performance. Therefore the use of the ‘Constrained Action Hypothesis’ is possibly replaced by the ‘Posture First Principle’ with the passing of time in children with
postural control difficulties as the cognitive challenge increases beyond the child’s available central processing resources. The limitation to applying this principle to the results of this study are that the participants’ cognitive performance during the cognitive load task was not measured formally and they were not given any instructions regarding maintaining an upright sitting posture.

Previous studies have consistently used short, non functional cognitive load tasks, such as rote counting backwards or colour identification, as the dual task activity [5, 24, 26]. These activities are not considered adequate for use in occupational therapy and the models supporting the philosophy of the profession. It is accepted in occupational therapy that purposeful activity, presenting the just right challenge, is essential to elicit performance in activities of daily living, including personal management, work or leisure [4, 36]. It is therefore relevant for occupational therapy research to employ similar activities.

This study made use of dual task conditions that lasted for 10 minutes in comparison to the 20-60 second trials in the literature [5, 23, 24, 26, 29, 43], as concentration in the classroom and therapy environment is required to be maintained for longer periods of time. In addition the study was carried out sitting at a desk as this is the most commonly used posture in the classroom for the development of academic skills. The use of a longer term and more functional activity may account for the findings being inconsistent with the literature and that are varied according to the application of the hypothesis presented by the various authors.

The need to maintain the sitting posture for a longer period of time results in more interference of postural background movements, which are a normal part of postural control [16, 65], but are not relevant to studies in which the participant is only required to maintain a stable posture for a minute or less. In addition the children in this study were not instructed to maintain a stable posture. Therefore assessment of postural sway, which is less in sitting versus standing due to the larger base of support load-bearing through the buttocks and thighs versus the feet [25, 42], was not relevant to the study. Postural background movements were
employed to maintain the dynamic antigravity position and postural sway is most commonly seen when maintaining stable postures. The changes in postural sway noted in the literature were interpreted as changes in postural control and were assessed as such in this study.

5.4 Summary

This study has shown that the addition of a cognitively demanding activity that presents the just right challenge has an effect on the postural control of children with and without postural control difficulties. The study was however unable to adequately identify significant differences between the two sample groups, nor the impact of the dual task (i.e. non-cognitive and cognitive load conditions) between the groups, due to the limitations with the modified assessment.

A trend did however emerge that indicated that Group B scored better on most components as well as the overall scores when assessed using the Modified Chailey Levels of Sitting Ability. In both groups scores were higher for the cognitive load condition.

These findings lend support to the ‘Constrained Action Hypothesis’ [24] showing that as the cognitive load increases the child’s attention is directed away from maintaining their posture to participation in the task at hand. As a result of the change in focus of attention children with postural control difficulties restrict the degrees of freedom to allow for the stabilisation of posture against gravity while cognitive resources [17, 18, 43], which were used for postural control [22], are used to engage in the cognitive task. In addition there appears to be a difference in the effect of the cognitive load in children with and without postural control difficulties.

Due to the positive effect on postural control with the addition of a cognitively challenging activity the results of this study support Blanchard et al’s (2005) [43] theory that the inclusion of cognitive load during the treatment of balance and posture will improve the outcomes of intervention. This is true whether the improvement seen is due to the child restricting the degrees of freedom due to the
cognitive activity or the shift of attention away from posture as postural tone and stability develop through practice [16]. In addition the novelty of the cognitive load condition [25] as well as the challenge [26] influence the dual task effect and therefore the use of progressively more challenging cognitive tasks in the treatment of postural control may be warranted.

The implications of the positive effect of cognitive load in both groups, particularly with regards to ‘Spinal Profile’, ‘Head Alignment’, ‘Pelvic Girdle Position’ and ‘Activity’ performance (with regards to bilateral integration and crossing the midline) is to support the CO-OP approach which is based on traditional cognitive and cognitive/behavioural theory [31-33]. This addresses the treatment of children with DCD through a focus on activity performance as the result of interactions between the person, environment and task [32, 34, 35]. As such the use of cognitively challenging tasks within therapy planning and intervention will improve the efficacy of treatment of postural control.

The use of sitting at a desk relates to classroom based school work as this is the most common postural requirement within the school day. This is dependent on the use and therefore the development of fine motor skills as well as other academic learning. As academic performance is the most common area of shared concern amongst children with DCD, their parents and teachers [11] the use of concurrent cognitive tasks with that are sufficiently challenging for the child within the classroom would improve their postural control and therefore their occupational performance in the work domain. It is however important to note that the brain’s processing abilities are thought to be limited to available resources. Therefore if the concurrent cognitive tasks are too challenging the ‘Posture First Principle’ according to the ‘Limited Capacity Theory’ may result in either a decrease in postural control or a decrease in cognitive performance and participation [26]. It is important for therapists and teachers to be aware of children with DCD’s perceptual and cognitive abilities in order to maximise postural and cognitive performance. This requires in depth knowledge of each individual child to allow tailoring of the school and therapy environment.
CHAPTER 6
CONCLUSION

The objectives of this study were to ascertain the difference in sitting posture at desk between children with and without postural control difficulties and how cognitive load affected the posture of these children. Findings indicate that although there was an observable difference between the two groups with Group A sitting posture being less efficient than Group B, as was to be expected as Group A had identified postural control difficulties while Group B did not. This difference was not statistically but maybe clinically significant due to the limitations in the sensitivity of the Modified Chailey Levels of Sitting Ability and the small sample size used in the study.

The null hypotheses were therefore accepted in terms of the differences between Group A and B, as well as for the effect of cognitive load on sitting posture. Clinical differences were however noted in the postural control of those participants with postural control difficulties (Group A) and typically developing participants without postural control difficulties (Group B) in all components of the Modified Chailey Levels of Sitting Ability assessment. The exceptions were for ‘Load-bearing’ and ‘Shoulder Girdle Position’ in which the majority of participants regardless of their group scored a level 7, the highest possible score.

A difference was noted between the baseline sitting ability in both groups and the non-cognitive load and cognitive load conditions. In Group A most of the scores on the Modified Chailey Levels of Sitting Ability were lower than the baseline for all the non-cognitive load trials and higher than the baseline in the cognitive load condition. In Group B however the majority of non-cognitive load scores were initially similar to the baseline scores, and except for the ‘Pelvic Girdle Position’ component the cognitive load condition scores were also higher that the baseline scores.

Both groups showed an improvement in postural control when sitting at a desk when participating in a concurrent cognitive task that is suitably challenging for the
child in relation to age and visual perceptual skills. The areas of greatest difference were found in the ‘Spinal Profile’ and ‘Activities’ components of the assessment for both groups. Group A did however present with more statistically significant and clinical differences within the group than Group B, indicating a difference in the effect of cognitive load on the two groups, although the comparisons between the groups did not reflect this.

The results of this study support the ‘Constrained Action Hypothesis’ as the overall scores and component scores show an increase in sitting ability in the cognitive load versus the non-cognitive load conditions. The use of restriction of the degrees of freedom was evident in both groups for most components, particularly in Group A. The Limited Capacity Theory was also seen within the cognitive load trials as several components such as ‘Spinal Profile’, and ‘Trunk Position and Movement’ scores decrease with time as the complexity of the cognitive task increased.

The overall results however do show that the effect of cognitive load on postural control in sitting was greater in children with postural control difficulties than their typically developing counterparts; this effect was seen most profoundly in the ‘Spinal Profile’ and ‘Activities’ component test items as well as with the overall Modified Chailey Levels of Sitting Ability.

There were several major limitation to this study. Firstly the Modified Chailey Levels of Sitting Ability was not adequately piloted and therefore it was not sensitive enough in several of the component items to identify the differences between the two groups. Secondly the sample size was small and data for the groups was not normally distributed. Thirdly errors in data collection with the camera meant that missing data resulted for several components of the assessment, this error should have been identified in the pilot study. Finally the set up of the research venue could have been improved by having two cameras in situ rather than one to ensure that all items could be accurately assessed, or by completing an observation checklist in situ.
6.1 Recommendations

The Modified Chailey Levels of Sitting Ability assessment used in this study was not sensitive enough to discriminate between the two groups and only limited differences were found within group comparisons. This assessment should be looked at in detail and piloted on a greater population of children with and without postural control difficulties to ensure that it is valid and reliable before it is used in research or assessments in the future.

The results of this study show that when cognitive load provides the just right challenge postural control improves. The implications of this are that more cognitive based activities should be employed in occupational therapy intervention to assist in the treatment of postural control difficulties.

Further research into the impact of cognitive load on the postural control of children with and without postural control difficulties when sitting at a desk is warranted. The results of this study indicate that there are differences and if a suitable assessment and a larger sample size are used results may have a profound impact on the treatment of children with DCD within the occupational therapy context as well as in the classroom. In addition further research that addresses changes in cognitive performance as well as postural control should be conducted in order to get a complete picture of the effect of cognitive load on postural control in this population of children.

These results are inconsistent with the literature in which the varied hypotheses describe a decrease in postural control with an increase in cognitive load [5, 26, 30, 41, 43]. The ‘Posture First Principle’ may be applied to children with DCD in that postural control takes precedence over cognitive function [64] but this is hard to apply to this study as there was no measurement of cognitive performance, or the change thereof, in the trials. This is a limitation to the study and should be taken into consideration in any future studies of this nature. The ‘Constrained Action Hypothesis’ can however be successfully accepted in this instance as with the overall scores, as the focus on the cognitive task removes the child’s attention off the postural task with a positive effect [5, 24].
REFERENCES

20. Johnston, L.M., Y.R. Burns, S.G. Brauer, and C.A. Richardson, Differences in postural control and movement performance during goal directed reaching in


