# THE EFFECT OF A SINGLE VERSUS MULTIPLE CERVICAL SPINE MANIPULATIONS ON PEAK TORQUE OF THE ROTATOR CUFF MUSCLES IN ASYMPTOMATIC SUBJECTS WITH CERVICAL SPINE FIXATION

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# DEDICATION

This research is dedicated to my mother and late father, who have, through their lives and their love, given me the courage and determination to follow my dreams.

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# ABSTRACT

**Aim:**

The aim of the study was to assess the effect of a single versus multiple cervical spine manipulations, over a two week period, on peak torque of the rotator cuff muscles utilizing the Cybex Orthotron II Isokinetic Rehabilitation System. This study was a pre and post experimental investigation.

**Method:**

Forty asymptomatic (in terms of neck and shoulder pain) male chiropractic students were stratified into two equal groups of twenty subjects to ensure that each group consisted of an equal number of subjects from each year of study. All subjects underwent a familiarisation session on the Cybex Orthotron II Isokinetic Rehabilitation System. Group One received a single manipulation. Rotator cuff peak torque was measured pre-manipulation, immediately post manipulation and at a two-week follow up.  Group Two received four manipulations over a two week period. Rotator cuff peak torque was measured pre and immediately post the first manipulation. A third rotator cuff peak torque measurement was taken two weeks after the first manipulation.

**Results:**

There was no statistically significant effect of a single or multiple manipulations on rotator cuff peak torque (abduction, adduction, internal rotation and external rotation). Inter-group analysis revealed a trend of an effect for abduction as the single manipulation increased at the two-week follow up and the multiple manipulation group decreased; however, this was not statistically significant.

**Conclusion:**

No statistically significant results were found possibly due to small sample size and the fact that objective measurements were only taken at the beginning and the end of the research processes and not at regular intervals throughout the study.Further studies are needed to determine the effects of multiple manipulations on peripheral muscle activity, including the

treatment of symptomatic patients with rotator cuff pathology. It is also recommended that EMG readings be done in conjunction with peak torque measures to determine muscle activity.

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# DEFINITION OF TERMS/ ABBREVIATIONS

**ARTHROGENIC MUSCLE INHIBITION (AMI)**

The inability of a muscle to recruit all the motor units of a muscle group to their full extent during a maximal effort voluntary muscle contraction (Suter *et al*., 2000) due to a presynaptic, ongoing reflex inhibition of the musculature surrounding a joint, following distension or injury to that joint (Hopkins and Ingersol, 2000).

**CYBEX**

The Cybex Orthotron II Isokinetic Rehabilitation System was used to measure the peak torque of the rotator cuff muscles and the software used to record the readings was Humac 2004 Copyright Computer Sport Medicine Inc version 4.5.5.

**DORSAL ROOT GANGLIA (DRG)**

A ganglion found on the dorsal root of the spinal nerve where the cell body of the dorsal root ganglion neuron is found (Haldeman, 2005). Anatomically, they are found within the intervertebral foramen (IVF) in close proximity to the facet joints (Gatterman, 2005).

**ELECTROMYOGRAPHY (EMG)**

Electromyography graphically records the electrical activity of muscles (www.emedicinehealth.com, 2009). It can detect small changes within the neuromuscular system and provides useful information about the functioning of motor units (Rebechini-Zasadny *et al.,* 1981).

**FIXATION**

A state where an articulation has become temporarily restricted in a position that it may normally occupy during any phase of physiological movement (Haldeman, 1992). A component of motion segment dysfunction (below) where there is a decrease in the normal range of motion of the motion segment but without any other clinical signs and symptoms. In this study the subject groups had a fixation between C4-C7 which was assessed as a decrease in range of motion of a motion segment that was otherwise asymptomatic.

**MOTION SEGMENT DYSFUNCTION**

A disturbance of function that occurs within a motion segment characterised by signs of neuromuscular dysfunction, altered pain pressure threshold and changes in the quality and range of motion of the motion segment resulting in increased motion, decreased motion or aberrant motion (Leach, 2004; Peterson and Bergmann, 2002).

**MOTION PALPATION**

A palpatory diagnosis of passive and active segmental joint range of motion used to determine the location of a fixation (Haldeman, 1992).

**MOTION SEGMENT**

A motion segment is the most basic functional unit of the vertebral column. It is formed by two adjacent vertebrae and the connecting tissue joining them (Gatterman, 2005; Leach, 2004).

**MOTOR NEURON POOL**

A group of spinal motor neurons that innervate a single muscle (Simons, Travell and Simons, 1999).

**MOTOR UNIT**

A motor unit includes all the muscle fibres innervated by one motor neuron (Simons, Travell and Simons, 1999).

## MUSCLE STRENGTH

The measure of an individual's ability to exert maximum muscular force, statically and dynamically (De Ste Croix *et al*., 2003). The rotational effect of the force, generated by a single muscle or group of muscles, about a joint under consideration, and is also called the torque or moment (Dvir, 2004).

## PEAK TORQUE

The point in the range of motion of a joint where strength reaches its maximum force, is termed the peak torque. Peak torque is measured in newton-meters (Nm) which is the force (N) multiplied by the radius of range of motion (m) (Dvir, 2004). In this study the terms peak torque and maximal strength are synonymous.

## VERTEBRAL SUBLUXATION COMPLEX

A theoretical model of motion segment dysfunction that incorporates the complex interaction of pathologic changes in nervous, muscular, ligamentous, vascular and connective tissues (Gatterman, 2005). These pathological changes can be broadly categorised into mechanical, inflammatory-vascular and neurobiologic components (Bergmann, Peterson and Lawrence, 1993).

# CHAPTER ONE

# Introduction

## 1.1 Introduction

Motion segment dysfunction is defined as a disturbance of function that occurs within a motion segment characterised by signs of neuromuscular dysfunction, altered pain pressure threshold and changes in the quality and range of motion of the motion segment resulting in increased motion, decreased motion or aberrant motion (Leach, 2004; Peterson and Bergmann, 2002). The formation of fibrous adhesions in and around synovial joints, often as a result of trauma or immobilisation, can result in decreased joint motion and is a common clinical finding (Gatterman, 2005; Peterson and Bergmann, 2002; Rahlmann, 1987). However, patients often compensate and adapt to changes in the motion segment and may be asymptomatic despite the development of motion segment dysfunction (Gatterman, 2005; Peterson and Bergmann, 2002). The restriction of a motion segment in a position that it may normally occupy during any phase of physiological movement, but without any other clinical signs and symptoms, is known as a joint fixation (Peterson and Bergmann, 2002). It is these asymptomatic patients with a cervical spine fixation who formed the sample population for this study.

The 'breaking down' of articular adhesions has been hypothesised as one of the mechanical effects of manipulation in the treatment of spinal fixations. Sandoz (1976) proposed a model explaining the presence of a paraphysiological space, which exists beyond the passive range of motion but less than the anatomical limit, however, this model was based on the range of motion of a normal motion segment. In the case of a joint with clinically significant decreased range of motion, Vernon and Mrozek (2005) postulated that a fixated joint is manipulated within a 'clinical physiological range' and not into the paraphysiological space at the end range of 'normal' motion, as previously thought by Sandoz (1976). This is because the fixated joint requires the breaking down of adhesions, which restrict full range of motion and therefore, the expected result of a single manipulation is an increase in motion towards the 'normal' range of motion. Simultaneously, it is thought that there is an increase in neurological stimulation of the manipulated joint as the articular capsule and surrounding tissues are stretched to a greater extent as the articular adhesions are broken down (Leach, 2004). In support of this, Dixon (2005) found that manipulation of a non-fixated segment compared to a fixated segment caused a larger increase in rotator cuff peak torque post manipulation of the cervical spine. Dixon (2005) hypothesized that this was due to the increased neurological stimulation of the facet joint receptors and overlying muscle mechanoreceptors in the non-fixated segment as the joint capsule, muscles and ligamentous structures were stretched further, in comparison to the fixated segment, as there was no restriction of motion due to articular adhesions. The increased afferent neurological stimulation is thought to cause changes in the excitability of the motor neuron pool of the musculature that has the same innervation as the joint being manipulated, thus, increasing the rotator cuff peak torque following manipulation of the cervical spine (Suter *et al*., 2000; William, 1997).

Further to the local effects, spinal manipulations have been associated with consistent reflex responses, which have been shown to inhibit hypertonicity in muscles, decrease pain and increase functional ability of the patient (Herzog *et al.,* 1999; Nansel *et al.,* 1993). Studies have shown a reflexogenic increase in peripheral muscle strength and surface EMG readings post manipulation in patients with and without cervical spine dysfunction (Dixon, 2005; Naidoo, 2002; Suter *et al.,* 2000; Herzog *et al.*, 1999; Rebechini-Zasadny *et al.,* 1981). However, these studies measured the effect of a single segmental manipulation and there appears to be paucity in the literature on the effect of multiple manipulations on peripheral muscles.

Sobel *et al*., (1997) stated that patients with shoulder complaints, independent of the diagnosis made have limitations of mobility in the cervical spine. Shoulder pathologies in general are also associated with a decrease in strength of the rotator cuff muscles which may result in a decrease of the dynamic stability of the shoulder joint (McClure *et al*., 2006; Kibler *et al*., 2006; Cools *et al*., 2005). Therefore, the possibility of cervical spine manipulation increasing the strength of the rotator cuff muscle could lead to a more comprehensive rehabilitation protocol for shoulder injuries, which should assist in strengthening of the rotator cuff muscles.

Isokinetic Dynamometers have provided valuable information for the evaluation of shoulder strength assessment and have been shown to be a reliable measurement tool for determining peak torque produced by muscles moving a large joint (Chan and Maffuli, 1996; Scotville *et al*., 1997). Strength is defined as the rotational effect of the force generated by a single muscle or group of muscles around a joint (Dvir, 2004). The point in the range of motion where the strength reaches its maximum is also known as the peak torque (Newtons x meters) (Dvir, 2004).

Therefore, this research aimed to investigate the effect of a single and multiple cervical spine manipulations on peak torque of the rotator cuff muscles in asymptomatic subjects with cervical spine fixations utilising the Cybex.

## 1.2 Aims and Objectives of the Study

The aim of the study was to assess the effect of a single versus multiple cervical spine manipulations, over a two week period, on peak torque of the rotator cuff muscles utilizing the Cybex.

### 1.2.1 Objective one

To determine the effect of a single cervical spine manipulation on peak torque of the rotator cuff muscles utilizing the Cybex.

Null Hypothesis 1
A single cervical spine manipulation will result in no increase in peak torque of the rotator muscles immediately post manipulation.

### 1.2.2 Objective two

To determine the effect of multiple cervical spine manipulations, over a two week period, on peak torque of the rotator cuff muscles utilizing the Cybex.

Null Hypothesis 2
A series of multiple cervical spine manipulations, over a two week period, will result in no increase in peak torque of the rotator cuff muscles post manipulation.

### 1.2.3 Objective Three

To compare the effect of a single versus multiple cervical spine manipulations, over a two week period, on peak torque muscles of the rotator cuff utilizing the Cybex.

Null Hypothesis 3
There will be no difference between the single and multiple manipulation groups over a two week period.

## 1.3 Rationale for the study

### 1.3.1 Rationale One

Various studies (Dixon, 2005; Naidoo, 2002; Rebechini-Zasadny *et al*., 1981) have investigated the peripheral effects of a single cervical spinal manipulation. These studies found that there was an immediate increase in muscle strength and activity post adjustment. However, in a study by Bonci and Ratliff (1990) investigating the effect of a single cervical spinal manipulation on the strength of the biceps brachii muscle, they found no significant increase immediately post manipulation. This highlights the controversy surrounding the peripheral effects of manipulation.

Bonci and Ratliff (1990) after failing to show an increase post cervical spine manipulation in the biceps brachii muscle, recommended that the effect of a series of manipulations over a period of time be investigated, as the value of chiropractic treatment may only be realized with successive treatments. Botha (2005) made a similar recommendation after his study, where the short-term (24 hours) effect of cervical spine manipulation on rotator cuff peak torque was assessed. He recommended that future research should include the intermediate and long-term effects of manipulation on the peripheral musculature.

Vernon and Mrozek (2005) proposed a model of manipulation to a fixated joint suggesting that manipulation does not take place at the end range of 'normal' motion but instead within a 'clinical physiological range'. Manipulation causes 'breaking down' of adhesions within and around the fixated joint with a resultant improvement in range of motion towards the 'normal' range of motion (Leach, 2004). This, however, does not necessarily occur with a single manipulation and the degree of neurological stimulation is less, as the capsule and surrounding tissues are not stretched to the same extent in the 'clinical physiological range'. This is supported by Dixon (2005), who found that manipulation of a non-fixated segment caused a larger increase in rotator cuff peak torque post manipulation of the cervical spine compared to a fixated segment.

Therefore, this study attempts to test the adhesion theory proposed by Vernon and Mrozek (2005), by assessing the effect of a single versus multiple manipulations, to determine if through a series of manipulations there is an increase in the peripheral effects of manipulation due to the improvement in joint range of motion

### 1.3.2 Rationale Two

When treating an injured shoulder one of the aims is to increase strength of the rotator cuff muscles (Green *et al*., 1998, Kamkar *et al*., 1993, Reid 1992). The innervation of the cervical facet joints arises from the cervical spinal nerves, which also supply innervation to the upper limbs (Moore and Dalley, 2006). Manipulation causes stretching of the facet joint capsule and surrounding structures, resulting in reflex neurological pathways which not only affect the local musculature but also more distant musculature (Herzog *et al.,* 1999; Nansel *et al*., 1993). Dixon (2005), Naidoo (2002) and Rebechini-Zasadny *et al*., (1981) found changes in upper limb muscle strength and muscle activity immediately following manipulation of the cervical spine. Therefore, it is possible that if cervical spine manipulation increases the strength of the rotator cuff muscles then this could be used to develop a more effective treatment and rehabilitation protocol for patients with musculoskeletal painful shoulders. If this study indicates that cervical spine manipulation does increase the strength of the rotator cuff muscles this would justify the need for a similar study in a symptomatic population to determine if there is a clinically significant improvement in muscle strength post manipulation.

## 1.4 Limitations

All subjects who participated in the study were asymptomatic in terms of neck and shoulder pain. Majority of the general population would not seek chiropractic treatment if they were asymptomatic. Therefore, male chiropractic students were approached as the sample population for this study as they were deemed to be more compliant; however, it is unknown if regular manipulations during practical classes prior to this study may have affected the outcome of this study. At the time of conduction of the study the sample population consisted of 93 male chiropractic students. To account for exclusion criteria it was decided that 40 subjects was a reasonable sample size however, should this study reveal any trends it would indicate the need for larger studies to be conducted.

There are certain factors which may influence the reliability of isokinetic measurements of the shoulder (van Meerteren *et al*., 2002):

1. There is no general consensus on the functional axis of the shoulder, whereas, the axis of the dynamometer has a fixed position. Due to the extensive range of motion of the glenohumeral joint, the axis of rotation of the joint moves about 8 cm

during flexion and extension, and abduction and adduction. The effect that this has on the reliability of the measurement results is unknown however as all groups were subject to the same measurement tool this would have occurred across the groups negating its impact.

2. Different positions are used to measure the movements of the shoulder including sitting, standing, and lying supine. There is no consensus on the best position for abduction and adduction. In this study all subjects were tested in the seated position. It is not clear if this affects the reliability of the testing.

3. In general, the preset angular velocity is low when measuring maximum voluntary contraction of the shoulder and a high velocity is used when testing muscle co-ordination. In this study a preset angular velocity of 60° per second was used.

## 1.5 Conclusion

There is an accumulating body of knowledge on the clinically beneficial effects of manipulation on peripheral musculature. However, further investigation is needed in this area, in particular with regard to the effects on multiple manipulations over a longer period. With rehabilitation in mind, the potential clinical benefit of increasing peripheral muscle strength post manipulation could be shown to be an integral part of future rehabilitation protocols by including manipulative therapy as part of the rehabilitation program.

In order to assess the effect of multiple manipulations on rotator cuff peak torque, Chapter Two will include a review of the related literature; Chapter Three describes the methodology utilized to collect and analyze the data; Chapter Four presents the results obtained from the study; Chapter Five discusses these results and Chapter Six presents the conclusion and recommendations for future studies.

# CHAPTER TWO

# Review of Related Literature

## 2.1 Introduction

In this chapter a review of the related literature will be presented. Current theories related to motion segment dysfunction and fixation are explored, and there is an investigation into the reflex effects of manipulation both locally and peripherally, including changes in peripheral muscle activity. Relevant anatomy of the cervical spine and rotator cuff musculature are also discussed, as well as the neurological link between the two anatomical areas.

## 2.2 The Cervical Spine

### 2.2.1 Anatomy of the Cervical Spine

A motion segment is the most basic functional unit of the vertebral column. It is formed by two adjacent vertebrae and the connecting tissue joining them. The two vertebrae are joined anteriorly by the intervertebral disc between the two vertebral bodies and articulate posteriorly at the facet joints.

The cervical spine consists of seven vertebrae; three atypical vertebrae (C1, C2 and C7) and four typical vertebrae (C3, C4, C5 and C6) (Moore and Dalley, 2006). This study focused on manipulation of C4-C7 vertebrae and therefore, the lower cervical spine will be discussed below.

The lower cervical vertebrae (C3-C7) consist of a vertebral body, a vertebral arch and seven processes (Moore and Dalley, 2006). The vertebral body is the large anterior part of the vertebra, which provides strength and support to the vertebral column. Two small uncinate processes project superiorly from the posterior aspect of the vertebral body forming the uncovertebral joint with the posterior aspect of the vertebral body above. The vertebral arch is formed by two short, rounded pedicles and two long, narrow laminae that meet to form the spinous process posteriorly. The spinous processes are bifid, except for C7, which has a longer more prominent spinous process. At the junctions of the pedicles and laminae two processes project superiorly and posteriorly and two project inferiorly and anteriorly, forming the articular surfaces of the facet joints. Two transverse processes project posterolaterally from the pedicle–lamina junction and they are characterized by oval transverse foramina. The vertebral artery passes through these transverse foramina except for C7 where the foramen is small and sometimes absent (Moore and Dalley, 2006).

The pedicles join the vertebral arch to the posterior surface of the vertebral body, which together form the walls of the vertebral canal which contains the spinal cord and its nerve roots. The vertebral canal is characteristically larger between C3-C7 to accommodate the enlarged portion of the cervical spinal cord, which corresponds to the brachial plexus nerves which provide innervation to the upper limbs. The spinal nerves exit the vertebral canal through the intervertebral foramina (IVF) which are formed by the vertebral body, pedicles, articular processes and intervertebral disc of two articulating vertebrae. Between every pair of vertebrae, two foramina are formed and they provide passage for the spinal nerve roots, segmental arteries, communicating veins and lymphatic channels and two to four recurrent meningeal nerves (Moore and Dalley, 2006; Gatterman, 2005; Peterson and Bergmann, 2002).

Anteriorly, the vertebral bodies are interposed by an intervertebral disc, which forms a cushioning support between adjacent vertebrae. The intervertebral disc is made up of an outer fibrocartilaginous annulus fibrosis and an inner gelatinous nucleus pulposus, which becomes progressively more collagenous with age. The annulus fibrosis extends collagen fibres into the articular surface of the vertebral bodies, forming a strong attachment between the vertebral body and the intervertebral disc (Moore and Dalley, 2006; Gatterman, 2005; Leach 2004).

Posteriorly, the adjacent vertebrae articulate between the superior and inferior articular processes, forming the facet joints. The facet joints are synovial planar joints, which allow movement between the vertebrae determining both the direction and range of motion that occurs. The facet joints are stabilized by the joint capsule and small segmental ligaments together with larger ligaments, which provide support to the contiguous spinal vertebrae (Gatterman, 2005; Peterson and Bergmann, 2002).

The main cervical spinal ligaments are summarized in the following table:

**Table 2.1: Main Cervical Spinal Ligaments and Attachments**

| Ligament | Attachment |
|---|---|
| Anterior longitudinal ligament | Extends from the anterior tubercle of C1 and the occipital bone, anterior to the foramen magnum, to the pelvic surface of the sacrum connecting the anterolateral aspects of the vertebral bodies and intervertebral discs. |
| Anterior atlanto-occipital membrane | Extends from the anterior arch of C1 to the anterior margin of the foramen magnum. |
| Posterior longitudinal ligament | Extends from the posterior aspect of C2 vertebral body, within the vertebral canal, to the sacrum attaching to the posterior edges of the vertebral bodies and intervertebral discs. |
| Posterior atlanto-occipital membrane | Extends from the posterior arch of C1 to the posterior margin of the foramen magnum. |
| Ligamentum Flavum | Extends throughout the spine within the vertebral canal joining adjacent lamina. |
| Interspinous ligaments | Joins adjacent spinous processes by attaching from the root of one spinous process to the apex of the next spinous process. |
| Nuchal ligament | Joins the spinous processes of the cervical vertebrae extending from the external occipital protuberance and posterior edge of the foramen magnum to C7, where it unites with the supraspinous ligament inferiorly. |
| Intertransverse ligament | Extends between adjacent transverse processes. |

(Moore and Dalley, 2006; Peterson and Bergmann, 2002).

### 2.2.2 Innervation of the Cervical Spine

Each spinal nerve that exits through the IVF of the lower cervical motion segments divides into dorsal and ventral primary rami. The medial branch of the dorsal primary rami of the spinal nerves innervates the facet joints; the deep muscles of the neck; the periosteum of the posterior vertebral arch; the interspinous, supraspinous and intertransverse ligaments and ligamentum flavum; and the overlying skin. The lateral branch of the dorsal ramus innervates the erector spinae muscles, splenius capitus and cervicis muscles and the overlying skin (Moore and Dalley, 2006; Gatterman, 2005).

Each facet joint receives innervation from the articular branches of that spinal level and the level above (Moore and Dalley, 2006; Gatterman, 2005). The intrinsic sensory receptors of the facet joints and primary afferent receptors in the cervical musculature are of particular interest with regard to this study, as the facet joints were manipulated during study. Stimulation of these receptors through the use of spinal manipulative therapy has been associated with reflexogenic changes in muscles locally and peripherally (Herzog *et al*., 1999). The facet joint receptors, as classified by Wyke (1985), and the muscle receptors are summarized in the table below:

**Table 2.2: Facet Joint and Muscle Receptors**

| | **Type** | **Location** | **Characteristics** |
|---|---|---|---|
| **Joint Receptors** | I | Superficial layers of joint capsule. | Low threshold, slow adapting mechanoreceptors some of which fire even when there is no joint movement. |
| | II | Deeper layers of joint capsule. | Low threshold, fast adapting mechanoreceptors, which quickly stop firing when the joint is not moving. |
| | III | Surfaces of joint ligaments (intrinsic and extrinsic). | High threshold, slow adapting mechanoreceptors that are not abundant in facet joints. |
| | IV | Throughout fibrous joint capsule and ligaments. | High threshold, non-adapting nociceptors. |
| | Ia | Throughout the skeletal muscle and lie parallel with | Respond to the amount and rate of change in muscle length during |

| | | | |
|---|---|---|---|
| | (Muscle Spindles) | extrafusal muscle fibres. They are found in relatively high density in the cervical musculature compared to peripheral skeletal muscles. | muscle stretch through activation of intrafusal receptors and are inhibited by muscle contraction except when gamma motor neurons are activated. |
| | Ib (Golgi tendon organs) | Found at the proximal and distal musculotendinous junctions. | Monitor changes in muscle tension responding to the force produced by contraction of muscle fibres and together with Ia afferents contribute proprioceptive information monitoring skeletal muscle function. |
| **Muscle Receptors** | II | Throughout the skeletal muscle alongside the Ia afferent receptors. | Consist of secondary muscle spindles, which are sensitive to changes in muscle length and referred to as mechanoreceptive afferents along with Group I. |
| | III and IV | Throughout the skeletal muscle. | Small diameter slow conducting afferents generally classified as nociceptors. Display a high degree of specificity and can respond to stimuli in a graded fashion. The characteristics of type III and IV afferents in the vertebral column as well as the effect of spinal manipulation on these receptors are poorly understood. |

(Umphred, 2007; Leach, 2004; Gatterman, 2005; Peterson and Bergmann, 2002; Wyke, 1985).

## 2.3 The Rotator Cuff

### 2.3.1 Anatomy of the Rotator Cuff Muscles

The primary role of the rotator cuff muscles (supraspinatus, infraspinatus, teres minor and subscapularis) are to provide dynamic stability to the glenohumeral joint (Moore and Dalley, 2006; Wilk and Arrigo, 1993). This is accomplished by contraction of the rotator cuff muscles to increase compression and congruency between the humeral head and glenoid fossa. The tendons of the rotator cuff muscles also blend with the capsule of the glenohumeral joint, tightening the capsule when the muscles contract and providing proprioceptive input during movement of the joint (Wilk and Arrigo, 1993).

Table 2.3 below summarizes the anatomical attachments of the rotator cuff muscles:

**Table 2.3: Anatomical Attachments of the Rotator Cuff Muscles**

| Muscle | Proximal attachment | Distal attachment |
|---|---|---|
| Supraspinatus | Medial two-thirds of the supraspinous fossa of the scapula. | Superior facet on greater tubercle of the humerus. |
| Infraspinatus | Infraspinous fossa of the scapula. | Middle facet on greater tubercle of the humerus. |
| Teres minor | Upper two-thirds of lateral border of the scapula. | Inferior facet on greater tubercle of the humerus. |
| Subscapularis | Subscapular fossa. | Lesser tubercle of the humerus. |

(Moore and Dalley, 2006; Simons, Travell and Simons, 1999)

Although the rotator cuff muscles act as dynamic stabilizers of the glenohumeral joint, they each have individual actions which act together to produce muscle force couples, stabilizing and centering the joint (Souza, 1994; Wilk and Arrigo, 1993).

### 2.3.2 Movements and Innervation of the Rotator cuff Muscles

The suprascapular, subscapular, and axillary nerves supply the rotator cuff muscles and arise from the brachial plexus, which is formed by the ventral rami of C5-C8 nerve roots and the majority of T1 ventral ramus. The nerve roots of the brachial plexus unite to form three trunks, the superior, middle and inferior trunks. Each trunk divides into anterior and posterior divisions which supply the anterior and posterior compartments of the upper limb respectively. The anterior and posterior divisions then form the medial, lateral and posterior cords of the brachial plexus, which branch to form the terminal radial, median, ulnar, musculocutaneous and axillary nerves (Moore and Dalley, 2006).

The suprascapular nerve arises from the posterior aspect of the superior trunk of the brachial plexus. It is found superior to the brachial plexus and passes through the scapular notch to supply the Supraspinatus, Infraspinatus and glenohumeral joint. The upper and lower subscapular nerves arise from a branch of the posterior cord of the brachial plexus. The upper subscapular nerve supplies Subscapularis and the lower subscapular nerve supplies the inferior part of Subscapularis and Teres Major. The axillary nerve is a terminal branch of the posterior cord. It passes to the posterior aspect of the arm and then winds around the surgical neck of the humerus innervating Teres Minor, Deltoid, the shoulder joint and the skin over the inferior part of the Deltoid muscle (Moore and Dalley, 2006).

The movements and innervation of the rotator cuff muscles are summarized in Table 2.4. In this study the Cybex was used to measure the peak torque of the rotator cuff muscles. The Cybex measures abduction and adduction simultaneously and so even though adduction is not a primary movement of the rotator cuff muscles, it was included in the study.

**Table 2.4: Movements and Innervation of the Rotator Cuff Muscles**

| **Movement of shoulder** | **Muscle involved** | **Innervation** |
|---|---|---|
| Abduction | Supraspinatus | Suprascapular nerve C4, **C5** and C6 |
| External rotation | Infraspinatus<br><br>Teres minor | Suprascapular nerve **C5** and C6<br><br>Axillary nerve **C5** and C6 |
| Internal rotation | Subscapularis | Upper and lower subscapular nerves C5, **C6** and C7 |
| Adduction | Pectoralis major<br><br>Lattisimus dorsi<br><br>Teres major<br><br>Subscapularis | Lateral and medial pectoral nerves C5, **C6, C7,C8** and T1<br><br>Thoracodorsal nerve **C6, C7**, C8<br><br>Lower subscapular nerve **C6** and C7<br><br>Upper and lower subscapular nerves C5, **C6** and C7 |

**Boldface** indicates the main spinal segmental innervation.

(Moore and Dalley, 2006, Simons, Travell and Simons, 1999, Souza, 1994).

The construction of the brachial plexus, therefore, allows many levels to contribute to a single peripheral nerve. The nerves innervating the rotator cuff muscles all originate from the brachial plexus and exit the vertebral canal between C4-C7 cervical spinal vertebrae and are derived from the same segmental nerves innervating the C4-C7 cervical facet joints and overlying cervical musculature. The rotator cuff muscles and cervical musculature, therefore, fall within the same motor neuron pool. Any altered afferent input which results in reflex motor neuron activity will, therefore, not only affect the muscles locally but more distant muscles as well (Herzog *et al*., 1999).

## 2.4 The Vertebral Subluxation Complex

### 2.4.1 Definition

'The vertebral subluxation complex is a theoretical model of motion segment dysfunction that incorporates the complex interaction of pathologic changes in nervous, muscular, ligamentous, vascular and connective tissues' (Gatterman, 2005, p.136).

Pathologic changes that disrupt the movement, alignment, and/or the physiologic equilibrium of the spinal motion segment are thought to contribute to the production of motion segment dysfunction (Gatterman, 2005; Leach, 2004). Motion segment dysfunction has been used to describe the chiropractic spinal manipulable lesion, however, not all motion segment dysfunction responds to manipulation and it is important to determine the underlying cause of dysfunction (Leach, 2004).

The potential pathologic effects of the theoretical vertebral subluxation complex can be broadly categorized into mechanical, inflammatory-vascular and neurobiologic components (Bergmann, Peterson and Lawrence, 1993), as well as, psychosocial factors (Gatterman, 2005).

### 2.4.2 Mechanical Component

The mechanical causes of motion segment dysfunction include meniscoid entrapment, displaced disc fragments, muscle spasm, articular adhesions, mechanical joint locking and hypermobility and may result from, but are not limited to, acute injury, repetitive use injury, incorrect posture or co-ordination, ageing, congenital anomalies, developmental defects, immobilization and static overstress injuries (Bergmann, Peterson and Lawrence, 1993).

2.4.2.1 <u>Meniscoid Entrapment</u>

Meniscoids are fibroadipose extensions of the periarticular tissues that are found on the inner surface of the joint capsule and project into the joint between the superior and inferior articular processes. Entrapment of these meniscoids between the articulating surfaces of the facet joint may cause a fixation resulting in motion restriction and stress on the joint capsule, which may contribute to pain and muscle spasm (Jones *et al.,*1989).

They occur regularly in the cervical facet joints and are a possible causative factor of intra-articular adhesions (Section 2.4.2.4) (Mercer and Bogduk, 1993).

2.4.2.2 Displaced Disc Fragments

Internal derangement of the intervertebral disc (IVD), where part of the nucleus pulposus is forced through a weakened area of the annulus fibrosis resulting in disc fragmentation, has been proposed as a probable cause for segmental dysfunction (Gatterman, 2005). It is hypothesized that joint restriction is most likely as a result of painful muscle splinting, as tension on the posterolateral annulus and joint capsule causes pain (Gatterman, 2005).

2.4.2.3 Muscle spasm

Irritation of any of the highly innervated structures of the spinal motion segment could trigger reflex muscle spasm resulting in restricted joint motion and is often a source of pain. A positive feedback loop develops and the muscle spasm is perpetuated by gamma motor neurons, which continue to supply afferent proprioceptive stimuli (Gatterman, 2005; Peterson and Bergmann, 2002).

Korr (1975) suggested aberrant muscle spindle activity, as a result of rapid approximation of two muscular attachments or the sudden removal of a load during isometric muscle contraction, as the cause for intersegmental muscle spasm and decreased joint motion. He explained that if the vertebral attachments of intersegmental muscles are approximated in an unguarded, uncoordinated movement and there is sudden shortening of the extrafusal muscle fibers, the muscle spindles become slack and there is silencing of annulospiral activity. This decrease in annulospiral activity causes the central nervous system to increase gamma motor neuron activity to the intrafusal fibres. The increased gamma motor neuron activity stimulates increased alpha motor neuron impulses to the extrafusal muscle fibres, causing contraction of the muscle. The vertebral attachments cannot return to their original position as a result of the continued gamma motor neuron activity and when the muscle is stretched it resists, resulting in further exacerbation of muscle spasm.

2.4.2.4 Articular Adhesions

Both trauma and immobilization can cause the formation of fibrous adhesions around and within the facet joints resulting in a decrease in motion segment range of motion. Acute and repetitive trauma may lead to injury of articular soft tissue with resultant inflammatory responses leading to fibrotic repair and adhesion formation (Gatterman, 2005). Immobilization causes dehydration of the synovial fluid resulting in approximation of proteoglycan molecules. With prolonged immobilization, fibrofatty adhesions can form within the facet joint and there can be thickening and shortening of the articular capsule further restricting joint motion (Gatterman, 2005; Leach, 2004).

2.4.2.5 Mechanical Joint Locking

Degenerative changes within the osseous structures of the motion segment, in particular the facet joints, can cause ‘mechanical joint locking’ affecting the motion of the joint. Trophic facets can also disrupt normal motion segment biomechanics due to asymmetric joint angles. The ‘mechanical locking’ can be associated with muscle spasm which exacerbates the ‘locking’ effect (Gatterman, 2005).

2.4.2.6 Hypermobility

Motion segment hypermobility is often associated with fixation of an adjacent motion segment in order to compensate for the regional change in spinal mobility (Schafer and Faye, 1990). Hypermobility can cause irritation of the surrounding connective tissue resulting in muscle spasm and pain, however, the functional changes in the hypermobile joint are often reversible (Bergmann, Peterson and Lawrence, 1993).

### 2.4.3 Inflammatory and Vascular Components

#### 2.4.3.1 Inflammation

The inflammatory component of the vertebral subluxation complex is most commonly initiated by joint injury and perpetuated by post injury immobilization. All inflammatory reactions are associated with inflammatory mediators which cause pain and vasodilation. The pain may also cause local muscle contraction, further reducing joint range of motion (Leach, 2004). Both inflammation and immobilization of a motion segment will eventually result in intra and extra articular adhesions, as described in Section 2.4.2.4. Anatomically it is possible that inflammation of a facet joint can by reasons of proximity cause inflammation of the dorsal root ganglia and spinal nerves which results in abnormal afferent impulses (Gatterman, 1995).

#### 2.4.3.2 Vascular Component

Asymmetrical blood supply to the nerve roots and spinal cord due to insufficient anastomosis of the dorsal and ventral radicular arteries with the spinal arteries can contribute to localized pain and muscle spasm. The radicular arteries are also susceptible to mechanical compression within the IVF which may alter blood flow (Gatterman, 1995).

The Batson venous plexus is found in the vertebral canal and is responsible for venous drainage of the spinal cord. There are no valves present in the plexus and therefore, venous drainage is dependent on posture and gravity. This, however, may allow movement of toxins and inflammatory mediators from one area of the spine to another. Immobilization of a motion segment is likely to cause localized venous stasis with a decreased rate of removal of toxins which will result in inflammation and possible neural irritation (Gatterman, 1995).

### 2.4.4 Neurobiologic Component

2.4.4.1 Nerve and Dorsal Root Ganglion Compression

It has been hypothesized that motion segment dysfunction can cause compression of the neural contents within the IVF, either through direct anatomical compression or indirectly through disruption of blood flow, resulting in an increase or decrease of neural activity. It appears unlikely that motion segment dysfunction, in the absence of degenerative joint or disc disease, can cause direct compression of the nerve roots, however, the nerve roots are susceptible to inflammation, ischemia and pressure due to edema, which may alter nerve function (Bergmann, Peterson and Lawrence, 1993). The dorsal root ganglia, however, lie within the IVF in close proximity to the articular capsule of the facet joint except for the first and second cervical segments. They are sensitive to mechanical compression and chronic irritation which leads to prolonged repetitive firing that continues even once the stimulus has been removed, possibly manifesting as clinical and pathological signs and symptoms (Gatterman, 1995). It has also been shown that stimulation of primary afferent nerve fibres promotes the release of neuropeptides such as substance P (SP) and vasoactive intestinal peptide (VIP) at their peripheral terminal, which have been shown to stimulate the breakdown of structural proteins. Therefore, DRG irritation may result in the release of neuropeptides at the terminals of their afferent innervation, including the facet joints and annulus of the IVD, possibly resulting in pathological changes over time (Gatterman, 2005).

2.4.4.2 Impulse based model

The mechanical, inflammatory and painful components of motion segment dysfunction have been shown to cause altered nociceptive and proprioceptive input to the CNS. It is hypothesized that this altered afferent input causes a lower firing threshold of the local nerves and the establishment of abnormal somatosomatic and somatovisceral reflexes.

Localized somatic stimuli can produce patterns of reflex responses in segmentally related somatic structures known as somatosomatic reflexes. An example of a somatosomatic reflex is the segmental muscle spasm associated with motion segment dysfunction. The altered afferent stimuli causes a lower firing threshold of the motor neuron pool and a positive feedback loop of proprioceptive afferent stimuli and efferent motor neuron impulses perpetuate the muscle spasm. This will result in a decrease in motion and possibly pain and inflammation of the motion segment. This is referred to as the 'facilitated segment' (Bergman, Peterson and Lawrence, 1993).

Another example of a somatosomatic reflex is the inhibition of the muscles surrounding a joint following injury or distension of the joint, otherwise known as arthrogenic muscle inhibition. The altered afferent input, arising from the mechanoreceptors and nociceptors surrounding the injured joint, act on inhibitory interneurons. The interneurons synapse with the motor neuron pool of the muscles surrounding the injured joint and decrease the recruitment ability of the motor neuron pool. The force of contraction of the muscle supplied by the motor neuron pool is, therefore, decreased to protect the joint from further injury (Hopkins and Ingersol, 2000).

Somatovisceral reflexes have also been found, an example of which is the association of mid-thoracic motion segment dysfunction with dyspepsia (Bergmann, Peterson and Lawrence, 1993). Manipulation has also been shown to have somatovisceral affects including, but not limited to, changes in papillary diameter, gastric function, blood pressure and angina pain (Gatterman, 2005; Gatterman, 1995; Bergman, Peterson and Lawrence, 1993). The affect that spinal lesions have on these organic disorders is, however, unclear and therefore, further investigation is required (Gatterman, 2005).

Thus, motion segment dysfunction may result as a product of altered sensory and proprioceptive input from other somatic or visceral tissues or cause dysfunction in tissues with shared segmental innervation (Bergman, Peterson and Lawrence, 1993).

### 2.4.5 Psychosocial Factors

Many of the activities of daily living, including posture, exercise, nutrition, toxic exposure and occupation can contribute to motion segment dysfunction. Stress and anxiety can also have a significant effect on the endocrine system and muscle tension and therefore, needs to be considered as a possible causative mechanism of motion segment dysfunction (Gatterman, 2005). These psychosocial factors may result in one or a combination of the previously discussed components of the vertebral subluxation complex.

The placebo effect also appears to play a role in the therapeutic effect of any health care approach and therefore, needs to be considered when assessing motion segment dysfunction (Gatterman, 2005).

### 2.4.6 Conclusion

It is possible to see from the above that the causes of motion segment dysfunction are multiple and that one causative factor could predispose the motion segment to be affected by another. Temporary restriction of movement of a joint in a position it may normally occupy during any phase of physiological movement (fixation), is often a natural outcome of the pathological changes that occur in motion segment dysfunction and is a common clinical finding (Gatterman, 2005; Peterson and Bergmann, 2002). Gatterman (2005) states that despite the early pathological changes that occur with motion segment dysfunction, patients compensate and adapt to these changes and are often asymptomatic and therefore, the presence or absence of pain cannot be used to exclude or confirm motion segment dysfunction (Bergman, Peterson and Lawrence, 1993).

Therefore, for the purpose of this study the manipulable lesion was defined as a motion segment fixation between C4-C7. The subjects were asymptomatic in terms of neck and shoulder pain and the location of the fixation was determined using motion palpation, which followed the techniques set out by Schafer and Faye (1990).

## 2.5 Manipulation

### 2.5.1 Definition of Manipulation

Manipulation is defined as a manual procedure in which the hands are used to apply a high velocity, low amplitude thrust in order to induce joint distraction without exceeding the limits of anatomic joint motion (Gatterman, 2005; Peterson and Bergmann, 2002). Manipulation has been shown to influence both joint and neurological function (Gatterman, 2005).

In this study a motion segment fixation between C4-C7 was defined as the manipulable lesion.

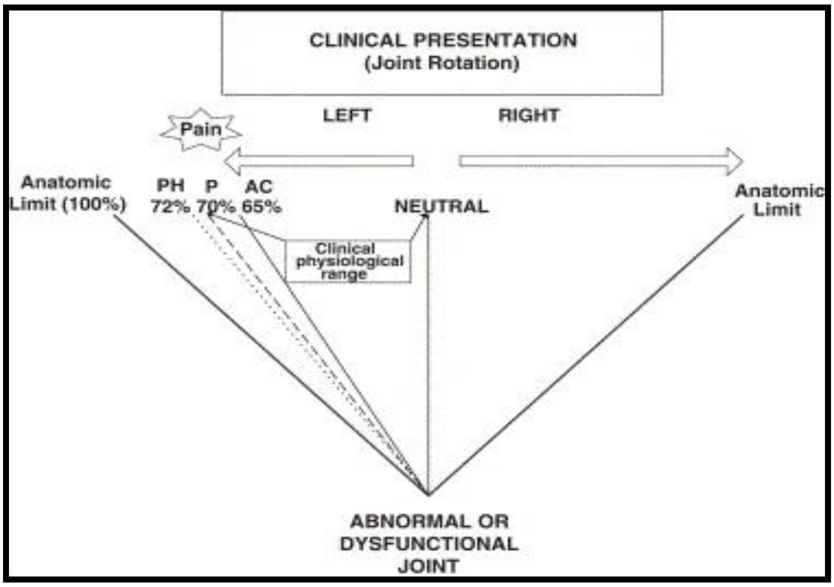
Encompassed in the definition of manipulation is the range of motion of the joint. This must be taken into consideration, as a fixated joint will have a decreased range of motion and therefore, manipulation may not necessarily take place at the end range of 'normal' joint motion. Range of motion models, discussed in Section 2.5.2, have been proposed to explain this.

### 2.5.2 Range of Motion Models

Sandoz (1976) proposed a model based on the range of motion of a 'normal joint'. He explained the presence of a 'paraphysiological' space, which exists beyond the passive range of motion but less than the anatomical limit. This space is described as a zone of elasticity. It is into this space that he postulated that manipulation takes place. However, the theory proposed by Sandoz (1976) is based on the range of motion of a 'normal joint' with manipulation taking place at the limit of passive range of motion. Under clinical circumstances, however, the range of motion of the joint will often be decreased, as described in Section 2.4.

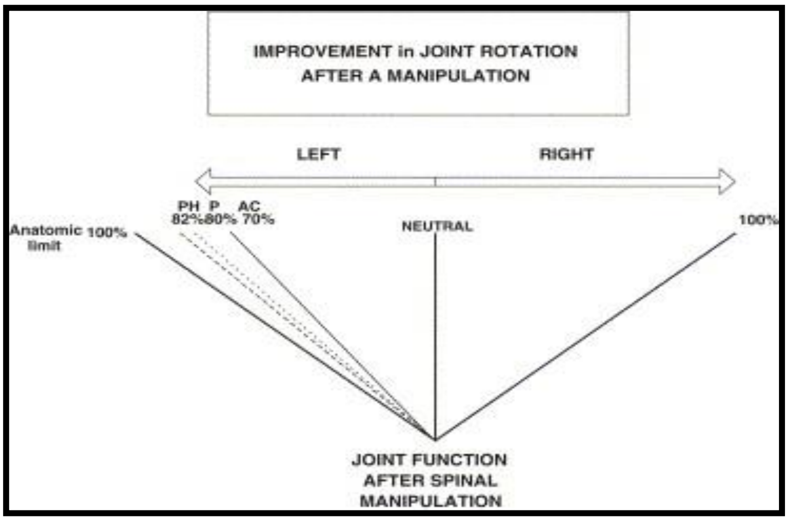
Vernon and Mrozek (2005), therefore, questioned the model proposed by Sandoz (1976) and counter proposed a model of joint range of motion for a joint with restricted range of motion. In the clinical situation, where the range of motion of a joint is decreased, they termed the total range of active and passive motion as the 'clinical physiological range'.

They argued that manipulation delivered to a joint with clinically significant decreased range of motion will not occur at the end of normal range of motion but instead slightly before that, in the clinical physiological range. They proposed that a ‘paraphysiological’ space is available at the limit of the clinical physiological range and into which the impulse of the manipulative thrust is performed. However, because the range of motion of the joint is decreased the manipulative thrust does not approximate the anatomical limit, as proposed by Sandoz (1976), in the ‘normal’ joint. The expected result of a single manipulation within the clinical physiological range is an increase in both active and passive range of motion (Vernon and Mrozek, 2005). The range of motion of the clinical physiological range increases; however, it does not necessarily improve to the normal range. Thus, manipulation of a fixated joint is aimed at increasing the range of motion of the joint towards its normal range and does not necessarily occur with a single manipulation. Simultaneously, as the joint passes into the paraphysiological space, there is stimulation of mechanoreceptors in the facet joint capsule and surrounding ligaments and musculature, as there is mechanical stretching of these structures during manipulation (Leach, 2004; Wyke, 1985). It is, however, thought that the degree of neurological stimulation is less, following manipulation of a fixated joint, as the range of motion of the joint is less and therefore, the joint capsule, muscles and ligaments are not stretched to the same extent as they would be in a joint with ‘normal’ range of motion (Leach, 2004). Vernon and Mrozek (2005) allude to the possibility of multiple manipulations gradually improving the range of motion of the joint towards its normal range, with manipulation taking place within the paraphysiological space closer to the anatomical limit of the joint. It is, therefore, possible that the neurological stimulation of the joint capsule and surrounding ligaments and muscles will increase, as they are stretched further during manipulation, as the range of motion of the joint increases towards its ‘normal’ range with multiple manipulations.




AC = Active range, P = Passive, PH = Paraphysiological space

**<u>Figure 2.1: Clinical Model of Manipulation</u> (Vernon and Mrozek, 2005)**




AC = Active range, P = Passive, PH = paraphysiological space

**<u>Figure 2.2: Expected Results Following Manipulation</u> (Vernon an Mrozek, 2005)**

However, the hypothetical percentages for a joint with a normal physiological range of motion could be represented by Active range = 80%, Passive range = 90% and Paraphysiological space = 92%; indicating that following a single manipulation the range of motion of the joint improves towards normal but does not necessarily reach normal range of motion.

### 2.5.3 The Mechanical Effects of Manipulation

2.5.3.1 Cavitation

Manipulation of a joint is often associated with an audible release known as joint cavitation. This occurs as the joint is distracted to a point where it passes the elastic barrier and there is a sudden separation of the joint surfaces (Sandoz, 1976). In this context the ‘cracking sound’ has been attributed to a negative pressure that exists within a synovial joint. Separation of the joint surfaces causes a decrease of intra-articular pressure below that of the vapour pressure within the joint, and gas bubbles are formed within the synovial fluid, which burst almost immediately producing a cavitation (Peterson and Bergmann, 2002). After manipulation the gasses are gradually reabsorbed back into the synovial fluid.

Brodeur (1995) proposed a slightly different theory as to the cause of the audible cavitation. He proposed that as the joint surfaces are distracted during manipulation the capsular ligament invaginates to maintain the intra-articular pressure. As the load on the joint is increased, the synovial capsule moves inward until it reaches its elastic barrier where it suddenly ‘snaps back’ from the synovial fluid interface, which results in an audible cavitation. There is a rapid increase in joint volume and gas bubbles join in the centre of the joint, which are released from the synovial fluid.

The only conclusive effect of the cavitation is that there is a temporary increase in the joint space between the opposing articular surfaces (Gatterman, 2005) which could possibly contribute to the increased range of motion found post manipulation, as postulated by Vernon and Mrozek (2005). The cavitation represents an event where there is separation of the joint surfaces and stretching of the periarticular tissues which results in stimulation of facet joint mechanoreceptors and nociceptors. It is these events which are theoretically associated with decreasing pain (Section 2.5.4) and muscle spasm (Section 3.5.3.4) and improving joint range of motion (Section 3.5.3.5) (Peterson and Bergmann, 2002).

2.5.3.2 Meniscoid Release

Manipulation causes a separation of the joint surfaces, which may result in the release of a meniscoid that has become trapped between the articulating surfaces of a facet joint. The removal of the meniscoid obstruction reduces the joint fixation, decreasing pain and muscle spasm (Peterson and Bergman, 2002).

2.5.3.3 Displaced Disc Fragments

Manipulation is thought to not only have a distractive effect on the facet joints but also a direct effect on the IVD. It is unlikely that manipulation can reduce an external protrusion of the nucleus pulposus; however, it has been proposed that it can direct the nuclear material back towards the centre of the IVD or it can shift the nuclear fragment away from the nerve root, thereby minimizing potential mechanical and inflammatory effects due to the herniation (Bergman, Peterson and Lawrence, 1993).

2.5.3.4 Reducing Muscle Spasm

Manipulation of a joint causes stretching of the facet joint capsule and mechanical deformation of the overlying muscles and ligaments, which has been shown to activate mechanoreceptors from structures in and around the manipulated joint (Wyke, 1985). Stimulation of the Wyke receptors in the facet joints and afferent receptors in the overlying muscles results in an altered afferent input, which is thought to cause changes in motor neuron excitability which will affect the activity of the muscles innervated by these motor neurons (Suter *et al*., 2000; William, 1997). The articular mechanoreceptor afferent fibres project polysynaptically to gamma motorneurons in the motor neuron pools of the central nervous system, supplying continuous input to the muscle spindles of the skeletal muscles supplied by that motor neuron pool. The mechanoreceptors, therefore, reflexogenically influence muscle tone and the excitability of the intrafusal muscle fibres (Wyke, 1985). It is through this mechanism that manipulation gives rise to reflex changes, in both facilitation and inhibition of muscle tone (Wyke, 1985)

Wyke (1985) proposed that since the articular mechanoreceptor afferent nerve fibres give off collateral branches that extend segmentally, as well as intersegmentally, through the neuraxis, manipulation of a joint will not only affect motor unit activity in the muscles overlying the manipulated joint, but also more distant muscles.

Research has shown that the altered afferent input arises mainly from the afferent innervation of the deep intersegmental muscles of the spine where the muscle spindles are found (Boyling and Jull, 2004). This supports the theory proposed by Korr (1975) (Section 2.4.2.3) where he stated that manipulation of a fixated joint would cause rapid stretch of the intrafusal muscle fibres resulting in a barrage of afferent impulses. The central nervous system would respond by decreasing the gamma motor neuron activity to the intrafusal muscle fibres and the hypertonicity of the extrafusal muscle fibres would be decreased.

#### 2.5.3.5 Decreasing Articular Adhesions

It has been hypothesized that manipulation causes the mechanical breakdown of intra and extra-articular adhesions, as described in Section 2.4.2.4. Manipulation presumably causes mechanical breakdown of the fibrous adhesions that have formed within the joint and around the joint capsule. There is an associated increase in movement, which results in the movement of fluid into the dehydrated synovial joint. The fluid moves in-between the layers of proteoglycan molecules, further increasing joint mobility (Gatterman, 2005; Peterson and Bergmann, 2002; Leach 1994). This is supported by Vernon and Mrozek (2005) who state that manipulation of a joint with clinically reduced range of motion takes place within a clinical physiological range and not at the end range of normal motion. The manipulation causes breaking down of adhesions, increasing the 'clinical physiological' range of motion. However, it is possible that adhesions will remain post manipulation and not all fibres will be broken after a single manipulation. Thus, multiple manipulations would have the beneficial effect of progressively breaking down intra-articular and capsular adhesions and improving the range of motion of the joint until there is no further restriction of the joint due to adhesions. Manipulation will then take place at the limit of 'normal' range of motion into a 'normal' paraphysiological space where there is increased neurological stimulation of the capsule, musculature and ligaments surrounding the joint (Leach, 2004), as described in Section 2.5.2. This results in an altered afferent input to the central nervous system, which is followed by an appropriate efferent response (Haldeman, 2005).

2.5.3.6 Mechanical Joint Locking

Immediate relief following manipulation is often found in a motion segment with mechanical joint locking. The manipulation cannot alter the orientation or osseous structure of the facet joints, however, the gapping of the joint surfaces may improve joint range of motion by 'breaking' articular adhesions (Section 2.5.3.5) and relieve possible associated muscle spasm (Section 3.5.3.4) (Gatterman, 2005).

2.5.3.7 Hypermobility

Manipulation to a hypermobile joint is often palliative and should not be administered over an extended period of time. Manipulation is used to relieve pain and muscle spasm which is often associated with hypermobile joints; however, it does not improve the hypermobility of the joint (Bergman, Peterson and Lawrence, 1993). Hypermobility is often the result of compensation for a fixated joint and following manipulation of the fixated joint will often resolve (Gillet, 1960).

### 2.5.4 Analgesic and Neurologic Effects of Manipulation

It is hypothesized that manipulation has the potential to remove the mechanical source of pain and inflammation, as described in Section 2.5.3, allowing structures to return to normal function, as well as afferent impulse based analgesia (Bergman, Peterson and Lawrence, 1993).

The 'gate-control theory', proposed by Melzack and Wall (1965), suggested that pain resulted from a balance of activity in non-nociceptive and nociceptive afferents in the spinal cord. Impulses in the large myelinated non-nociceptive afferents (mechanoreceptors) turn off a gate to the central transmission of nociceptive input and impulses from the small diameter nociceptive afferents turn on a gate to the central transmission of nociceptive input. Thus, decreased mechanoreceptor activity due to motion segment dysfunction could cause an increase in pain, and conversely, stimulation of joint mechanoreceptors during manipulation could cause presynaptic inhibition of nociceptive input, thereby reducing the perception of pain.

Wyke (1985) reported that manipulation of a joint caused mechanical stretching of the joint capsule which stimulated mechanoreceptors and nociceptors in the capsule and is associated with reflexogenic and analgesic effects. Type IV receptors are nociceptors, which are inactive in the absence of any painful stimulus. However, if Type I-III receptors, which are mechanoreceptors, are not able to function properly or if there is any mechanical or chemical irritation of the capsule, the Type IV receptors are stimulated turning on a gate to central transmission of nociceptive input and pain is perceived. The nociceptive afferents also project polysynaptically to the alpha motor neurons in the motor neuron pool of the muscles related to the joint and through this connection give rise to abnormal reflex activity in these muscles when the nociceptive system is activated. Therefore, restoration of normal function of the motion segment will allow Type I-III receptors to function normally and Type IV receptors will become overridden by the central 'gate-control' modulation of nociceptive input, thereby decreasing the person's pain.

The altered afferent input associated with motion segment dysfunction, which causes pathologic somatosomatic and somatovisceral reflexes, is also thought to be decreased post manipulation. By normalizing the joint mechanics, the stimulus for the altered afferent input is removed and function is returned to normal (Bergmann, Peterson and Lawrence, 1993).

Manipulation has also been shown to increase beta-endorphin levels in the blood plasma and cerebrospinal fluid and a local release of enkephalins, which increases pain tolerance (Gatterman, 2005; Vernon *et al.,* 1986).

### 2.5.5 Psychological Effects of Manipulation

The psychological effect of contact between patient and doctor cannot be discounted when manipulation is being used as a form treatment. The effect of placebo is also not clear; however, when manipulation is associated with an audible cavitation, the placebo effect appears to be greater (Paris, 1983).

## 2.6 The Effects of Spinal Manipulation on Peripheral Muscle Activity

There is accumulating knowledge on the clinically beneficial effects of manipulation both locally and peripherally. Numerous studies have reported a reflex electromyographic response in peripheral muscles following manipulation (Naidoo, 2002; Herzog *et al.*, 1999; Rebechini-Zasadny *et al*., 1981). This increase in motor unit activity has been associated with an increase in muscle strength through the stimulation of segmental and inter-segmental afferent nerve fibres (Dixon, 2005; Naidoo, 2002). It has also been proposed that manipulation to a 'non-fixated' motion segment causes increased neurological stimulation of the afferent joint and muscle receptors resulting in a greater peripheral effect (Section 2.5.2).

Herzog *et al*., (1999) found consistent reflex responses associated with spinal manipulative treatments. It was hypothesized that these reflex responses have the clinically beneficial effect of inhibiting hypertonic muscles, decreasing pain and increasing functional ability of the patient. Herzog *et al*., (1999) also found consistent and repeatable reflex responses in the musculature of the upper and lower limbs following spinal and sacroiliac joint manipulation, indicating that these reflex responses are not just localized to the muscles surrounding the joint being manipulated. Nansel *et al*., (1993) found a significant decrease in lumbopelvic muscle tone following lower cervical spine manipulation of asymptomatic subjects, supporting the fact that reflex pathways can result in changes in muscle activity distant from the site of manipulation.

Rebechini-Zasadny *et al*., (1981) conducted a study to determine the effect of cervical spine manipulation on the first interosseous muscle of the hand using a surface EMG reading. An increase in activity of the muscle post manipulation was reported and this was equated to an increase in strength of the muscle. However, since surface EMG measures myoelectric motor unit activity, it cannot be assumed that there was an increase in strength (Leach, 2004).

Naidoo (2002) found an increase in grip strength following cervical spine manipulation of C4-T1 spinal motion segments. In this study surface EMG was used to detect changes in muscle activity and a grip dynamometer was used to indirectly measure grip strength. A statistically significant increase in grip strength was found post manipulation, which corresponded to a statistically significant increase motor unit activity (surface EMG).

The results indicated that the increase in grip strength and motor unit activity was independent of the level of manipulation and Naidoo (2002) theorized that this was due to the effect of multiple levels of innervation and the inter-segmental innervation of the cervical spine, as explained by Wyke (1985). It is also possible that, due to the force applied to the cervical spine during the manipulation, more than one joint was affected during the manipulation as it is not always possible to isolate a single fixated joint (Schafer and Faye, 1990).

However, Bonci and Ratliff (1990) found no statistically significant difference in the strength of the biceps brachii muscles following a single manipulation of C4/5 motion segment. Naidoo (2002), Bonci and Ratliff (1990) and Rebechini-Zasadny *et al*., (1981) recommended that further studies be conducted on the peripheral effects of manipulation on muscle activity with particular focus on longer treatment schedules, as the therapeutic value of chiropractic treatment is often realized over a period of successive treatments. One of the possible reasons for this is the proposed hypothesis described in Section 2.5.2, where manipulation causes 'breaking of adhesions and improvement of joint range of motion with simultaneous neurological stimulation. However, the joint may not return to 'normal' range of motion following a single manipulation (Vernon and Mrozek, 2005). Multiple manipulations may progressively improve the joints range of motion towards 'normal' with increased neurological stimulation of the articular capsule, ligaments and surrounding musculature as the joint range of motion approximates 'normal' range of motion.

Dixon (2005) did a study to measure the reflex effect of manipulation on peak torque of the rotator cuff muscles in asymptomatic subjects. In this study the Cybex was used to measure the peak torque of the rotator cuff muscles immediately post manipulation of the cervical spine (C4/C5, C5/C6, C6/C7 spinal segments). An increase in peak torque in all movements (abduction, adduction, internal and external rotation) was observed immediately post manipulation. Results concurred with Naidoo (2002), indicating that changes in rotator cuff strength were independent of the level of manipulation; which was also possibly as a result of multiple levels of innervation of the of the rotator cuff muscles.

Dixon (2005) also found a clinically significant increase in peak torque of the rotator cuff muscles in the sample group that had no fixations and were randomly manipulated between C4-C7. Supported by Vernon and Mrozek (2005), Dixon (2005) speculated that by manipulating a non-fixated segment, a greater degree of neurological stimulation is expected in comparison to manipulation of a fixated segment due to the absence of adhesion formation between the facet joints, as described in Section 2.5.2. Through reflex pathways, as described by Wyke (1985), the increased neurological stimulation of the facet joint receptors was attributed to result in a larger increase in peak torque of the rotator cuff muscles in the sample group without a fixation between C4-C7.

Botha (2005) set out to determine the short-term effect of manipulation on rotator cuff peak torque. Results showed an increase in rotator cuff strength immediately post manipulation, however, these changes mostly returned to pre-manipulation values 24 hours post manipulation. The results were inconclusive due to a small sample size (n=25) and it was recommended that further studies be conducted on the peripheral effects of manipulation on muscle activity, including the long term effects of single and multiple manipulations.

It is apparent from the literature that there are peripheral changes in muscle strength and activity following a single manipulation of the spine. There also appears to be a positive relationship between muscle activity and strength (Naidoo, 2002). However, there is a paucity of literature on the effect of a series of manipulations on peripheral musculature.

Therefore, this study aimed to investigate the effect of manipulation of C4-C7 cervical motion segments on peak torque of the rotator cuff muscles utilizing the Cybex. The effect of a single manipulation was compared to the effect of a longer treatment schedule of 4 manipulations over a two week duration. An attempt was made to replicate a normal chiropractic treatment schedule of two treatments a week for three weeks as recommended by Nilsson *et al.,* (1997). However because the subjects in this study were asymptomatic this was reduced to two treatments a week for two weeks as the repeated treatment of an asymptomatic patients may have caused neck pain. There appears to be paucity in the literature on the recommended guidelines for manipulation of an asymptomatic patient.

## 2.7 The Clinical Significance of Increasing Rotator Cuff Strength

The subjects that took part in this study were asymptomatic in terms of neck and shoulder pain and had no shoulder pathologies (Section 3.7.2). If it is shown that there is an increase in rotator cuff peak torque following cervical spine manipulation the implications could include performance enhancement despite the fact that the athlete may be asymptomatic. The professional sporting world is becoming increasingly competitive to the point that even very small improvements in an athlete's performance can result in a competitive edge.

A further implication of manipulation increasing rotator cuff strength is the possible integration of manipulation as a beneficial added intervention in shoulder rehabilitation and conditioning for certain sports which place strain on the rotator cuff muscles.

According to McClure *et al*., (2006); Kibler *et al*., (2006) and Cools *et al*., (2005), shoulder pathologies in general are associated with a decrease in strength of the rotator cuff muscles. Wilk and Arrigo (1993) lay emphasis on strengthening of the rotator cuff and state that the aim of shoulder rehabilitation should be to improve the efficiency of contraction of the muscle force couples acting on the glenohumeral joint, which provide dynamic stability to the joint. Strengthening of the rotator cuff muscles, therefore, form an integral part of the rehabilitation program for the painful shoulder (Green *et al*., 1998; Kamkar *et al*., 1993; Reid 1992).

This strength deficit, following injury to the shoulder, may be attributed to arthrogenic muscle inhibition (AMI). AMI is defined as the inability of a muscle to recruit all the motor units of a muscle group to their full extent during a maximal effort voluntary muscle contraction (Suter *et al*., 2000) due to a presynaptic, ongoing reflex inhibition of the musculature surrounding a joint, following distension or injury to that joint (Hopkins and Ingersol, 2000). It is a natural response designed to protect a joint from further damage (Suter *et al*., 2000). Mechanoreceptor activity plays a primary role in AMI by relaying altered afferent input from the injured joint to the central nervous system. The mechanoreceptor afferents act on inhibitory interneurons synapsing on the motor neuron (MN) pool of the joint musculature, decreasing the force of contraction stemming from that motor neuron pool (Hopkins and Ingersol, 2000).

Manipulation of a joint has been proposed to activate mechanoreceptors and nociceptors from structures in and around the manipulated joint, as described in Section 3.5.3.4 and Section 2.5.4. The altered afferent input arising from the stimulation of joint and muscle receptors is thought to cause changes in the excitability of the motor neuron pool of the musculature that has the same innervation as the joint being manipulated, as well as closing the gate on nociceptive input which alters alpha motor neuron activity, with a subsequent decrease in arthrogenic muscle inhibition (Suter *et al*., 2000; William, 1997; Wyke, 1985).

Therefore, it is possible the manipulation of C4-C7 will have an effect on the AMI of a symptomatic rotator cuff due to the shared innervation of the rotator cuff musculature and C4-C7 motion segments. However the subjects used in this study were asymptomatic and therefore extrapolation of the results from this study could be applied to future studies which could address the effects of cervical spine manipulation on rotator cuff strength in a symptomatic population.

## 2.8 Isokinetic Muscle Testing

### 2.8.1 Introduction

‘Isokinetic’ refers to the contraction of a muscle or group of muscles against a constant angular or linear velocity causing a body segment to move within a controlled zone of its normal range of motion (Dvir, 2004).

Isokinetic dynamometry provides the resistance against the voluntary muscle contraction and measures the resisting force. The dynamometer is set at a constant velocity and therefore, the greater the voluntary muscle contraction, the greater the resisting force produced by the dynamometer. As force is basically a linear entity, the term strength is used; which is defined as the rotational effect of the force produced by a muscle or group of muscles around the joint under consideration. The point in the range of motion of the joint where strength reaches its maximum is termed the peak torque. Peak torque is measured in newton-meters (Nm), which is the force (N) X radius of range of motion (m) (Dvir, 2004).

Isokinetic testing, therefore, permits the isolation of certain muscles or muscle groups and provides an effective way of attaining objective measures of peak torque, work and power (Cybex, 1996).

### 2.8.2 Reliability of Isokinetic Muscle testing

Isokinetic dynamometers have been shown to be reliable (Dvir, 2004; Callaghan *et al*., 2000; Chan and Maffuli, 1996). The technical accuracy and reliability of isokinetic machines have shown correlation coefficients between 0.93 and 0.99 (Chan and Maffuli, 1996). This is supported by Callaghan *et al.*, (2000), who concluded that isokinetic testing for peak torque, average power and total work using dynamometry is highly reliable in both healthy subjects and patients.

Test re-test reliability is important for long term follow up isokinetic testing. Van Meerteren *et al*., (2002) tested the reliability of isokinetic testing of the shoulder over a two week period. They found an intra-group correlation co-efficient which ranged from 0.69-0.92, indicating excellent reliability in research groups.

### 2.8.3 Validity of Isokinetic Muscle Testing

There are certain factors which contribute to the convergent validity of isokinetic testing, which include but are not limited to (www.isokinetics.net, 2009; Dvir, 2004):

1. Gender Differences: It has been shown that men are consistently and significantly stronger than women. Concentric isokinetic peak torque measured at 60° per second has shown that on average women have about 55% the strength of men. However, when normalized to body weight this percentage is increased to approximately 72%.

2. Body weight: muscle mass increases proportionally with body weight, however, this increase is not linear. Therefore, a subject with a heavier body weight is likely to produce higher peak torque readings. It is possible to normalize peak torque to body weight, which is measured in Newton meters per kilogram.

3. Age: strength normally peaks in the third decade and then gradually decreases until the seventh decade, where there is a more rapid decline.

4. Activity level: participation in certain activities and sports can significantly influence muscle strength. Sports such as baseball and water polo have been shown to significantly increase rotator cuff strength of the dominant arm. This can also account for bilateral performance differences where there is asymmetrical use of the limbs.

5. Effort: Verbal and visual encouragement may influence the subjects effort. Wilk *et al*., (1991) found that aggressive verbal encouragement resulted in earlier onset fatigue and recommended that encouragement during Cybex testing should be moderate and consistent.

### 2.8.4 Conclusion

Isokinetic testing has shown both reliability and validity in the measurement of peak torque, work and power for selected muscles and muscle groups, including the shoulder (Dvir, 2004; Callaghan *et al*., 2000; Chan and Maffuli, 1996). It provides objective measures with the advantage of numerical values for peak torque, measured in Nm, which can be reliably compared over an extended period of time (Meerteren *et al*., 2002). The Cybex was, therefore, used in this study to measure the peak torque of the rotator cuff muscles pre-manipulation, post manipulation and at the two-week follow up.

## 2.9 Chapter Conclusion

The review of the literature has shown that there are consistent reflex responses associated with spinal manipulation, which include decreasing muscle hypertonicity and increasing peripheral muscle strength. It is also evident that these reflex responses are reproducible both locally and peripherally (Dixon, 2005; Naidoo, 2002; Herzog *et al.*, 1999; Nansel *et al.*, 1993).

Vernon and Mrozek (2005) proposed a model describing manipulation to a fixated vertebral segment and hypothesized that the fixation would decrease the chances of manipulation taking place at the end of the 'normal' range of motion. The degree of neurological stimulation would be less; however, the aim would be to increase the range of motion of the motion segment closer to its normal range.

Manipulation has been associated with the 'breaking' of intra-articular adhesions, which increase mobility and range of motion of a joint. Thus, it is possible that with a series of manipulations the ranges of motion of the joint will improve with the progressive break down of intra-articular adhesions until manipulation is taking place within the paraphysiological space with a greater degree of neurological stimulation.

Furthermore, if it is evident that manipulation causes a reflex increase in peripheral muscle strength, it could be included as an added intervention in the rehabilitation of rotator cuff injuries, as strengthening of the rotator cuff forms an integral part of shoulder rehabilitation.

Therefore, this study aimed to determine the effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles over a period of two weeks, utilizing the Cybex. Isokinetic testing provides reliable and valid measures for peak torque of the rotator cuff muscles.

# CHAPTER THREE

# Materials and Methods

## 3.1 Introduction

This chapter describes how the study was conducted. It includes the study design, the sampling methods, inclusion and exclusion criteria and the interventions used. The data collection process and statistical procedures are also discussed.

## 3.2 The Aim and Objectives

The aim of the study was to assess the effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles utilizing the Cybex.

Objectives:

1) To determine the effect of a single cervical spine manipulation on peak torque of the rotator cuff muscles utilizing the Cybex.
2) To determine the effect of multiple cervical spine manipulations, over a two week period, on peak torque of the rotator cuff muscles utilizing the Cybex.
3) To compare the effect of a single versus multiple cervical spine manipulations, over a two week period, on peak torque of the rotator cuff muscles utilizing the Cybex.

## 3.3 Study Design

This study was a pre and post experimental investigation (Mouton, 1996; Nansel *et al*., 1993) to determine the effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles. This research protocol was approved by the Durban University of Technology (DUT), Faculty of Health Sciences Research Committee where an ethics clearance certificate (Appendix G) was issued which is in line with the ethical standards of the Declaration of Helsinki, 1975.

## 3.4 Advertising

The researcher met with each chiropractic class at DUT where the nature of the study and the requirements to participate were explained. Advertisements were also placed at the Chiropractic Day Clinic at DUT (Appendix I).

## 3.5 Sampling

### 3.5.1 Sample Method

All male chiropractic students (N=93) were invited to participate in the study. Those who volunteered were recruited by means of consecutive convenience sampling (Mouton, 1996). The researcher then screened subjects who volunteered to take part in the study.

### 3.5.2 Sample size and Allocation

A total of 40 subjects were stratified into two equal groups of twenty subjects (Brink, 2006). The subjects were stratified by the year of study into either the single or multiple manipulation group, as each subject was accepted into the study they were then allocated to a specific group to ensure that each group contained the same number of participants from each year. This was done in order to control for expose to manipulation as this would vary between years due to manipulation classes.

### 3.6 Subject Screening

The subject evaluation and selection process began with all subjects who volunteered to participate in the study undergoing a cursory telephonic or personal discussion with the researcher. The following questions were asked:

1) Are you a registered chiropractic student at DUT?
2) Are you right hand dominant?
3) Do you have any neck or shoulder pain?
4) Have you had a fracture or surgery to the neck or shoulder region?

These questions were asked as an initial screen to determine subject eligibility.

All subjects who were successful with the initial screening process were evaluated at an initial consultation at the Chiropractic Day Clinic at DUT. Each subject received a letter of information (Appendix A) to read, which explained the details of the study. They were also informed that they would be required to attend three sessions at the Sharks Academy Medical Centre where testing would be done on the Cybex by a registered biokineticist (Appendix H). They were then required to sign an informed consent form (Appendix B), indicating that they agreed to participate in the study and that they were free to withdraw from the study at any time. The remainder of the consultation consisted of a full case history (Appendix C), physical examination (Appendix D), and a cervical spine (Appendix E) and shoulder regional examination (Appendix F) to ensure the following inclusion and exclusion criteria were met:

### 3.6.1 Inclusion Criteria

1) All subjects were between 18 and 35 years of age, as this was the age range of the male chiropractic students at DUT at the time of the study (DUT, 2008).
2) Subjects had to be registered chiropractic students at the DUT.
3) Only males were used in the study. Males have been shown to be significantly and consistently stronger than women (www.isokinetics.net, 2009; Dvir, 2004). Limiting the study to males allowed for sample homogeneity (Mouton, 1996).
4) For sample homogeneity subjects had to be right hand dominant. Peak torque was measured on the dominant side only (i.e. right hand side) (van Meerteren *et al*., 2002).
5) The subjects had to have a fixation between C4-C7 on the right, as the innervation of the rotator cuff muscles originates from the nerve roots exiting the vertebral canal at these levels (Moore and Dalley, 2006).
6) All subjects had to sign an informed consent form indicating their agreement to participate in the study (Appendix B).
7) Subjects had to be asymptomatic in terms of neck and shoulder pain to eliminate the regional effects of pain (Ingersoll, Palmieri and Hopkins, 2003; Suter *et al.,* 2000).

### 3.6.2 Exclusion Criteria

1) Subjects demonstrating any neurological deficits (Edmund 1993).
2) A history of fracture or trauma to the neck and/or shoulder region (Peterson and Bergman, 2002; Edmund, 1993).

3) A history of surgery to the cervical spine or shoulder.
4) Any relative contra-indications to cervical spine manipulation, including but not limited to (Peterson and Bergman, 2002; Edmund, 1993; Gatterman, 1990):
   - Disc prolapsed,
   - Spondylolisthesis,
   - Severe scoliosis,
   - Vertebrobasilar insufficiencies,
   - Hypertension,
   - Systemic disorders affecting the cervical region including arthritis, infections and malignancies.
6) Subjects had to refrain from having any manipulative procedures performed on them either for treatment or during spinal manipulative practical classes for at least one week prior to and for the duration of the study (three weeks).
7) Subjects who experienced pain post manipulation or post cybex testing were excluded from the study.
8) The subjects were asymptomatic, however, they were excluded if they developed any contraindications to isokinetic testing, which included but was not limited to (Chan and Maffuli, 1996):

   Relative Contra-indications
   - Pain,
   - Limited range of motion,
   - Effusion / synovitis,
   - Chronic third degree sprain and
   - Subacute strain (musculo-tendinous unit).

   Absolute Contra-indications
   - Soft tissue healing constraints,
   - Severe pain,
   - Extremely limited range of motion,
   - Severe effusion,
   - Fractures,
   - Acute strain (musculo-tendinous unit) and
   - Acute sprain.

## 3.7 Clinical Procedure

The first 40 subjects who met the inclusion and exclusion criteria at the initial consultation were invited to participate in the study. All dropouts were replaced until 40 subjects were recruited. No treatment or Cybex measurements were performed at the initial consultation. Due to the small population of male chiropractic students (N=93) a sample size of 40 subjects was estimated as a reasonable sample size to account for subjects that did not meet the inclusion criteria.

The second consultation took place at the Sharks Academy Medical Centre where the subjects underwent a familiarization session on the Cybex. The familiarization session decreased the effect of practice based improvement ('learning') on the test results (Wright, 2008; Dvir, 2004). It ensured that maximal effort was applied at the test session as the subjects were already familiar with the movements required on the machine. The Cybex testing was done by a registered biokineticist, who agreed to work with the researcher on this study (Appendix H).

The familiarization session involved the subjects being seated on the Cybex where they underwent an initial warm up of six repetitions of abduction and adduction, at 50% of their maximum strength. There was a one minute rest and then they performed six repetitions of abduction and adduction; three at 80% and three at 100% of their maximum strength. The Cybex was then set up for internal and external rotation where the subjects were seated and the right arm was in a modified neutral position with the elbow flexed to 90 degrees. They then underwent a warm up of six repetitions for internal and external rotation, at 50% of their maximum strength. There was a one minute rest and then they performed six repetitions of internal and external rotation; three at 80% and three at 100% of their maximum strength. No manipulation took place at the familiarization session.

The subjects were then scheduled for their next consultation to begin with the intervention.

### 3.7.1 Interventions

The third consultation took place at the Sharks Academy Medical Center, a minimum of 24hrs after the familiarization session. This was to allow for full recovery of the muscles (Wright, 2008).

The third consultation consisted of both Group One and Group Two undergoing Cybex testing pre and post manipulation of the cervical spine to determine the peak torque of the rotator cuff muscles.

The Cybex was used to determine the objective measurement of peak torque of the rotator cuff muscles. Four movements were measured: internal rotation, external rotation, abduction and adduction. Even though adduction is not a primary movement of the rotator cuff muscles, the Cybex measures abduction and adduction simultaneously and therefore, adduction was included in the study. Peak Torque was measured in Newton-meters (Nm) and indicated the point in the range of motion of the shoulder joint where the muscles acting on the joint reached maximum force.

3.7.1.1 <u>Cybex Testing:</u>

The subjects were seated on the Cybex machine which was firstly set up for abduction and adduction. They performed a warm up of five sub-maximal isokinetic contractions for abduction and adduction followed by a one minute rest. They then performed five maximal contractions and the maximum peak torque reading of the five repetitions was recorded (Wright, 2008; Chan and Maffulli, 1996). The Cybex was then immediately set up for internal and external rotation which took no longer than one minute. The subjects were seated on the Cybex and performed a warm up of five sub-maximal isokinetic contractions for internal and external rotation, followed by a one minute rest. They then performed five maximal contractions and the maximum peak torque reading of the five repetitions was recorded (Wright, 2008; Chan and Maffulli, 1996). The patient received verbal encouragement from the biokineticist during the isokinetic contractions to ensure maximal effort (www.isokinetics.net, 2009). Two sets of readings were recorded; one prior to manipulation and one immediately following the manipulation. The subjects were given a four minute rest between pre and post manipulation readings and not more than one minute was allowed to elapse between the cervical spine manipulation and the post manipulation testing (Dixon, 2005).

3.7.1.2 Spinal Manipulation:

Spinal manipulation took place at a fixated spinal motion segment between C4-C7 and followed the techniques set out by Schafer and Faye (1990). If the subject had more than one fixation, the motion segment with the greatest decrease in motion was manipulated. The subject's cervical spine was motion palpated (Schafer and Faye, 1990) by the researcher in the supine position to determine the location of the fixation. A qualified chiropractor then independently motion palpated the subject. The researcher then discussed the location of the fixation with the qualified chiropractor. Humphreys *et al.,* (2004) justify the clinical use of motion palpation in the diagnosis of cervical spine fixations; however the inter-examiner reliability of motion palpation has been questioned. Research shows a low level of inter-examiner reliability in the middle cervical spine and a moderate level in the lower cervical spine (Deboer *et al*., 1985). Therefore if there was a discrepancy between the researcher and the qualified chiropractor, the subject was manipulated by the researcher at the level determined by the qualified chiropractor. The subject's cervical spine was then reassessed post manipulation by both the researcher and the qualified chiropractor to determine whether the fixation had improved or not. Therefore, the criterion for successful manipulation was an improvement in the quality and point of the end feel of the specific facet joint on motion palpation (Bergmann, Peterson and Lawrence, 1993). A record of the level of manipulation was kept.

### 3.7.2 Follow up procedures

Group One received only one manipulation at the third consultation where Cybex measurements were taken pre and post manipulation. A second Cybex measurement was taken two weeks later to measure the peak torque of the rotator cuff muscles with no further manipulations.

Group Two received one manipulation at the third consultation where the initial pre and post manipulation Cybex measurements were taken. A further three manipulations were administered in the following two weeks, with a minimum of one day between subsequent manipulations, equalling a total of four manipulations. This treatment schedule was chosen to replicate a recommended treatment schedule for chiropractic patient of two treatments per week for three weeks (Nilsson *et al*., 1997); however it was shortened to two treatments per week for two weeks as the subjects were asymptomatic and repeated manipulation of the same motion segment in the absence of a fixation may have resulted in neck pain. A second Cybex measurement was then taken two weeks after the first manipulation and at least two days after the final manipulative procedure. This was to ensure that the immediate effects of the last manipulation did not influence the Cybex measurement, as Botha (2005) showed that peak torque of the rotator cuff muscles had mostly returned to normal 24 hours post manipulation

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## 3.8 Outcome Measures

### 3.8.1 Objective Data

#### 3.8.1.1 Cybex: Isokinetic Muscle Testing

The Cybex was used to collect the objective measurements of peak torque of the rotator cuff muscles. Isokinetic dynamometers have been shown to be reliable (Dvir, 2004, Callaghan *et al*., 2000, Chan and Maffulli, 1996). The technical accuracy and reliability of isokinetic machines have shown correlation coefficients between 0.93 and 0.99 (Chan and Maffuli, 1996). This is supported by Callaghan *et al.*, (2000), who concluded that isokinetic testing for peak torque, average power and total work using dynamometry is highly reliable in both healthy subjects and patients. Furthermore, it has provided valuable information for the evaluation of shoulder strength ratios, as well as rehabilitation and conditioning of athletes (Scotville *et al.,* 1997). The Cybex was therefore chosen to record the outcome measures of rotator cuff peak torque to determine if there was a functional change in rotator cuff peak torque following manipulation as opposed to measuring a change in muscle activity as measure by EMG in previous studies (Naidoo, 2002; Herzog *et al.*, 1999; Rebechini-Zasadny *et al*., 1981)

### 3.8.2 Subjective data

No subjective data was taken as the sample population was asymptomatic and therefore, subjective measures would not be assessed.

## 3.9 Statistical Analysis

The research data was captured in an MS Excel spread sheet and SPSS version 15.0 (SPSS Inc., Chicago, Illinois, USA) was used to analyze the data. A $p$ value $<0.05$ was considered as statistically significant.

The demographic data was compared between the two treatment groups using t-tests for quantitative normally distributed variables, Pearson's chi square tests for categorical nominal or ordinal variables, and Mann-Whitney tests for ordinal non-normally distributed variables.

Baseline (pre-adjustment) quantitative outcomes were compared between the two groups using t-tests. To determine the effect of the single and multiple manipulations on peak torque, intra-group comparisons of outcomes over time were achieved using repeated measures ANOVA generalized linear models and Pearson's correlations. The time points were compared using simple contrasts.

To compare the effect of the single versus the multiple manipulations, repeated measures ANOVA generalized linear models were used with inter-group comparisons. A significant time*group interaction effect indicated a statistically significant differential treatment effect. Profile plots were generated to compare the trends visually. (Esterhuizen, 2009).

# CHAPTER FOUR

# Presentation of results

## 4.1 Introduction

This chapter includes the statistical analysis of the data collected during the study. It discusses the demographic data obtained from the 40 subjects who participated in the study, which were divided into two equal groups of 20 subjects. Intra-group analysis and inter-group analysis reflects the changes that occurred in peak torque of the rotator cuff muscles over the two week period.

**Key for Abbreviations/Symbols in Tables and Graphs:**

N : Number of subjects

Post : Post manipulation

Pre : Pre-manipulation

Std : Standard

Time : Measurement intervals

Time 1 – Pre-manipulation reading

Time 2 - Post manipulation reading

Time 3 – Two-week follow up reading

Vs : Versus

***** : Indicates the correlation co-efficient present between two variables

## 4.2 Results

### 4.2.1 Demographics

Forty subjects were stratified into two equal groups according to their year of study to ensure an equal distribution between the two groups in terms of the subjects' year of study. The demographics and baseline (pre-adjustment) outcomes were checked for consistency between the two groups to see if the two groups were equivalent at the beginning of the study. Thus, any changes found at the endpoints would reflect the intervention's effect only and not chance or coincidence (Esterhuizen, 2009).

#### 4.2.1.1 Age

Table 4.1 shows that the mean ages of both groups were very similar and not significantly different (*p*=0.506).

**Table 4.1 : Comparison of mean age between treatment groups**

| | Group | N | Mean | Std. Deviation | Std. Error Mean | *p* value |
|---|---|---|---|---|---|---|
| Age | Single manipulation group | 20 | 23.10 | 3.243 | 0.725 | 0.506 |
| | Multiple manipulation group | 20 | 23.80 | 3.350 | 0.749 | |

#### 4.2.1.2 Year of Study

There was no significant difference between the groups in terms of year of study (*p*=0.758), as the subjects were stratified to either the single or multiple manipulation group according to their year of study. The proportions in the different years were similar between the groups.

**Table 4.2: Cross-tabulation of group by year of study**

| | | | Year of Study | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | |
| Group | Single manipulation group | Count | 4 | 3 | 3 | 3 | 2 | 5 | 20 |
| | | % within group | 20% | 15% | 15% | 15% | 10% | 25% | 100% |
| | Multiple manipulation group | Count | 3 | 3 | 3 | 3 | 3 | 5 | 20 |
| | | % within group | 15% | 15% | 15% | 15% | 15% | 25% | 100% |

Mann-Whitney U = 188, *p*=0.758

#### 4.2.1.3 Weight

There was no statistically significant difference between the two groups in terms of weight (*p*=0.498).

**Table 4.3: Comparison of mean weight between treatment groups**

| | Group | N | Mean | Std. Deviation | Std. Error Mean | *p* value |
|---|---|---|---|---|---|---|
| Weight | Single manipulation group | 20 | 77.6 | 13.18 | 2.95 | 0.498 |
| | Multiple manipulation group | 20 | 80.15 | 10.15 | 2.27 | |

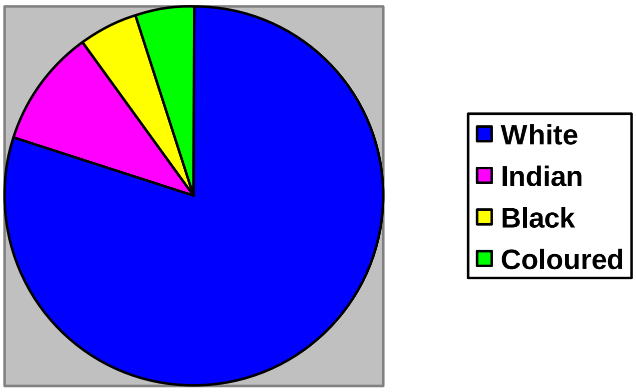
#### 4.2.1.4 Race

Table 4.4 shows that the proportion of different race groups was identical between the treatment groups.

**<u>Table 4.4: Cross-tabulation of group by race</u>**

| | | | Race | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | White | Indian | Black | Coloured | |
| Group | Single manipulation group | Count | 16 | 2 | 1 | 1 | 20 |
| | | % within group | 80% | 10% | 5% | 5% | 100% |
| | Multiple manipulation group | Count | 16 | 2 | 1 | 1 | 20 |
| | | % within group | 80% | 10% | 5% | 5% | 100% |

Pearson's chi square 0.00, *p*=1.000




**<u>Figure 4.1: Race distribution for both groups</u>**

### 4.2.2 Baseline outcomes between groups

#### 4.2.2.1 Level of fixation

Similarly, no significant difference was found between the groups in terms of level of fixation ($p$=0.577, Table 4.5), however, the single manipulation group had more fixations at C5 and the multiple manipulation group had more fixations at C6 and C7.

**Table 4.5: Cross-tabulation of group by level of fixation**

| | | | Level of fixation | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | C4 | C5 | C6 | C7 | |
| Group | Single manipulation group | Count | 6 | 8 | 6 | 0 | 20 |
| | | % within group | 30% | 40% | 30% | 0% | 100% |
| | Multiple manipulation group | Count | 6 | 5 | 8 | 1 | 20 |
| | | % within group | 30% | 25% | 40% | 5% | 100% |

Pearson's chi square 1.978, $p$=0.577

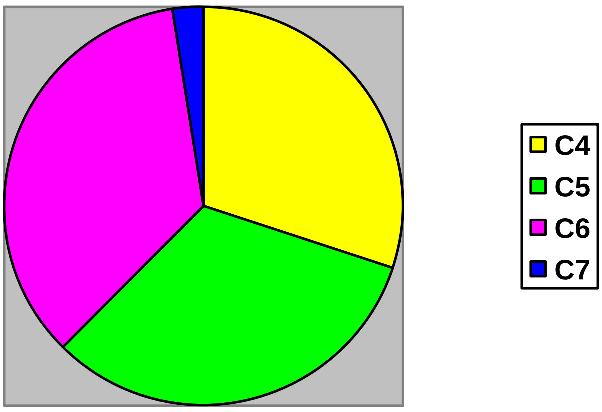



**Figure 4.2: Level of fixation for both groups**

#### 4.2.2.2 Baseline Peak Torque

Table 4.6 shows that only pre-adjustment abduction was significantly different at baseline between the groups ($p$=0.04). The other baseline outcomes did not differ significantly between the groups.

**Table 4.6: Comparison of pre-adjustment reading between the two treatment groups**

| | Group | N | Mean | Std. Deviation | Std. Error Mean | *p* value |
|---|---|---|---|---|---|---|
| Reading 1- pre-adjustment internal rotation | Single manipulation group | 20 | 66.55 | 18.115 | 4.051 | 0.328 |
| | Multiple manipulation group | 20 | 72.20 | 17.940 | 4.012 | |
| Reading 2- pre-adjustment external rotation | Single manipulation group | 20 | 31.00 | 6.553 | 1.465 | 0.315 |
| | Multiple manipulation group | 20 | 33.35 | 7.962 | 1.780 | |
| Reading 3- pre-adjustment abduction | Single manipulation group | 20 | 53.40 | 15.038 | 3.363 | **0.040** |
| | Multiple manipulation group | 20 | 64.85 | 18.852 | 4.215 | |
| Reading 4- pre-adjustment adduction | Single manipulation group | 20 | 102.35 | 31.098 | 6.954 | 0.508 |
| | Multiple manipulation group | 20 | 109.05 | 32.238 | 7.209 | |

## 4.2.3 Objective One:

To determine the effect of a single cervical spine manipulation on peak torque of the rotator cuff muscles utilizing the Cybex.

### 4.2.3.1 Single Manipulation - Abduction

Abduction increased over time, but not statistically significantly overall (*p*=0.230). There was a borderline non-significant change between pre and two weeks post manipulation (*p*=0.085) and a non-significant change between pre and post manipulation (*p*=0.681).

**Table 4.7: Intra-group comparison of time effects of abduction for the single manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.849 | 0.230 |
| Time post vs. pre | F=0.174 | 0.681 |
| Time 2 weeks post vs. pre | F=3.301 | 0.085 |

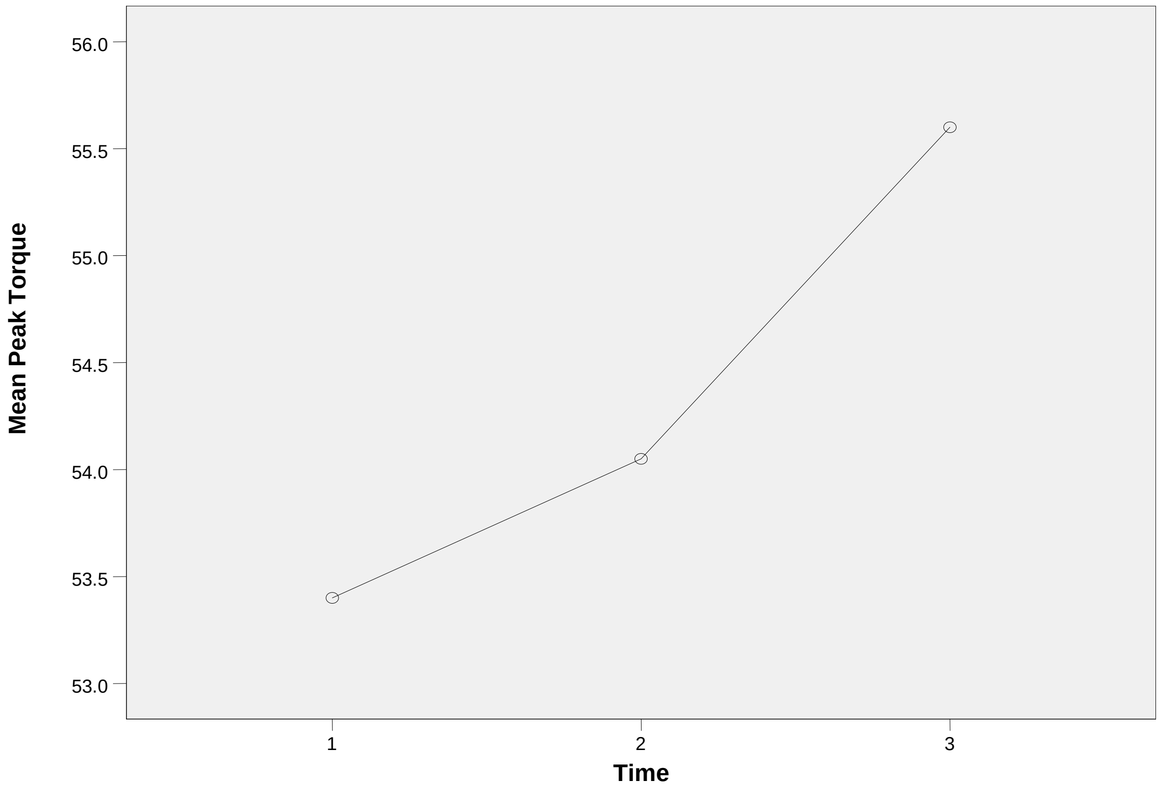


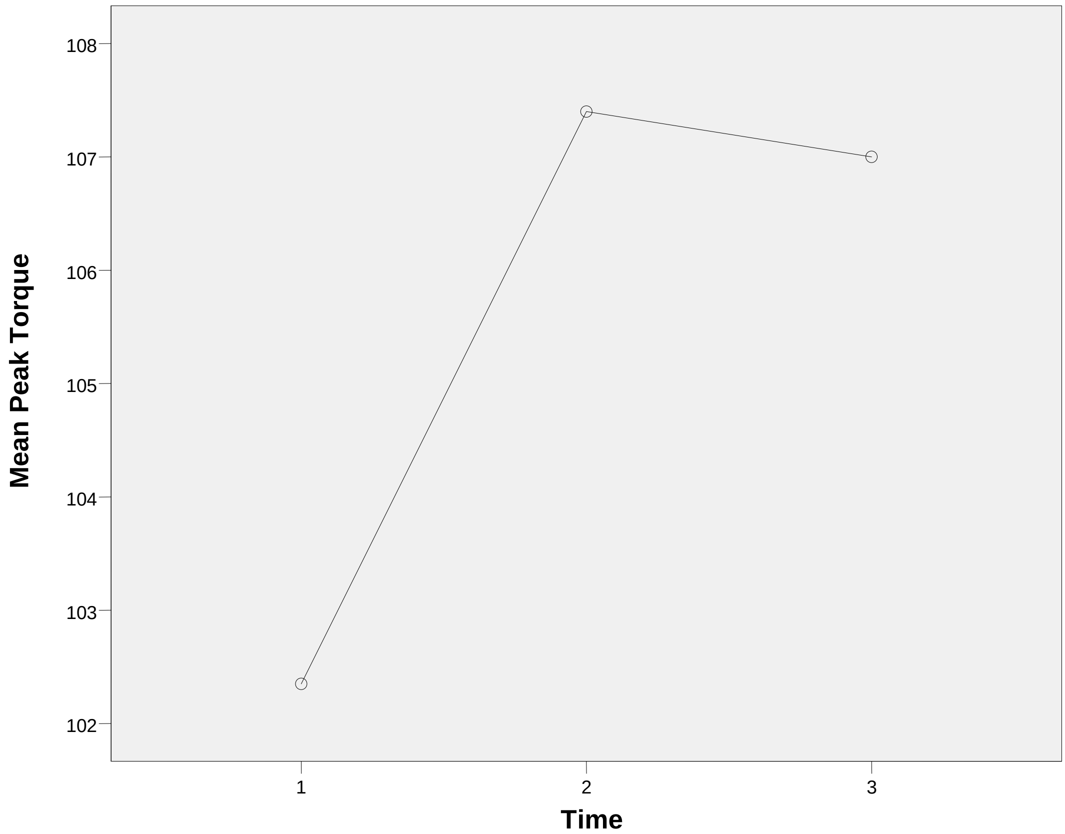

**Figure 4.3: Mean abduction by time in the single manipulation group**

#### 4.2.3.2 Single Manipulation - Adduction

Adduction also increased but not overall significantly (*p*=0.114). Between pre and post manipulation there was an almost significant increase (*p*=0.052) and between pre and two weeks post manipulation the change was also almost statistically significant (*p*=0.060) but there was a slight decrease between post manipulation and the two week follow up (Table 4.8).

**<u>Table 4.8: Intra-group comparison of time effects of adduction for the single manipulation group</u>**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.785 | 0.114 |
| Time post vs. pre | F=4.285 | 0.052 |
| Time 2 weeks post vs. pre | F=3.995 | 0.060 |




**<u>Figure 4.4: Mean adduction by time in the single manipulation group</u>**

#### 4.2.3.3 Single Manipulation - Internal Rotation

In terms of internal rotation there was no significant change overall (*p*=0.809). There was a non-significant change between pre and post manipulation (*p*=0.627) and between pre and two weeks post manipulation (*p*=0.673). Figure 4.3 shows that there was a decrease between pre and post manipulation in internal rotation and a small increase at the two-week follow up.

**Table 4.9: Intra-group comparison of time effects of internal rotation for the single manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.977 | 0.809 |
| Time post vs. pre | F=0.244 | 0.627 |
| Time 2 weeks post vs. pre | F=0.184 | 0.673 |

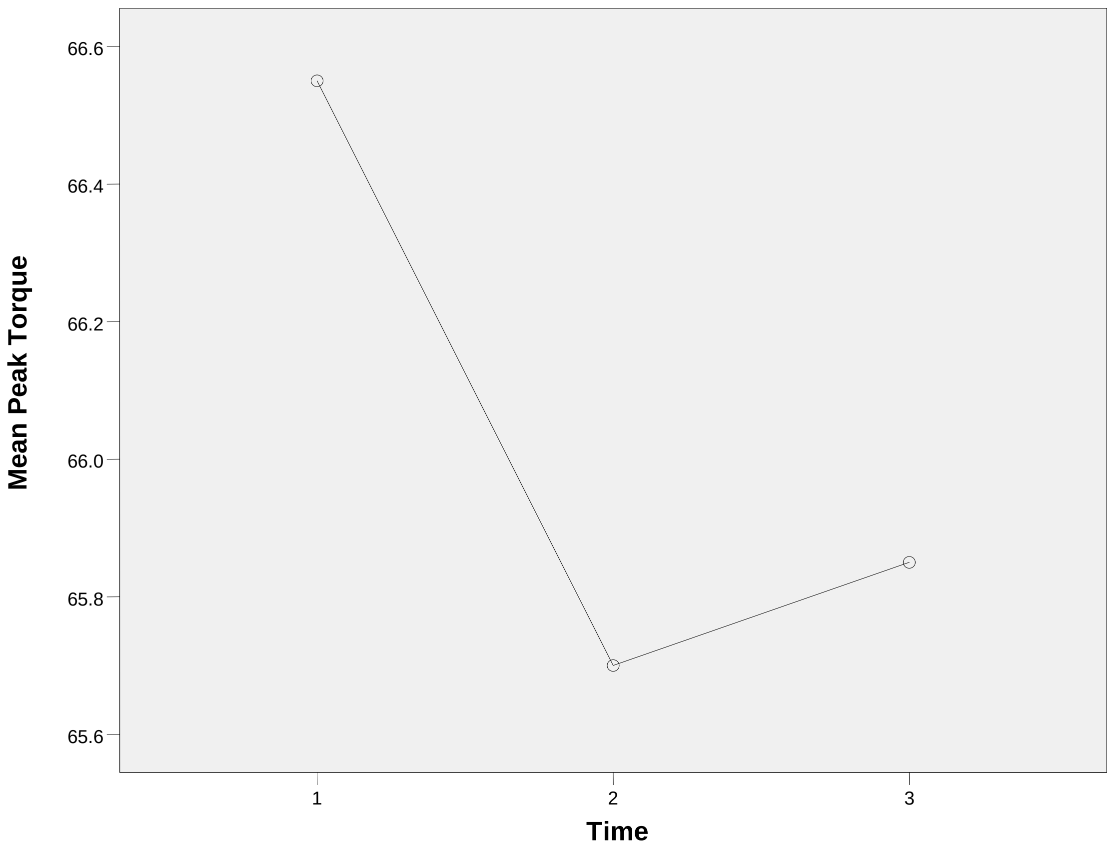



**Figure 4.5: Mean internal rotation by time in the single manipulation group**

#### 4.2.3.4 Single Manipulation - External Rotation

Table 4.10 shows that there was no significant overall change in external rotation ($p$=0.178). There was a borderline non-significant decrease between pre and post manipulation ($p$=0.064) but a non-significant change between pre and two weeks post manipulation ($p$=0.446).

**Table 4.10: Intra-group comparison of time effects of external rotation for the single manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.825 | 0.178 |
| Time post vs. pre | F=3.862 | 0.064 |
| Time 2 weeks post vs. pre | F=0.605 | 0.446 |

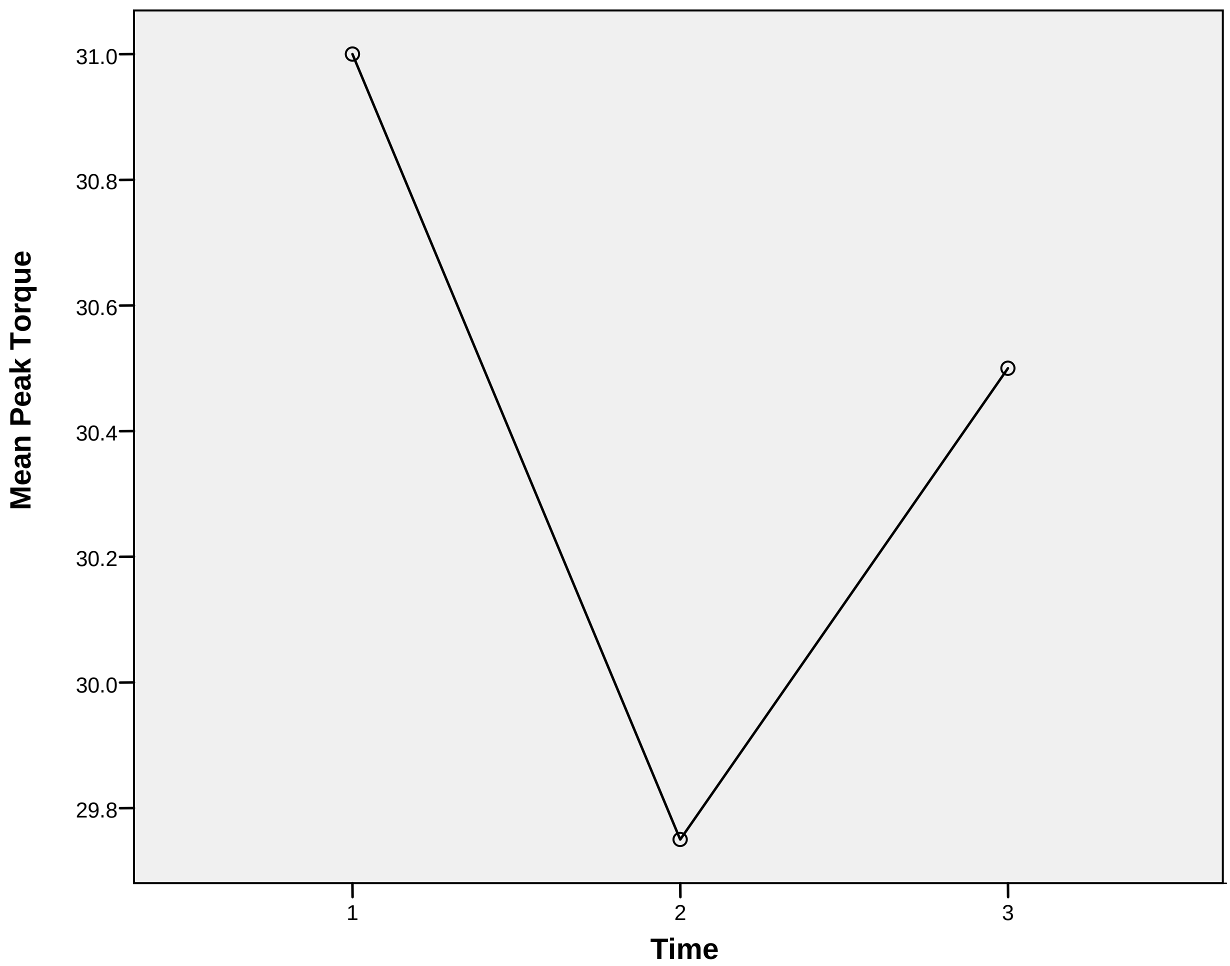



**Figure 4.6: Mean external rotation by time in the single manipulation group**

### 4.2.4 Objective Two:

To determine the effect of multiple cervical spine manipulations on peak torque of the rotator cuff muscles utilizing the Cybex.

#### 4.2.4.1 Multiple Manipulation - Abduction

Abduction decreased over time, but not statistically significantly overall (*p*=0.623) nor between pre and post manipulation (*p*=0.870) or pre manipulation and the two-week follow up (*p*=0.326) (Table 4.10).

**Table 4.11: Intra-group comparison of time effects of abduction for the multiple manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.949 | 0.623 |
| Time post vs. pre | F=0.028 | 0.870 |
| Time 2 weeks post vs. pre | F=1.019 | 0.326 |

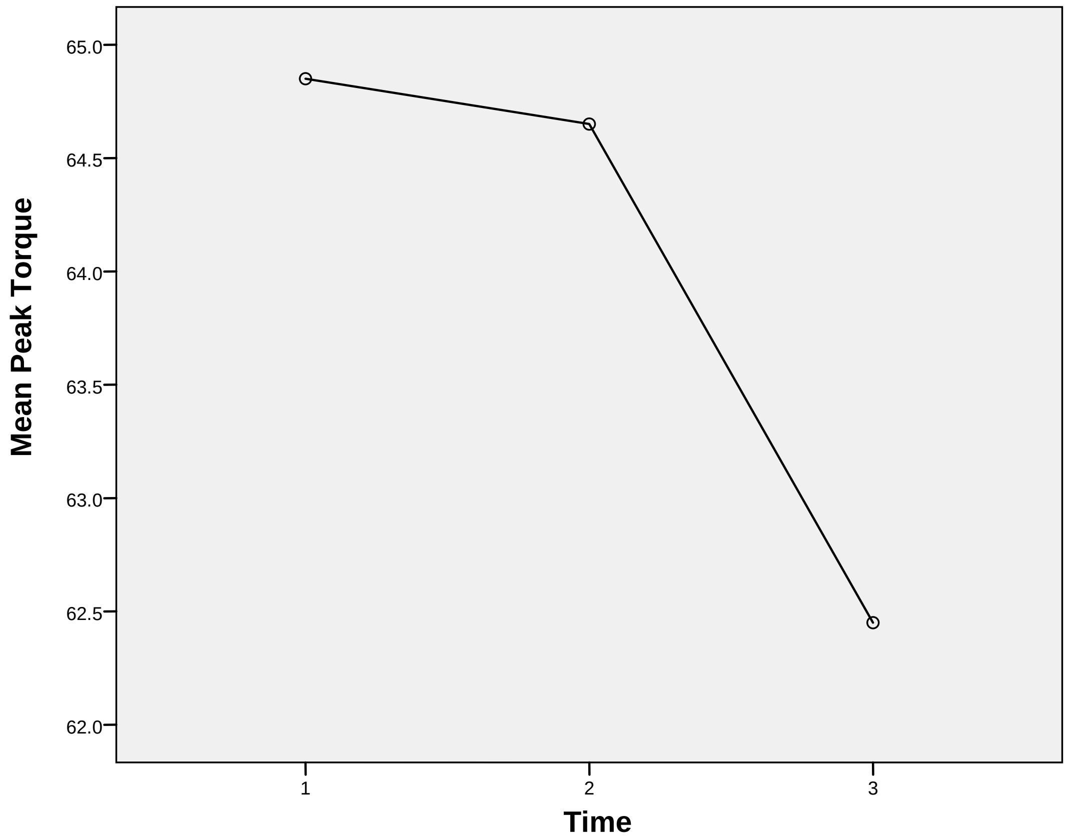



**Figure 4.7: Mean abduction by time in the multiple manipulation group**

#### 4.2.4.2 Multiple Manipulation - Adduction

Adduction also increased, but not overall significantly ($p$=0.371). Between pre and post manipulation there was a steep but non-significant increase ($p$=0.171), but a smaller change at the two-week follow up ($p$=0.258) (Table 4.12).

**Table 4.12: Intra-group comparison of time effects of adduction for the multiple manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.896 | 0.371 |
| Time post vs. pre | F=2.203 | 0.171 |
| Time 2 weeks post vs. pre | F=1.358 | 0.258 |

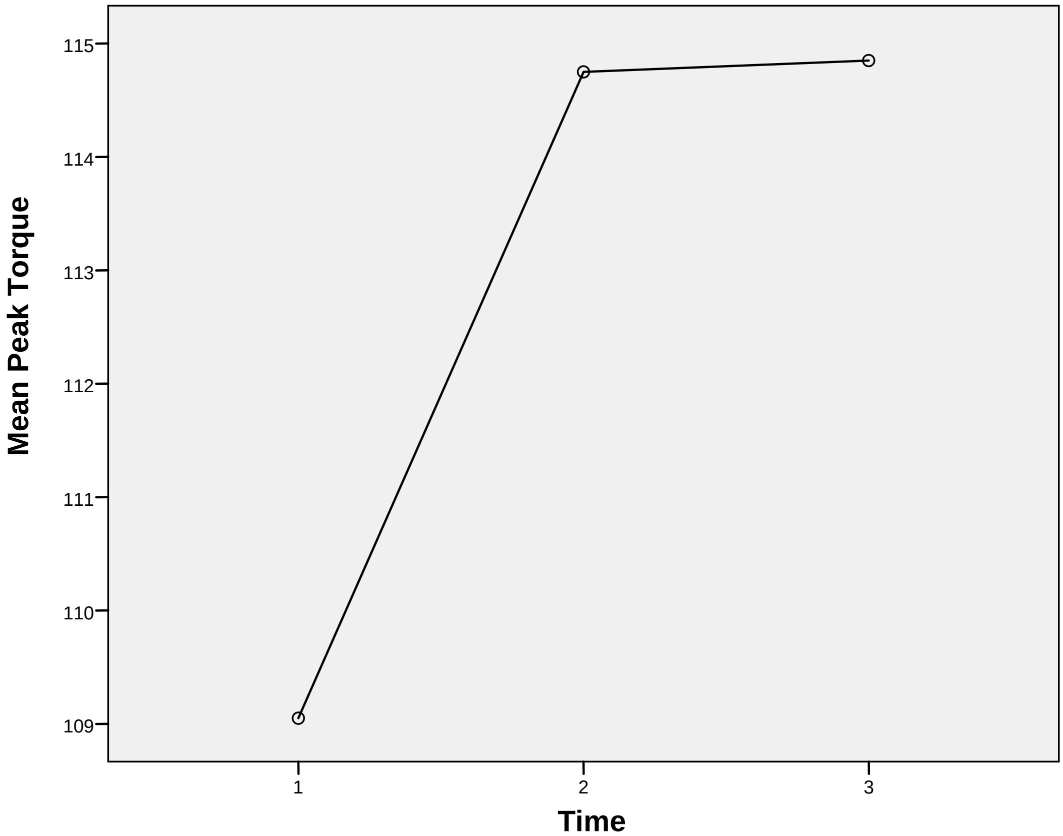



**Figure 4.8: Mean adduction by time in the multiple manipulation group**

#### 4.2.4.3 Multiple Manipulation - Internal Rotation

There was an overall non-significant change over time for internal rotation (*p*=0.385). There was a non-significant decrease between pre and post manipulation (*p*=0.272) with a non-significant increase at the two-week follow up (*p*=0.931) (Table 4.13).

**Table 4.13: Intra-group comparison of time effects of internal rotation for the multiple manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.899 | 0.385 |
| Time post vs. pre | F=1.282 | 0.272 |
| Time 2 weeks post vs. pre | F=0.008 | 0.931 |

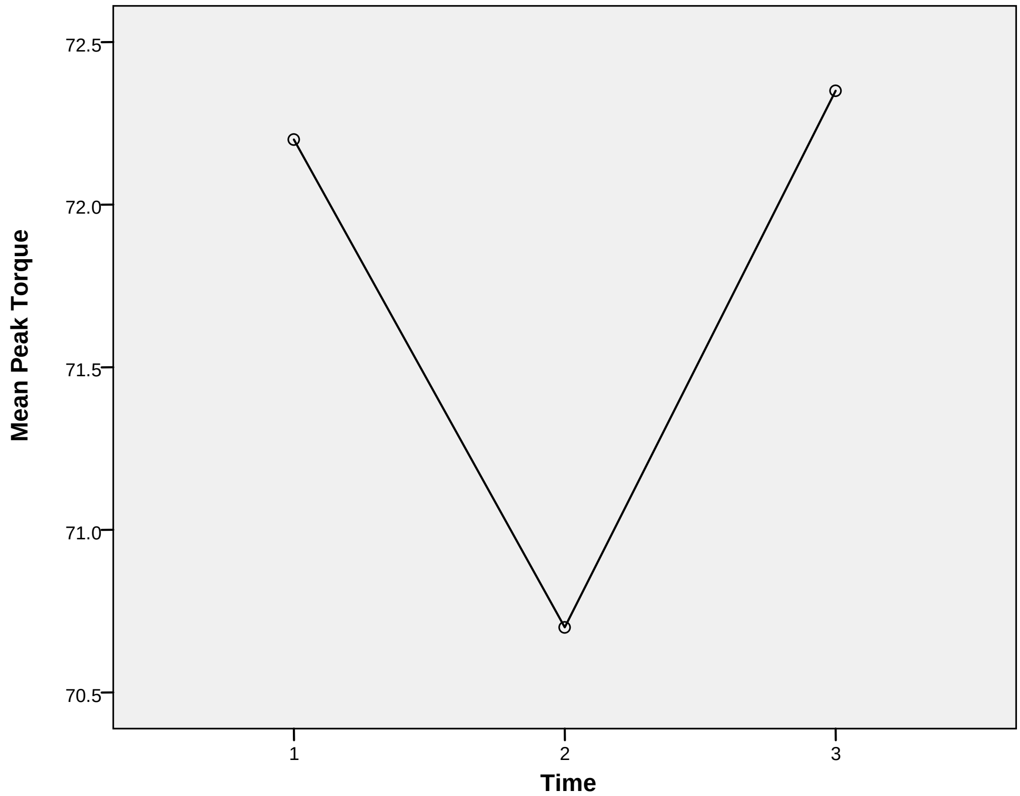



**Figure 4.9: Mean internal rotation by time in the multiple manipulation group**

#### 4.2.4.4 Multiple Manipulation - External Rotation

Table 4.14 shows that there was no significant overall change in external rotation ($p$=0.343). There was a very slight decrease between pre and post manipulation ($p$=0.875), followed by a steep increase at the two-week follow up, but this was non-significant ($p$=0.179).

**Table 4.14: Intra-group comparison of time effects of external rotation for the multiple manipulation group**

| Effect | Statistic | *p* value |
|---|---|---|
| Time (overall) | Wilk's lambda=0.888 | 0.343 |
| Time post vs. pre | F=0.025 | 0.875 |
| Time 2 weeks post vs. pre | F=1.944 | 0.179 |

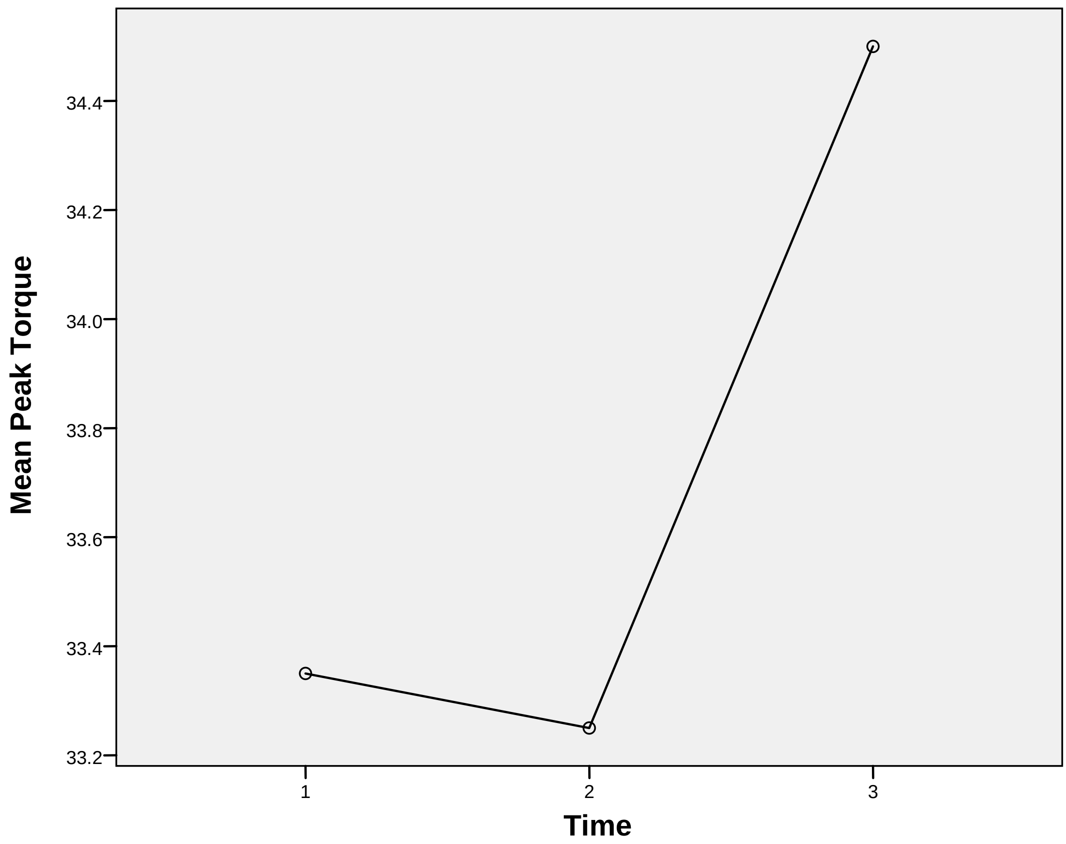



**Figure 4.10: Mean external rotation by time in the multiple manipulation group**

### 4.2.5 Intra-group Correlations between changes in outcomes over two weeks

#### 4.2.5.1 Single manipulation group

Table 4.15 shows that there was a significant positive correlation between changes in internal rotation and external rotation in the single manipulation group ($r$=0.477, $p$=0.034). Thus, the changes occurred in the same direction and if one measure increased so did the other and vice versa. There were no other correlations in this group.

**<u>Table 4.15: Pearson's correlations between changes in outcomes from pre-treatment to 2 weeks follow up in the single manipulation group</u>**

| | | Change in internal rotation | Change in external rotation | Change in abduction | Change in adduction |
|---|---|---|---|---|---|
| Change in internal rotation | Pearson Correlation | 1 | 0.477(*) | -0.046 | 0.265 |
| | Sig. (2-tailed) | | 0.034 | 0.849 | 0.259 |
| | N | 20 | 20 | 20 | 20 |
| Change in external rotation | Pearson Correlation | 0.477(*) | 1 | -0.088 | -0.085 |
| | Sig. (2-tailed) | 0.034 | | 0.712 | 0.721 |
| | N | 20 | 20 | 20 | 20 |
| Change in abduction | Pearson Correlation | -0.046 | -0.088 | 1 | -0.123 |
| | Sig. (2-tailed) | 0.849 | 0.712 | | 0.606 |
| | N | 20 | 20 | 20 | 20 |
| Change in adduction | Pearson Correlation | 0.265 | -0.085 | -0.123 | 1 |
| | Sig. (2-tailed) | 0.259 | 0.721 | 0.606 | |
| | N | 20 | 20 | 20 | 20 |

* Correlation is significant at the 0.05 level (2-tailed).

#### 4.2.5.2 Multiple manipulation group

Table 4.16 shows that there was a significant positive correlation between changes in abduction and adduction in the multiple manipulation group ($r$=0.530, $p$=0.016). Thus, the changes occurred in the same direction and if one measure increased so did the other and vice versa. There were no other correlations in this group.

**Table 4.16: Pearson's correlations between changes in outcomes from pre-treatment to 2 weeks follow up in the multiple manipulation group**

| | | Change in internal rotation | Change in external rotation | Change in abduction | Change in adduction |
|---|---|---|---|---|---|
| Change in internal rotation | Pearson Correlation | 1 | 0.364 | 0.282 | -0.001 |
| | Sig. (2-tailed) | | 0.115 | 0.229 | 0.998 |
| | N | 20 | 20 | 20 | 20 |
| Change in external rotation | Pearson Correlation | 0.364 | 1 | 0.128 | -0.364 |
| | Sig. (2-tailed) | 0.115 | | 0.592 | 0.115 |
| | N | 20 | 20 | 20 | 20 |
| Change in abduction | Pearson Correlation | 0.282 | 0.128 | 1 | 0.530(*) |
| | Sig. (2-tailed) | 0.229 | 0.592 | | 0.016 |
| | N | 20 | 20 | 20 | 20 |
| Change in adduction | Pearson Correlation | -0.001 | -0.364 | 0.530(*) | 1 |
| | Sig. (2-tailed) | 0.998 | 0.115 | 0.016 | |
| | N | 20 | 20 | 20 | 20 |

* Correlation is significant at the 0.05 level (2-tailed).

### 4.2.6 Objective Three:

To compare the effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff utilizing the Cybex.

#### 4.2.6.1 Abduction

Table 4.17 shows that the differential treatment effect was not statistically significant for abduction (*p*=0.246). However, Figure 4.9 shows that there was a definite trend of an effect since the multiple manipulation group decreased over time and the single manipulation group increased over time. However, the changes were slight and not statistically significant.

**Table 4.17: Inter-group comparison of effects for abduction**

| Effect | Statistic | *p* value |
|---|---|---|
| Time | Wilk's lambda=0.998 | 0.969 |
| Time*Group | Wilk's lambda=0.927 | 0.246 |
| Group | F=3.416 | 0.072 |

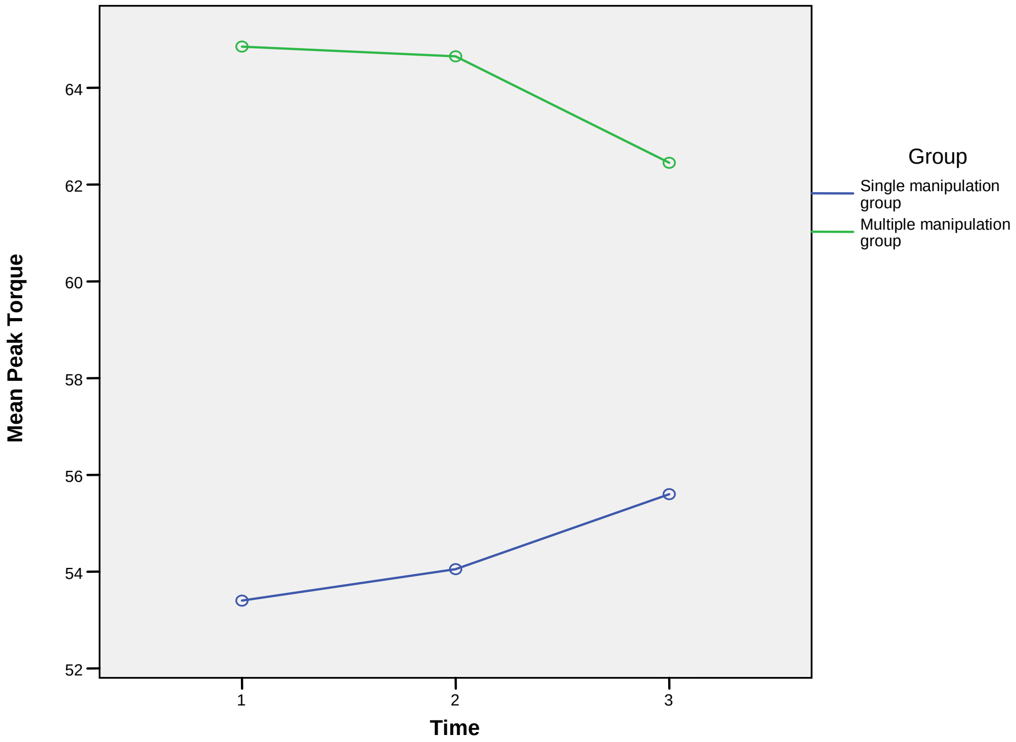



**Figure 4.11: Mean abduction by time and group**

#### 4.2.6.2 Adduction

For adduction there was no difference in the treatment effects of the different groups ($p$=0.979). Figure 4.10 shows that the profiles of the two groups were parallel and followed the same pattern over time.

**Table 4.18: Inter-group comparison of effects for adduction**

| Effect | Statistic | *p* value |
|---|---|---|
| Time | Wilk's lambda=0.868 | 0.073 |
| Time*Group | Wilk's lambda=0.999 | 0.979 |
| Group | F=0.715 | 0.403 |

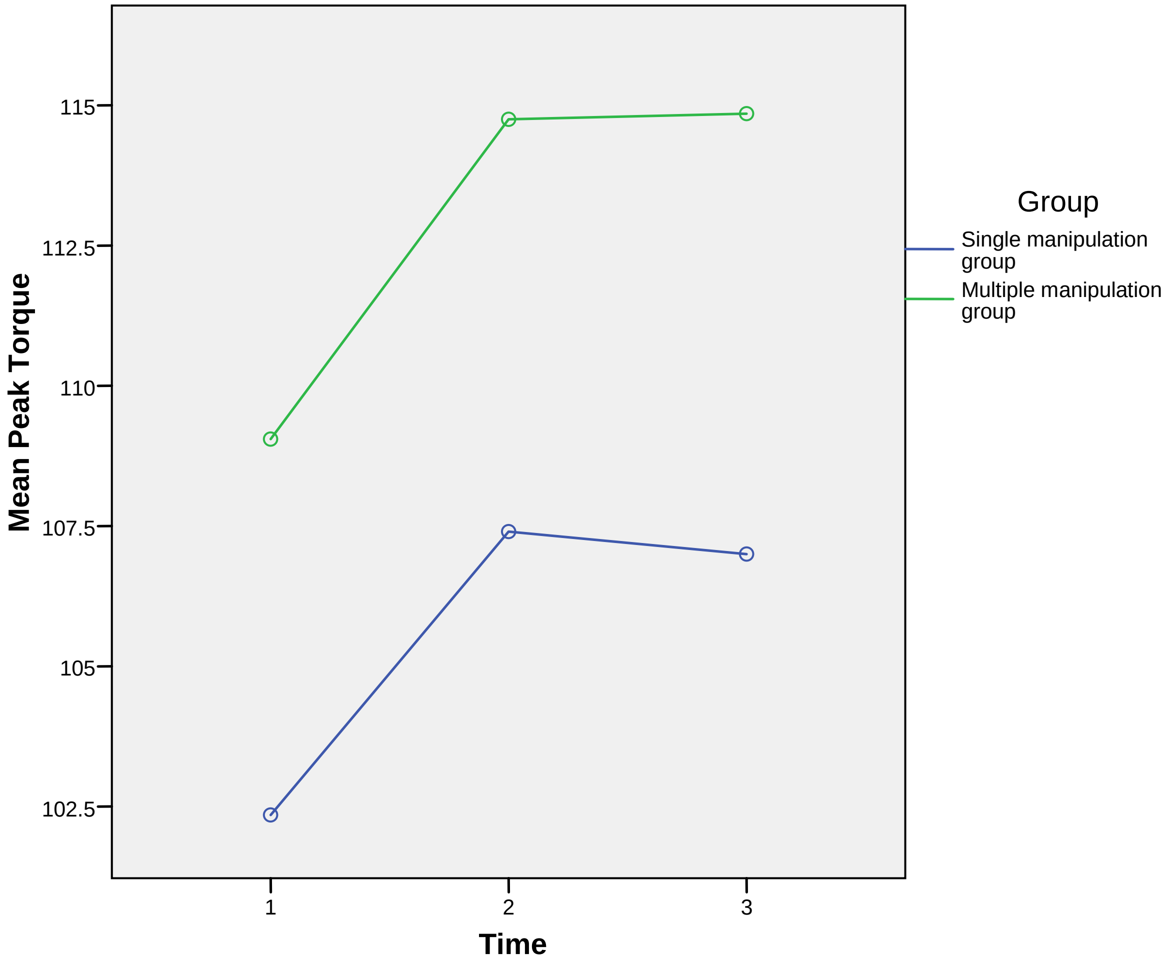



**Figure 4.12: Mean abduction by time and group**

### 4.2.6.3 Internal rotation

There was no evidence of a differential treatment effect in the two groups (*p*=0.872, Table 4.19). Figure 4.11 shows that the two groups' profiles were relatively similar except for a small increase between time 2 and 3 in the multiple manipulation group and a levelling off in the same time period in the single manipulation group.

**Table 4.19: Inter-group comparison of effects for internal rotation**

| Effect | Statistic | *p* value |
|---|---|---|
| Time | Wilk's lambda=0.970 | 0.570 |

| | | |
|---|---|---|
| Time*Group | Wilk's lambda=0.993 | 0.872 |
| Group | F=1.167 | 0.287 |

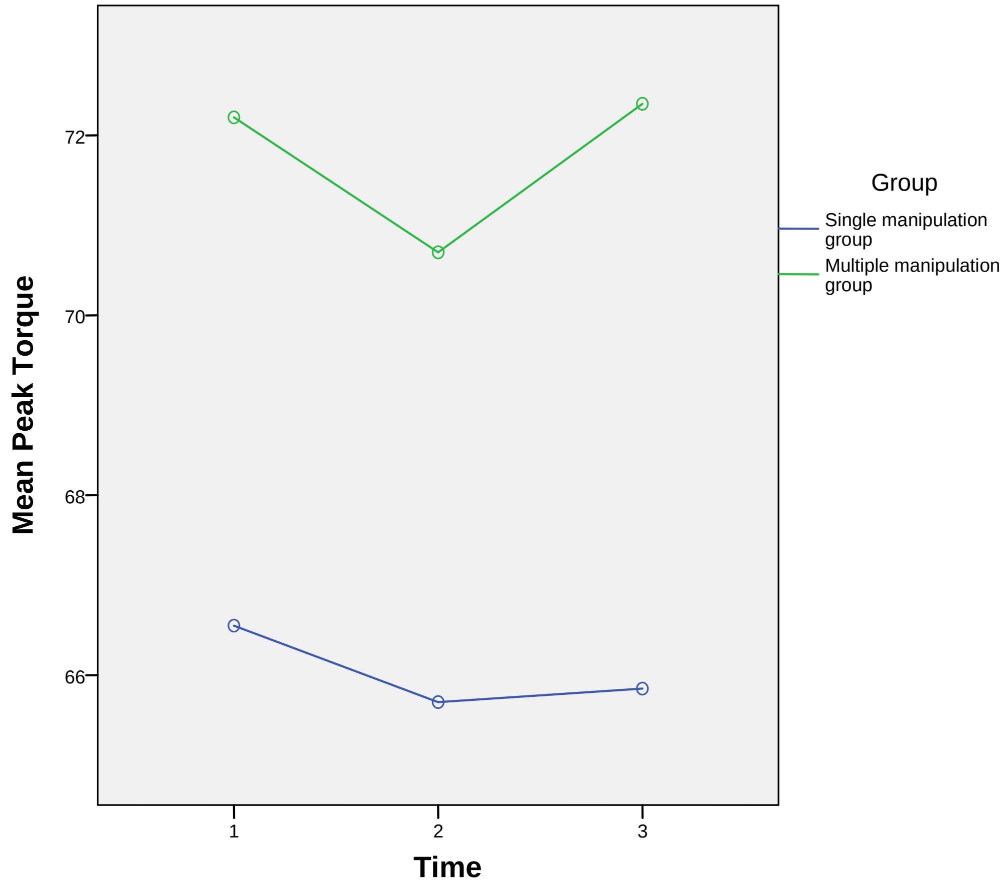



**Figure 4.13: Mean internal rotation by time and group**

#### 4.2.6.4 External rotation

Similarly, there was no statistically significant difference between treatment effects for external rotation of multiple manipulation versus single manipulation ($p$=0.217). Figure 4.12 shows that the multiple manipulation group showed a slightly larger increase over time than the single manipulation group but this difference was slight and not statistically significant.

**Table 4.20: Inter-group comparison of effects for external rotation**

| Effect | Statistic | *p* value |
|---|---|---|
| Time | Wilk's lambda=0.917 | 0.201 |
| Time*Group | Wilk's lambda=0.921 | 0.217 |
| Group | F=2.283 | 0.139 |

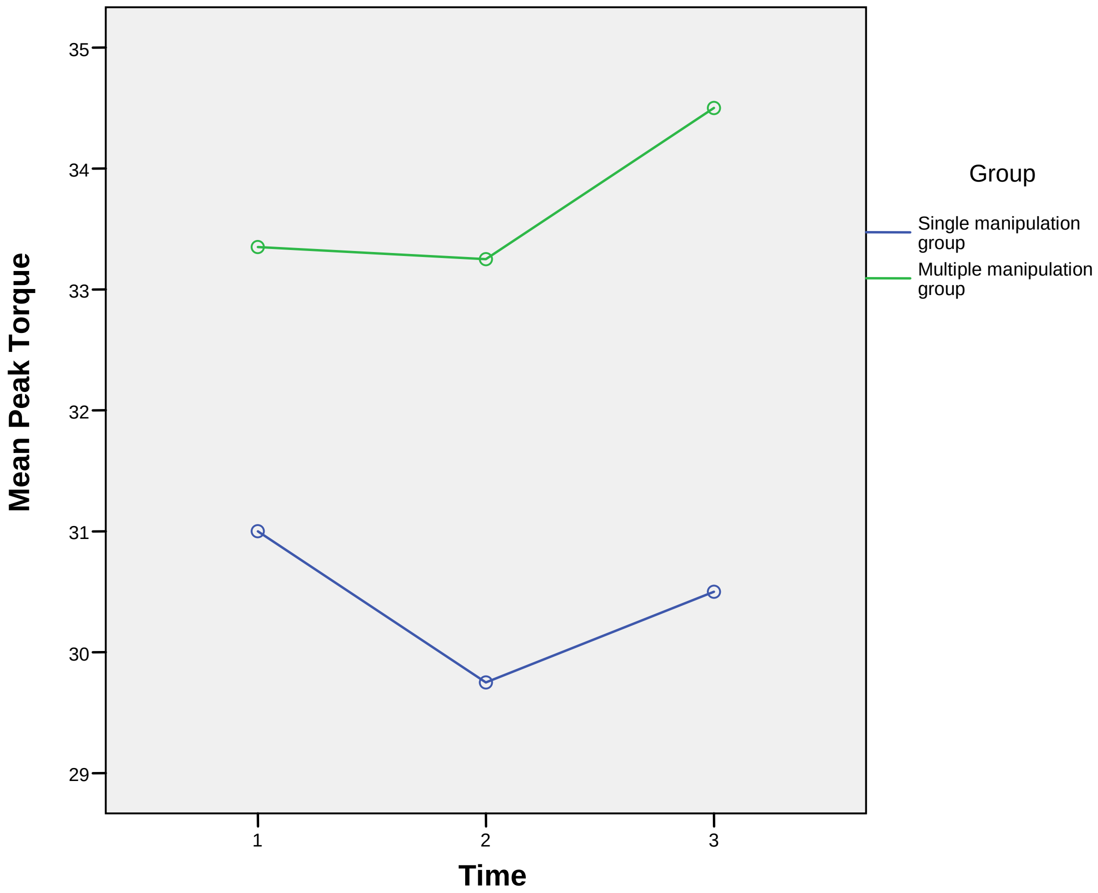



**Figure 4.14: Mean external rotation by time and group**

## 4.3 Summary and conclusion

At baseline, both the single and multiple manipulation groups were very similar in terms of age, year of study of the subjects, race and level of fixation. The baseline peak torque readings did not differ significantly between the two groups except for abduction where the multiple manipulation group had a significantly higher reading.

The intra-group changes over time were not statistically significant in either of the groups. In both the single and multiple manipulation groups there was a decrease between pre and post manipulation peak torque for internal and external rotation and peak torque either increased or remained the same for abduction and adduction between pre and post manipulation. Between post manipulation and the two-week follow up readings, there was mostly a non-significant increase in peak torque readings except for adduction in the single manipulation group and abduction in the multiple manipulation group, which decreased non-significantly.

Inter-group comparison of changes over time by group also showed no statistically significant effect in the multiple manipulation group compared with the single manipulation group for any outcome measurements. In the case of abduction there was a non-significant trend towards a treatment effect, in that the multiple manipulation group showed a general decrease over time while the single manipulation group showed an increase over time.

# CHAPTER FIVE
# Discussion of results

## 5.1. Introduction

This chapter discusses the results of the study including the demographics of the sample in terms of age, race and year of study; baseline comparisons of the two groups followed by both intra-group and inter-group analysis.

Research (Naidoo, 2002; Herzog *et al.*, 1999; Rebechini-Zasadny *et al.*, 1981) has shown that following a single spinal manipulation there is reflex activation of peripheral musculature. It is hypothesized by Vernon and Mrozek, (2005) that with a series of manipulations to a fixated motion segment there is an improvement in range of motion of the joint with a possible simultaneous increase in neurological stimulation (Leach, 2004). The aim of this study was to assess the effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles to determine the effect of manipulation on rotator cuff peak torque and if multiple manipulations had a greater functional effect on rotator cuff peak torque. With rehabilitation in mind this could prove to be valuable added intervention in the treatment protocol for patients with musculoskeletal painful shoulders.

## 5.2 The Data

### 5.3.1 Primary Data

The Cybex was used to determine the objective measurement of peak torque of the rotator cuff muscles. Four movements were measured: internal rotation, external rotation, abduction and adduction. Even though adduction is not a primary movement of the rotator cuff muscles the Cybex measures abduction and adduction simultaneously and therefore, adduction was included in the study. Peak Torque was measured in Newton-meters (Nm) and indicated the point in the range of motion of the shoulder joint where the muscles acting on the joint reached maximum force.

## 5.3 Patient Inclusion and Drop Outs

Forty subjects were required to participate in the study. All drop outs were replaced until two groups of twenty subjects had completed the two week duration of the study.

In total there were four subjects who dropped out of the study. One subject developed right elbow pain following the post adjustment Cybex measurement. The other three subjects were excluded as they received chiropractic treatment, including dry needling and manipulation, during the course of the study which resulted in them being excluded from the study.

## 5.4 Results

### 5.4.1 Demographics

#### 5.4.1.1 Discussion

The group allocation process ensured an equal distribution of subjects between the two groups according to their year of study. The groups did not differ significantly in terms of age, weight or race. The latter was coincidental as the method by which the subjects were allocated to their groups was determined by their year of study and the order in which they had their initial consultation. It was, however, noted that the purposive allocation of subjects according to their year of study may have influenced the age distribution.

Strength normally peaks in the third decade and then gradually decreases until the seventh decade where there is a more rapid decline (www.isokinetics.net, 2009). This may have influenced the results if there was a large age difference between the two groups, however, this was not the case with almost no difference in mean age between the two groups (Table 4.1). Dixon (2005) measured rotator cuff peak torque and found that Indians were weaker than Whites, however, these results were not statistically significant and the sample size was small (n=25) with only 8% of the sample being Indian (n=2) and therefore, this needs to be interpreted with caution. At the time of this study the population of male chiropractic students at DUT (N=93) consisted of a race distribution of 64 White, 16 Indian, 5 Coloured, and 7 Black students (DUT, 2008). Therefore, due to the sample population, there was an overrepresentation of Whites (n=32, 80%), with only four Indian (10%), two Coloured (5%) and two Blacks (5%) making up both groups. However, the proportion of the different race groups was identical between the two groups and therefore, when comparing the two groups any effect due to race will be eliminated, if there is any effect at all. The subjects were purposively allocated to Group One or Group Two according to their year of study because of the subjects' exposure to previous manipulation during practical classes which vary between year of study and which may have influenced their response to the manipulation/s in the study. The subjects were, however, prevented from having any manipulation including during practical classes for two weeks prior to, and for the duration of the study.

Muscle mass increases proportionally with body weight, however, this increase is not linear (www.isokinetics.net, 2009). Therefore, a subject with a heavier body weight is likely to produce higher peak torque readings (Dvir, 2004); however, the two groups were similar in terms of body weight ($p$=0.498) and therefore, this was unlikely to have affected the results.

The groups were, therefore, similar at the beginning of the study in terms of age, weight, race and year of study which is important because the two groups were compared to each other. Thus, any changes found at the end of the study should not be influenced by the demographics of the two groups (Esterhuizen, 2009).

### 5.4.2 Baseline Outcomes

#### 5.5.2.1 Discussion

Baseline outcomes were very similar between the two groups pre-manipulation. There was no statistically significant difference between the two groups in terms of level of fixation. In a comparison of the pre-manipulation peak torque readings between the two groups there was no statistically significant difference between the two groups for internal rotation, external rotation or adduction. However, the multiple manipulation group had a significantly higher peak torque in abduction ($p$=0.040), which was also found to be higher in comparison to previous studies. Possible reasons for the higher peak torque could have included:

1. Activity level: participation in certain activities and sports can significantly influence muscle strength (Dvir, 2004). The subjects who participated in this study were not questioned on activity level or the type of activity they participated in. Sports such as baseball and water polo have been shown to significantly increase rotator cuff strength of the dominant arm (Dvir, 2004). As the subjects in this study were all right handed and were only tested on their dominant side it is possible that the multiple manipulation group consisted of more active subjects and therefore, produced a higher abduction peak torque.

2. Body weight: muscle mass increases proportionally with body weight, however, this increase is not linear (www.isokinetics.net, 2009). Therefore, a subject with a heavier body weight is likely to produce higher peak torque readings (Dvir, 2004). It is possible to normalize peak torque to body weight, which is measured in Newton meters per kilogram. In this study the peak torque readings were not normalized to body weight as the relationship between body weight and muscle mass is not linear, however, the two groups were similar in terms of body weight ($p$=0.498).
3. Effort: both groups received verbal encouragement from the biokineticist during the Cybex testing. Verbal encouragement is difficult to standardize and even though the biokineticist made every effort to be consistent throughout the study, the execution and interpretation may have varied between the subjects. Wilk *et al*., (1991) found that aggressive verbal encouragement resulted in earlier onset fatigue and recommended that encouragement during Cybex testing should be moderate and consistent.

Two other factors which influence peak torque are gender and age, however, in this study only male subjects were used and therefore, gender would not have influenced the results. The mean age between the two groups was almost identical, as indicated in 5.5.1.1, and therefore, would not have influenced abduction peak torque readings.

## 5.4.3 Intra-group Analysis

### 5.5.3.1 Discussion

During the Cybex testing process abduction and adduction were measured first, followed by internal and external rotation directly afterwards. At the pre-manipulation readings the subjects underwent a five repetition sub maximal warm up for abduction and adduction, followed by a 30 second rest and then five maximum contractions for abduction and adduction. The Cybex was then set up for internal and external rotation which took approximately one minute and then the same process of a five repetition sub maximal warm up and five maximum contractions ensued for internal and external rotation. The same process was followed for the post manipulation Cybex readings.

The procedure that occurred from the pre-manipulation Cybex measurements to the post manipulation Cybex measurements was the same for both the single and multiple manipulation groups. The intra-group analysis supports this, as both groups followed a similar trend of results between pre and post manipulation, except for abduction where the single manipulation group increased non-significantly and the multiple manipulation group decreased non-significantly.

The single and multiple manipulation groups followed a similar trend for adduction between pre and post manipulation with both groups increasing non-significantly.

This increase in post manipulation adduction peak torque is supported by Wyke (1985), who stated that manipulation of a joint causes activation of mechanoreceptors from structures in and around the manipulated joint resulting in an altered afferent input. This altered afferent input is thought to cause changes in motor neuron excitability, which not only affects the muscles overlying the manipulated joint, but also more distant muscles (Naidoo, 2002, Suter *et al*., 2000, Herzog *et al*., 1999, Nansel *et al*., 1993). Rebechini-Zasadny *et al*., (1981) showed an increase in motor neuron activity following cervical spine manipulation which could possibly influence the strength of the muscle. In this study only peak torque of the muscles was measured, which is the point in the range of motion being tested where the muscle reaches maximum voluntary contraction force, or strength. No surface EMG readings were taken and therefore, it was not possible to determine if there was an associated change in motor neuron activity.

For internal and external rotation, both the single and multiple manipulation groups decreased non-significantly between pre and post manipulation. It is possible that this decrease in peak torque was due to fatigue of the rotator cuff muscles following the pre and post manipulation Cybex readings. The rotator cuff muscles act as dynamic stabilizers of the glenohumeral joint working together to centralize the glenohumeral joint during movement of the shoulder (Souza, 1994, Wilk and Arrigo, 1993). The rotators would have contributed to the stabilization of the glenohumeral joint during the abduction and adduction testing and therefore, would not have been rested immediately prior to Cybex testing as was the case for the abductors and adductors. The converse applies for the abductors and adductors during Cybex testing for internal and external rotation. The abductors and adductors may have been fatigued from the maximum contraction readings taken immediately prior to the Cybex testing for the rotators. This may have affected the stabilization of the glenohumeral joint inhibiting the rotators from performing maximally.
Dixon (2005) found an increase in internal and external rotation peak torque following manipulation of the cervical spine, however, no Cybex familiarization was done and is a possible reason why similar results were not seen in this study. Familiarization is designed to decrease the effect of practice based improvement on the test results (Wright, 2008;

Dvir, 2004). As no familiarization was done by Dixon (2005) it is possible that the increase in rotational peak torque may have been influenced by the learned effect of using the Cybex.

Between the post manipulation reading and the two-week follow up reading, the single manipulation group received no further interventions, whereas, the multiple manipulation group received three additional manipulations before the two-week follow up reading.

The single manipulation group increased in internal and external rotation from post manipulation to marginally below baseline level at the two-week follow up. Adduction decreased slightly between post manipulation and the two-week follow up, however, remained above the baseline peak torque. This is supported by the literature which states that manipulation of a joint not only affects the overlying muscles but more distant muscles as well (Naidoo, 2002; Suter *et al*., 2000; Herzog *et al.*, 1999; Nansel *et al.*, 1993). Abduction peak torque increased non-significantly between post manipulation and the two-week follow up for the single manipulation group also remaining above the pre-manipulation peak torque. All of these results were however non-significant and therefore need to be interpreted with caution.

In the multiple manipulation group there was no difference between the post manipulation adduction peak torque and the two-week follow up. The effect of the single manipulation was maintained for the two week duration and the peak torque remained above baseline pre-manipulation peak torque. Abduction peak torque, however, decreased in the multiple manipulation group between post manipulation and the two-week follow up, with a non-significant decrease overall, indicating that manipulation possibly had a detrimental effect on rotator cuff peak torque.

There was a non-significant increase in internal and external rotation peak torque for the multiple manipulation group between post manipulation and the two-week follow up reading to a peak torque above the baseline pre-manipulation peak torque. This is in line with the theory proposed by Vernon and Mrozek (2005), where they hypothesized that manipulation of a fixated joint would require the breaking down of adhesions and that a single manipulation will not necessarily enter the ‘normal’ paraphysiological space at the end range of ‘normal’ motion, due to the restriction caused by these adhesions. However, with additional manipulation of the same motion segment there would be a progressive ‘break down’ of adhesions with the manipulation taking place closer to the limit of ‘normal range of motion. This would result in increased neurological stimulation of the joint capsule and surrounding ligaments and muscles, which could increase the reflex effects of manipulation as described by Herzog *et al.,* (1999). However, the increase in rotator cuff peak torque, in the multiple manipulation group, at the two-week follow up was not significant and therefore, these results need to be interpreted with caution.

### 5.4.4 Intra-group Correlations

#### 5.4.4.1 Discussion

Correlations between the changes in outcomes in each group over the two week period were made for each movement tested. Positive correlations indicated that changes occurred in the same direction and if one measure increased so did the other and vice versa (Esterhuizen, 2009).

In the single manipulation group there was a significant positive correlation between changes in internal rotation and external rotation ($r$=0.477, $p$=0.034). Whereas, in the multiple manipulation group there was a significant positive correlation between changes in abduction and adduction ($r$=0.530, $p$=0.016).

It appears from the profile plots for abduction and adduction in the multiple manipulation group (figure 4.5 and figure 4.6) that abduction decreases over time and adduction increases over time; however, the profile plots are based on the mean values in that group at each time point. The correlation is based on every difference between time one and three. The correlation coefficient is not very strong ($r$=0.530) however there is a significant positive relationship overall between changes in abduction and adduction in the multiple manipulation group.

### 5.4.5 Inter-group Analysis

#### 5.5.5.1 Discussion

Abduction showed a non-significant differential treatment effect between the single and multiple manipulation groups. The single manipulation group increased between post manipulation and the two-week follow up, whereas the multiple manipulation group decreased non-significantly.

The Supraspinatus and Deltoid muscles are the primary abductors of the glenohumeral joint and are innervated by C4-C6 ventral rami, however, main segmental innervation arises from C5 ventral rami (Moore and Dalley, 2006). In comparison to internal rotation, external rotation and adduction, which have larger muscles assisting with these movements (e.g. Latissimus dorsi, Pectoralis Major, Teres Major) and more muscles contributing to each movement, the two muscles contributing to abduction are relatively small (Moore and Dalley, 2006). It is possible that this allowed for greater isolation of the effect of the manipulation on the rotator cuff muscles. If this is the case then it would seem that multiple manipulations may have had a detrimental effect on peripheral muscle activity. The subjects in the multiple manipulation group were manipulated at the same level for the duration of the study, regardless of the presence or absence of a fixation at that level following the first manipulation. It is possible that the fixation may have resolved at a point during the two weeks of the research process before the fourth manipulation and that subsequent manipulation to a joint with normal range of motion may have resulted in detrimental afferent stimulation of the joint and muscle receptors. This is supported by Korr's (1975) theory of aberrant muscle spindle activity, where unguarded movement to normal muscle fibres results in increased gamma motor neuron activity to the intrafusal muscle fibres, causing muscle spasm. This may have happened as a result of manipulating a non-fixated joint. However, these results need to be interpreted with caution as the changes were slight and not statistically significant.

Simultaneous EMG readings taken during the Cybex testing would have provided valuable added information on the degree of excitation of the motor units supplying the muscle being tested (Naidoo, 2002; Herzog *et al.*, 1999; Rebechini-Zasadny *et al*., 1981). It would then be possible to evaluate any changes in motor neuron end plate activity following manipulation. As EMG readings were not taken in this study, it was not possible to determine motor unit activity; however, it is included as one of the recommendations of this study in chapter 6.

For adduction there was no difference between the single and multiple manipulation groups in terms of treatment effect. The effect of the single manipulation was maintained, however, the additional manipulations received by the multiple manipulation group appeared to have no further effect on the adduction peak torque.

For internal and external rotation, the only differential treatment effect was a small increase in the multiple manipulation group between post manipulation and the two-week follow up, whereas the single manipulation group appeared to level off close to the baseline peak torque. The multiple manipulation group received four manipulations in total and the single manipulation group only received one. This indicates that the additional manipulations received by the multiple manipulation group may have caused an increase in internal and external rotation peak torque; however, this needs to be interpreted with caution as the results were not statistically significant.

## 5.5 Chapter Conclusion

From pre-manipulation to post manipulation Cybex readings, both groups behaved similarly which was expected, as the intervention up until this point was the same for both groups. Between pre and post manipulation abduction peak torque appeared to remain the same indicating no immediate treatment effect. Adduction peak torque, however, increased post manipulation indicating a beneficial treatment effect immediately post manipulation. Internal and external rotation decreased post manipulation, however, it is not clear if these changes were due to the reflex effects of the manipulation or due to fatigue as rotational measurements were taken immediately following abduction and adduction peak torque measurements.

Between post manipulation and the two-week follow up there appeared to be no differential treatment effect between the single and multiple manipulation groups, except for abduction where the single manipulation group increased between post manipulation and the multiple manipulation group decreased; indicating that multiple manipulations could possibly have a detrimental effect on peripheral muscle activity.

These results, however, need to be interpreted with caution as none of the changes were statistically significant.

The following null hypotheses which were developed at the outset of the study can either be rejected or accepted:

The first null hypothesis indicated that a single cervical spine manipulation would result in no increase in peak torque of the rotator cuff muscles immediately post manipulation. This null hypothesis was accepted because internal rotation, external rotation and abduction either decreased or remained at baseline peak torque and even though abduction increased, this increase was not significant.

The second null hypothesis indicated that a series of cervical spine manipulations would result in no increase in peak torque of the rotator cuff muscles. This null hypothesis was accepted because there was no significant increase in peak torque of the rotator cuff muscle in the multiple manipulation group and abduction decreased non-significantly.

The third null hypothesis indicated that there will be no difference between the single and multiple manipulation groups in terms of rotator cuff peak torque. This hypothesis was accepted, as the only differential treatment effect was seen in abduction; however, the changes were slight and not statistically significant.

# CHAPTER SIX

## Conclusion and Recommendations

## 6.1 Conclusion

Previous studies have shown a reflexogenic increase in peripheral motor unit activity and muscle strength immediately post manipulation (Dixon, 2005; Naidoo, 2002, Suter *et al.,* 2000; Herzog *et al.*, 1999; Rebechini-Zasadny *et al*., 1981). However, there appears to be a paucity of literature on the effect of a series of manipulations, over a period of time, on peripheral muscle activity and strength. Therefore, the purpose of this study was to investigate the effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles.

The subjects who participated in this study were asymptomatic in terms of neck and shoulder pain, however, they presented with a cervical spine fixation between C4-C7. Peterson and Bergmann (2002) describe how a person can adapt and compensate to changes in the spinal motion segment and can be asymptomatic despite the presence of a fixation.

Vernon and Mrozek (2005) hypothesized that manipulation takes place within a 'clinically physiological range', due to the restriction of movement of the fixated joint and that the progressive breaking down of adhesions during spinal manipulation results in an increased range of motion, closer to the 'normal' range of motion. Manipulation of a joint within the paraphysiological space at the end of the 'normal' range of motion is thought to increase the neurological stimulation of the surrounding tissues and segmental spinal nerves which could affect peripheral muscle activity (Leach, 2004; Wyke, 1985).

The Intra-group analysis did not reveal any statistically significant results for both the single and multiple manipulation groups indicating that manipulation had no effect on rotator cuff peak torque immediately post manipulation or at the two-week follow up. There was, however, a non-significant trend of an increase in adduction peak torque immediately post manipulation which was maintained at the two-week follow up, for both the single and multiple manipulation groups.

The Inter-group analysis indicated that there was no statistically significant differential treatment effect between a single manipulation versus multiple manipulations on rotator cuff peak torque. There was, however, a non-significant trend of a treatment effect for abduction peak torque. The single manipulation group increased between post manipulation and the two-week follow up, whereas the multiple manipulation group decreased, indicating a possible detrimental effect of the further three manipulations on abduction peak torque.

Therefore, according to the results of this study, manipulation of a fixated motion segment between C4-C7 does not result in an increase in rotator cuff peak torque immediately post manipulation and that there appears to be no significant differential treatment effect of a single manipulation compared to a series of manipulations on rotator cuff peak torque.

## 6.2 Recommendations

It is recommended that future studies use EMG readings in conjunction with peak torque readings to determine if there is a correlation between motor neuron activity and peak torque immediately post manipulation.

When using the Cybex to determine peak torque, it is recommended that the activity level of the subjects is controlled and that either an active or inactive population is used. It would also be beneficial to normalize peak torque to body weight, which is measured in Newton meters per kilogram.

Although strict exclusion criteria were used to prevent subjects from receiving chiropractic treatment 1 week prior to and for the duration of the study, the sample population was chiropractic students who had regular exposure to manipulation. The effect of this on the outcome of the study is unknown; however, a general population sample group who does not have regular manipulations may have responded differently. The reason for the use of chiropractic students as the sample population was because the subjects were asymptomatic in terms of neck or shoulder pain. Chiropractic students' knowledge of the fact that a fixation may be present in the absence of pain made it more likely that they would be willing to participate in the study.

It is also recommended that objective measurements be taken at regular intervals throughout the study following subsequent manipulations. This would assist the researcher in determining if there is a point in a series of manipulations, to the same motion segment, where the dysfunction is resolved and subsequent manipulations become detrimental.

This study was limited to 40 subjects due to a small sample population (N=93). The researcher had to allow for subjects that would not meet the inclusion criteria and therefore a sample size of 40 subjects was estimated as an acceptable sample size. Future studies should use a larger sample size and conduct a power analysis to ensure that reliable results are achieved with a particular level of confidence

Lastly, arthrogenic muscle inhibition causes weakness in muscles that move a joint as it decreases the ability of a muscle to recruit all the motor units of a muscle group to their full extent during a maximal effort voluntary muscle contraction (Suter *et al*., 2000). The effects of cervical spine manipulation on patients with rotator cuff pathologies should be investigated to assess the effects of manipulation on peripheral muscle strength in the clinical situation.

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# APPENDIX A
# LETTER OF INFORMATION

Dear Participant, welcome to my research project.

**Title of Research:**
The effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles in asymptomatic subjects with cervical spine fixation.

**NAME OF RESEARCH SUPERVISORS**
**Dr. Laura Wilson** Contact Number (031) 373 2923
[MTech-Chiropractic]
**Dr. Charmaine Korporaal** Contact Number (031) 373 2094
[MTech-Chiropractic; CCFC; CCSP; ICSSD]

**NAME OF RESEARCH STUDENT**
**Carmen Blakeney** Contact Number (031) 2042205

You have been selected to take part in a study to investigating the effect of a single cervical spine manipulation versus multiple manipulations on peak torque of the rotator cuff muscles. Forty people will be required to complete this study. All participants, including you, will be randomly allocated into two equal groups. One group will receive a single manipulation and the second group will receive 4 manipulations over the period of 2 weeks. Measurements will be taken at the first session and a second measurement will be taken two weeks later for both groups.

**Research process:**
At the first consultation you will be screened for suitability as a participant and a case history, physical examination, cervical spine and shoulder regional examination will be done. This consultation will take place at the Chiropractic Clinic at Durban University of Technology. A second appointment will then be scheduled which will take place at Sharks Academy Medical Centre. You will be asked to complete a series of tests on the Cybex machine, which is a machine that measures muscle strength during range of motion. In this study we will be measuring strength of the shoulder muscles before and after a cervical spine adjustment. Participants in one group will then return for 3 follow up consultations at the Chiropractic clinic. All participants will return to Sharks Academy Medical Centre for a final Cybex reading 2 weeks after their first reading.
All treatments will be performed under the supervision of a qualified chiropractor by the research student.
Inclusion and Exclusion:
Participants in this study must be registered, male chiropractic students at Durban University of Technology. They must be asymptomatic in terms of shoulder and neck pain and be right hand dominant.

Participants will need to refrain from any manipulative procedures during the study including during spinal manipulative practical classes.
Any patients with spinal tumours or metastases, recent fractures of the neck or shoulder, inflammatory and metabolic diseases of the spine, progressive neurological deficits and hypertension would be excluded from this study due to it being a contra-indication to manual therapy.



*Please try not to alter your normal lifestyle or daily activities in any way* as this could interfere with the results of the study.

**Risks and discomfort:**
The treatment is unlikely to cause any adverse side effects, however transient pain and tenderness may occur which will most likely subside within 24 hours. There is a small chance that the neck pain may persist. Should this happen you will receive free treatment at the Chiropractic Day Clinic.

**Benefits of the study:**
Your full co-operation will assist the Chiropractic profession in expanding its knowledge on the effect of manipulation on peripheral muscle strength thus improving the efficacy of certain treatment protocols. Results of the study will be made available in the form of a dissertation at the Durban University of Technology library.

**Withdrawal from the study:**
You are free to withdraw at any stage.

Patients that are found to be dishonest in the history provided by them and all patients that fail to comply with the informed consent form will be excluded from the study.

**Remuneration and costs:**
Treatment for the duration of the research process will be free of charge and the subject will not be expected to cover any costs to participate in the study. Subjects taking part in the study will not be offered any form of remuneration for taking part in the study.

**Confidentiality:**
All patient information is confidential and will be kept in a patient file at the Chiropractic clinic for five years after which it will be destroyed.

Please don't hesitate to ask questions on any aspect of this study. Should you wish you can contact my research supervisor on the above details or alternatively you could contact the Faculty of Health Sciences Research and Ethics Committee as per Mr. Vikesh Singh (031) 373 2701.

**Statement of agreement to participate in the study:**

I, ……………………………………………., ID number……………………………., have read this document in it's entirety and understand its contents. Where I have had any questions or queries, these have been explained to me by the researcher to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health care will not be compromised. I therefore, voluntarily agree to participate in this study.

Subject's name:……………………...............Signature:..……………….Date:……..

Researcher's name:……………………………Signature……………….Date:………



Witness' name:…………………………………Signature……..……….Date……….

**APPENDIX B**

**INFORMED CONSENT FORM**

(To be completed by patient / subject )

**Date :**

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**Title of research project: The effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles in asymptomatic subjects with cervical spine fixation.**

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**Name of supervisor : Dr Laura Wilson [Mtech: Chiropractic]**
**Tel : (031) 373 2923**
**Name of co-supervisor : Dr Charmaine Korporaal [MTech: Chiropractic; CCFC; CCSP; ICSSD]**
**Tel : (031) 373 2094**

---

**Name of research student : Carmen Blakeney**
**Tel : (031) 373 2205**

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| **Please circle the appropriate answer** | **YES /NO** | |
|---|---|---|
| 1. Have you read the research information sheet? | Yes | No |
| 2. Have you had an opportunity to ask questions regarding this study? | Yes | No |
| 3. Have you received satisfactory answers to your questions? | Yes | No |
| 4. Have you had an opportunity to discuss this study? | Yes | No |
| 5. Have you received enough information about this study? | Yes | No |
| 6. Do you understand the implications of your involvement in this study? | Yes | No |
| 7. Do you understand that you are free to withdraw from this study? | Yes | No |

- at any time
- without having to give any a reason for withdrawing, and
- without affecting your future health care.

| | | |
|---|---|---|
| 8. Do you agree to voluntarily participate in this study | Yes | No |

9. Who have you spoken to? ________________________________________

**Please ensure that the researcher completes each section with you. If you have answered NO to any of the above, please obtain the necessary information before signing**

**Please Print in block letters:**

Participant's Name:________________________________Signature: _______________

Witness Name:____________________________________Signature:_______________

Researcher's Name: _______________________________Signature:________________

Supervisor's Name: ________________________________Signature:_______________

**APPENDIX C**

**DURBAN UNIVERSITY OF TECHNOLOGY**

**CHIROPRACTIC DAY CLINIC**

**CASE HISTORY**

Patient: ______________________________ Date: ____________

File # ______________________________

Occupation: ______________________________

Inten: ____________________ Signature: ____________________

**FOR CLINICIANS USE ONLY:**

Initial visit

Clinician: Signature :

| **Case History:** |
|---|
| |

Examination:

Previous: Current:

X-Ray Studies:

Previous: Current:

Clinical Path. lab:

Previous: Current:

**CASE STATUS:**

| PTT: | Signature: | Date: |
|---|---|---|

| **CONDITIONAL:**<br>Reason for Conditional: |
|---|
| |
| |
| Signature: Date: |

| | | |
|---|---|---|
| Conditions met in Visit No: | Signed into PTT: | Date: |
| | | |
| Case Summary signed off: | | Date: |

**Intern’s Case History:**

**1. Source of History:**

**2. Chief Complaint : (patient’s own words):**

**3. Present Illness:**

| | **Complaint 1** | **Complaint 2** |
|---|---|---|
| < Location | | |
| < Onset : Initial: | | |
| Recent: | | |
| < Cause: | | |
| < Duration | | |
| < Frequency | | |
| < Pain (Character) | | |
| < Progression | | |
| < Aggravating Factors | | |
| < Relieving Factors | | |
| < Associated S & S | | |
| < Previous Occurrences | | |
| < Past Treatment | | |
| (a) Outcome: | | |

**4. Other Complaints:**

**5. Past Medical History:**

< General Health Status

< Childhood Illnesses

< Adult Illnesses

< Psychiatric Illnesses

< Accidents/Injuries

< Surgery

< Hospitalizations

**6. Current health status and life-style:**

< Allergies

< Immunizations

< Screening Tests incl. x-rays

< Environmental Hazards (Home, School, Work)

< Exercise and Leisure

< Sleep Patterns

< Diet

< Current Medication
Analgesics/week:

< Tobacco

< Alcohol

< Social Drugs

**7. Immediate Family Medical History:**

< Age

< Health

< Cause of Death

< DM

< Heart Disease

< TB

< Stroke

< Kidney Disease

< CA

< Arthritis

< Anaemia

< Headaches

< Thyroid Disease

< Epilepsy

< Mental Illness

< Alcoholism

< Drug Addiction

< Other

**8. Psychosocial history:**

< Home Situation and daily life

< Important experiences

< Religious Beliefs

**9. Review of Systems:**

< General

< Skin

< Head

< Eyes

< Ears

< Nose/Sinuses

< Mouth/Throat

< Neck

< Breasts

< Respiratory

< Cardiac

< Gastro-intestinal

< Urinary

< Genital

< Vascular

< Musculoskeletal

< Neurologic

< Haematologic

< Endocrine

< Psychiatric

**APPENDIX D**

# Durban University of Technology
## PHYSICAL EXAMINATION: SENIOR

**Patient Name :** ______________________________ **File no :**__________ **Date :**________
**Student :** **Signature :**

**VITALS:**

| | | | | | |
|---|---|---|---|---|---|
| Pulse rate: | | | | Respiratory rate: | |
| Blood pressure: | R | | L | Medication if hypertensive: | |
| Temperature: | | | | Height: | |
| Weight: | Any recent change? Y / N | | If Yes: How much gain/loss | | Over what period |

**GENERAL EXAMINATION:**

| | | |
|---|---|---|
| General Impression | | |
| Skin | | |
| Jaundice | | |
| Pallor | | |
| Clubbing | | |
| Cyanosis (Central/Peripheral) | | |
| Oedema | | |
| Lymph nodes | Head and neck | |
| | Axillary | |
| | Epitrochlear | |
| | Inguinal | |
| Pulses | | |
| Urinalysis | | |

**SYSTEM SPECIFIC EXAMINATION:**

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

**Clinician:** **Signature :**

**APPENDIX E**

DURBAN UNIVERSITY OF TECHNOLOGY

REGIONAL EXAMINATION - CERVICAL SPINE

Patient: ........................................ File No: ....................

Date: .................... Student: ........................................

Clinician: ........................................ Sign: ....................

OBSERVATION:

Posture

Swellings

Scars, discolouration

Hair line

Body and soft tissue contours

Shoulder position

Left :

Right :

Shoulder dominance ( hand ):

Facial expression:

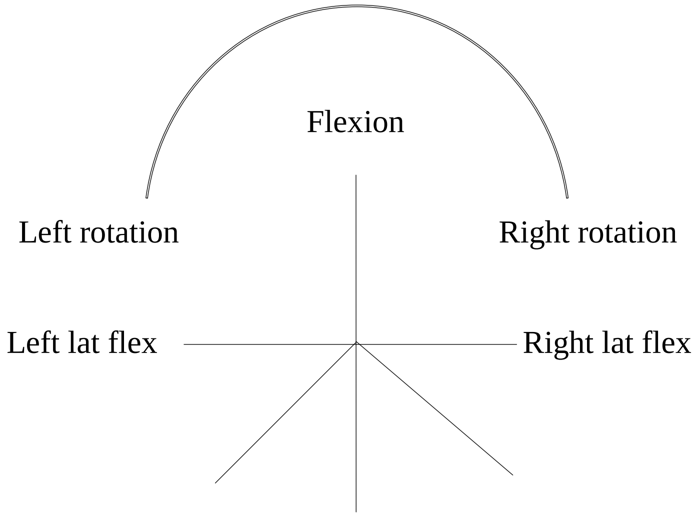
**RANGE OF MOTION:**

Extension ( 70º):

L/R Rotation ( 70º):

L/R Lat flex (45º):

Flexion ( 45º):




**PALPATION:**

Lymph nodes

Thyroid Gland

Trachea

**ORTHOPAEDIC EXAMINATION**:

| **Tenderness** | | Right | Left |
|---|---|---|---|
| Trigger Points: | SCM | | |
| | Scalenii | | |
| | Post Cervicals | | |
| | Trapezius | | |
| | Lev scapular | | |

| | Right | Left | | Right | Left |
|---|---|---|---|---|---|
| Doorbell sign | | | Cervical compression | | |
| Kemp's test | | | Lateral compression | | |
| Cervical distraction | | | Adson's test | | |
| Halstead's test | | | Costoclavicular test | | |
| Hyper-abduction test | | | Eden's test | | |
| Shoulder abduction test | | | Shoulder compression test | | |
| Dizziness rotation test | | | Lhermitte's sign | | |
| Brachial plexus test | | | | | |

**NEUROLOGICAL EXAMINATION:**

| **Dermatones** | **Left** | **Right** | **Myotomes** | **Left** | **Right** | **Reflexes** | **Left** | **Right** |
|---|---|---|---|---|---|---|---|---|
| C2 | | | C1 | | | C5 | | |
| C3 | | | C2 | | | C6 | | |
| C4 | | | C3 | | | C7 | | |
| C5 | | | C4 | | | | | |
| C6 | | | C5 | | | | | |
| C7 | | | C6 | | | | | |
| C8 | | | C7 | | | | | |
| T1 | | | C8 | | | | | |
| | | | T1 | | | | | |

| **Cerebellar tests**: | Left | Right |
|---|---|---|
| Disdiadochokinesis | | |

| **VASCULAR**: | **Left** | **Right** | | **Left** | **Right** |
|---|---|---|---|---|---|
| Blood pressure | | | Subclavian arts. | | |
| Carotid arts. | | | Wallenberg's test | | |

MOTION PALPATION & JOINT PLAY:
Left: Motion Palpation:
Joint Play:
Right: Motion Palpation:
Joint Play:

---

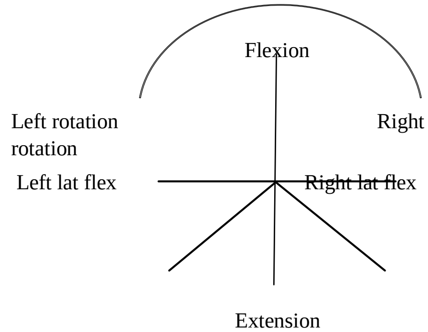
BASIC EXAM: SHOULDER:
Case History:

ROM: Active:
Passive:

RIM:
Orthopaedic:
Neuro:
Vascular:

BASIC EXAM: THORACIC SPINE:
Case History:

ROM:



**APPENDIX F**
# SHOULDER REGIONAL EXAMINATION

Patient: ………………………………………………………. File No: ………………….. Date: …………….
Intern: ……………………………………………… Signature:……………………………
Clinician: ………………………………………… Signature:………………………………

Observation

| | | | |
|---|---|---|---|
| Posture | | S-C Joints | |
| Skin | | Clavicles | |
| Swelling | | A-C Joints | |
| Shoulder levels | | Scapulae | |
| Comments | | | |

**Palpation**

| | | |
|---|---|---|
| S-C Joint: | SCM: | Scalenes: |
| Sternum: | Ribs and costal cartridge: | |
| Clavicle: | Coracoid process: | |
| A-C Joint: | Acromion: | |
| Greater Tuberosity: | | |
| Lesser Tuberosity: | | |
| Intertubercular (bicipital groove): | | |
| Trapezius: | Deltoid: | |
| Biceps: | Triceps: | |
| Supraspinatus insertion: | | |
| Musculotendinous portion of supraspinatus: | | |
| Axilla: | Lymph nodes: | |
| | Brachial artery: | |
| | Serratus anterior (medial wall): | |
| | Pectoralis major (anterior wall): | |
| | Lattisimus dorsi (posterior wall): | |
| Scapula | Borders: | Spine: |
| | Supraspinous fossa: | |
| | Infraspinous fossa: | |

| |
|---|
| Cervico-thoracic spine: |

**Active Movements ( note ROM and pain)**

| | |
|---|---|
| Elevation through abduction (170-180°): | |
| Painful arc with abduction: | |
| Elevation through forward flexion (160-180°): | |
| Elevation through scapula plane ( 170-180°): | |
| Lateral rotation (80-90°): | Medial rotation (60-100°): |
| Extension (50-60°): | Adduction (50-75°): |
| Horizontal adduction/abduction (130°): | |
| Circumduction (200°): | |
| Apley's Scratch: | |

**Passive movements (note end-feel, ROM and pain)**

Elevation through abduction (bone to bone or tissue stretch)…………………………………………………………
Elevation through forward flexion (tissue stretch)…………………………………………………………………
Lateral rotation (tissue stretch)………………………………………………………………………………………
Medial rotation (tissue stretch)……………………………………………………………………………………...
Extension (tissue stretch)……………………………………………………………………………………………
Adduction (tissue approximation) ………………………………………………………………………………
Horizontal adduction (tissue stretch or approximation)……………………………………………………………
Horizontal abduction (tissue stretch)………………………………………………………………………………
Quadrant Test……………………………………………………………………………………………….......

**Resisted Isometric Movements (note strength and pain)**

| | | | |
|---|---|---|---|
| Flexion | | Medial rotation | |
| Extension | | Lateral Rotation | |
| Adduction | | Elbow flexion | |
| Abduction | | Elbow extension | |

**Joint Play Movements (and motion palpation)**

| | |
|---|---|
| SC Joint | Supero-inferior (shrug shoulder with arm at side): |
| | Horizontal add/abduction (arm abducted 90°): |
| AC Joint | A-P Shear: |
| | Supero-inferior shear: |
| Scapula | Normal scapulo-humeral rhythm?: |
| | General mobility of scapula: |

**Glenohumeral Joint**

Lateral movement of humeral head ____________________
Inferior movement of humeral head (Caudal glide)(50°) ____________________
Anterior movement of humeral head (P-A glide) (25°) ____________________

Posterior shear of humeral head (A-P glide) At 10° flexion ____________
**>50%**

At 90° flexion ____________

Backward glide of humeral head in abduction ____________
Long-axis distraction of humeral head in abduction ____________
Downward and backward (S-I → A-P) ____________
Outward and backward (med-lat → A-P ____________
External rotation of humeral head ____________
Internal rotation of humeral head ____________

**<u>Instability Tests</u>**

**1. Anterior Instability Tests**

| | **R** | | | **L** | | |
|---|---|---|---|---|---|---|
| | Pos | Neg | n/a | Pos | Neg | n/a |
| Anterior drawer Test | | | | | | |
| Rowe Test | | | | | | |
| Fulcrum Test | | | | | | |
| Apprehension (crank) Test | | | | | | |
| Clunk Test (tear of labrum) | | | | | | |
| Rockwood Test | | | | | | |

**2. Posterior Instability Tests**

| | Pos | Neg | n/a | Pos | Neg | n/a |
|---|---|---|---|---|---|---|
| Posterior Apprehension Test | | | | | | |
| Norwood Stress Test | | | | | | |
| Push-pull Test | | | | | | |
| Jerk Test | | | | | | |

**3. Inferior and Multi-directional instability tests**

| | Pos | Neg | n/a | Pos | Neg | n/a |
|---|---|---|---|---|---|---|
| Inferior Shoulder Instability Test | | | | | | |
| Feagin Test (antero-inferior instability) | | | | | | |

**<u>A-C Joint Stress Test</u>:** ____________

**<u>S-C Joint Stress Test</u>:** ____________

**Tests for Muscle or Tendon Pathology**

| | | |
|---|---|---|
| 1. | Speed's Test (bicipital tendonitis) | |
| 2. | Gilchrest Sign (bicipital tendonitis) | |
| 3. | Supraspinatus Test (supraspinatus tendonitis) | |
| 4. | Hawkins-Kennedy Impingement Test (supraspinatus tendonitis) | |
| 5. | Drop –arm Test (rotator cuff tear) | |



| | | |
|---|---|---|
| 6. | Impingement Test | |

| | | |
|---|---|---|
| 7. | Pectoralis Major Contracture Test | |
| 8. | Ludington's Test (rupture of long head of biceps) | |

**Tests for neurological function**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brachial Plexus Tension Test | | Radial Nerve | | | | | | | | | | | |
| | | Median Nerve | | | | | | | | | | | |
| Tinel's Sign (Scalene triangle) | | | | | | | | | | | | | |
| Dermatones | C4 | | C5 | | C6 | | C7 | | C8 | | T1 | | T2 |
| Reflexes | Biceps(C5/6) | | | | | | Triceps (C7/8) | | | | | | |

**Thoracic Outlet Syndrome Tests**

| | | | |
|---|---|---|---|
| Adson's Test | | Halstead's Test | |
| Costoclavicular Test | | Eden's Test (cervical rib) | |
| Hyperabduction Test | | Roos Test | |
| Allen's Test | | | |

## APPENDIX G

DURBAN UNIVERSITY of TECHNOLOGY

Faculty of Health Sciences

### ETHICS CLEARANCE CERTIFICATE

| | | | |
|---|---|---|---|
| Student Name | Carmen Blakeney | Student No | 20200707 |
| Ethics Reference Number | FHSEC | Date of FRC Approval | |
| Research Title: | The effect of a single versus multiple cervical spine manipulations on peak torque of the rotator cuff muscles in asymptomatic chiropractic students with cervical spine fixation. | | |

*In terms of the ethical considerations for the conduct of research in the Faculty of Health Sciences, Durban University of Technology, this proposal meets with Institutional requirements and confirms the following ethical obligations:*

1. The researcher has read and understood the research ethics policy and procedures as endorsed by the Durban University of Technology, has sufficiently answered all questions pertaining to ethics in the DUT 186 and agrees to comply with them.
2. The researcher will report any serious adverse events pertaining to the research to the Faculty of Health Sciences Research Ethics Committee.
3. The researcher will submit any major additions or changes to the research proposal after approval has been granted to the Faculty of Health Sciences Research Committee for consideration.
4. The researcher, with the supervisor and co-researchers will take full responsibility in ensuring that the protocol is adhered to.
5. ***The following section must be completed if the research involves human participants:***

| | YES | NO | N/A |
|---|---|---|---|
| ❖ Provision has been made to obtain informed consent of the participants | X | | |
| ❖ Potential psychological and physical risks have been considered and minimised | X | | |
| ❖ Provision has been made to avoid undue intrusion with regard to participants and community | X | | |
| ❖ Rights of participants will be safe-guarded in relation to: - Measures for the protection of anonymity and the maintenance of Confidentiality. | X | | |
| - Access to research information and findings. | X | | |
| - Termination of involvement without compromise | X | | |
| - Misleading promises regarding benefits of the research | X | | |

SIGNATURE OF STUDENT/RESEARCHER — 22/7/2008 DATE

SIGNATURE OF SUPERVISOR/S — 22/07/08 DATE

SIGNATURE OF HEAD OF DEPARTMENT — 23/7/08 DATE

SIGNATURE: CHAIRPERSON OF RESEARCH ETHICS COMMITTEE — 24-07-08 DATE

**APPENDIX H**

Date: April 10th, 2008

To Whom it may concern

Re: Isokinetic Testing of Chiropractic Patients at Biokinetics Centre for J. Wright and Associates – Sharks Academy Medical Centre

This letter serves to confirm that Ms Carmen Blakeney has permission to utilise medical facility of J. Wright & Associates under the supervision of a qualified and registered Biokineticist for the isokinetic testing of chiropractic patients to assess chiropractic treatment on a test group of patients.

This letter also indemnifies the centre and attending practitioners from liability arising out of injury suffered at or during the use of the facility and or testing procedure.

Jimmy Wright
Registered Biokineticist

APPENDIX I

# ALL MALE CHIROPRACTIC STUDENTS

## WITHOUT NECK OR SHOULDER PAIN

WOULD YOU LIKE TO PARTICIPATE IN A RESEARCH STUDY AND MEASURE YOUR SHOULDER STRENGTH?

**Research is currently being done at the Durban University of technology Chiropractic Day Clinic. All consultations and treatment will be**

## FREE OF CHARGE

**if you meet the criteria for the research.**

FOR FURTHER INFORMATION
contact

**CARMEN**

**on**

**031 373 2205**