# THE SHORT-TERM EFFECT OF MANIPULATION OF SELECTED CERVICAL SPINAL SEGMENTS ON THE PEAK TORQUE OF THE ROTATOR CUFF IN ASYMTOMATIC PATIENTS WITH AND WITHOUT MECHANICAL CERVICAL SPINE DYSFUNCTION

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I, Warrick Botha, do declare that this dissertation represents my own work in both conception and execution.

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# DEDICATION

This research is dedicated to my parents for their constant love and support over the years. I could not have done it without you.

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## ABSTRACT

Strengthening of the rotator cuff muscles forms an integral part of any rehabilitation programme for the shoulder. Shoulder rehabilitation programmes which incorporate early motion and emphasize strengthening, have a lower incidence of recurrent subluxations and dislocations.

If cervical manipulation were proven to increase the strength of the rotator cuff muscles, then this could be used to develop and implement more effective treatment and rehabilitation protocols for patients with musculoskeletal painful shoulders and rotator cuff pathologies, and therefore provide future patients with more effective health care.

Studies have shown consistent reflex responses associated with spinal manipulative treatments. These reflex responses have been hypothesized to cause the clinically beneficial effects of decreasing hypertonicity in muscles, pain reduction and increasing the functional ability of the patient, and although spinal manipulation has been shown to affect muscle strength, it has not been extensively researched and it is unclear whether increased muscle strength is yet another reflex effect of manipulation.

As the rotator cuff is innervated by nerves arising from the mid and lower cervical spine, it is theorised that dysfunction of the spinal joints adversely affects nerve endings, causing inhibition of nerve function and affecting the rotator cuff. This is congruent with research which describes how there could be a decrease in muscular activity due to interference with the nerve supply of a muscle by means of a spinal joint fixation. In light of this, one could hypothesize that removal of a cervical joint dysfunction by manipulation, could increase motor unit recruitment and muscular activity of the muscles supplied by that cervical level and therefore possibly strengthen the muscles involved.

Therefore the aim of this study was to determine whether cervical manipulation could contribute to the strengthening process of the rotator cuff.

In order to achieve this, 25 participants for this study were recruited from a concurrent study, which used convenience sampling. The participants were divided evenly into 5 groups according to the level of fixation found in their cervical spines (C4/C5, C5/C6 or C6/C7, no fixation, random fixation), which is keeping with the levels of innervation of the rotator cuff. All participants had received a manipulation at selected cervical spinal levels, 1 day / 24 hours prior to the collection of objective measurements for this study. A control group was also included, whereby participants without any cervical spine dysfunction were manipulated 1 day / 24 hours prior to this study. There were no subjective measurements.

Isokinetic evaluation using the Cybex orthotron II isokinetic device renders objective and reliable data regarding muscular performance during a dynamic contraction and this form of isokinetic testing has been utilized frequently for determining the strength of the rotator cuff. It is for this reason that the Cybex orthotron II isokinetic device was utilized in this study.

The data from this study was analyzed using the SPSS statistical package (version 12). Comparison of categorical variables between independent groups utilized chi square or Fisher's exact tests where appropriate. Comparison of quantitative variables between independent groups utilized the t-test in the case of two groups, and ANOVA with Bonferroni post hoc tests for more than two groups. Repeated measures ANOVA was used to compare the treatment groups over the three time periods with regards to quantitative outcomes. A two tailed p value of $<0.05$ was considered statistically significant.

There appeared to be a beneficial short term effect of the treatment in group 2 relative to the other groups in respect of the cybex readings. Although the other groups also improved between pre and immediately post manipulation, this was not sustained to the same degree as that in group 2. However, since the sample sizes were small this could have happened by chance, since the p values were not statistically significant (except for external rotation). Thus the results should be interpreted with caution. A larger study would help to rule out the role of chance and increase the power to reject a false null hypothesis.

# TABLE OF CONTENTS

**CHAPTER THREE - MATERIALS AND METHODS**



**CHAPTER FOUR – PRESENTATION OF RESULTS AND DISCUSSION**

## LIST OF TABLES

## LIST OF FIGURES

**LIST OF APPENDICES**

## DEFINITION OF TERMS

**Abduction of Upper Limb**

Moving away from the median plane in the coronal plane (Moore, 1992)

**Adduction of Upper Limb**

Moving toward the median plane in the coronal plane (Moore, 1992)

**Cavitation**

This is the "cracking" sound often heard with a joint manipulation. Sandoz (Leach 1994) further describes the audible 'crack' as altered subatmospheric pressure in the joint space, causing gases to be released from the synovial space when the joint surfaces are suddenly separated.

**Coronal Plane**

Imaginary vertical plane passing through the body at right angles to the median plane, dividing it into anterior and posterior portions (Moore, 1992).

**EMG**

Electromyography is used to measure muscle activity and can detect small changes in the neuromuscular system. It provides useful information about the functioning of motor units (motor neuron and associated muscle fibres) (Rebechini-Zasadny *et al*, 1981).

**External Rotation of Upper Limb**

Turning or revolving this part of the body around its long axis, taking the anterior surface of the limb away from the median plane (Moore, 1992).

**Fixation**

A state whereby an articulation has become temporarily immobilized in a position that it may normally occupy during any phase of physiological movement (Haldemann, 1992), or simply put, the decrease in ROM in an anatomical segment that is otherwise normal.

**Internal Rotation of Upper Limb**

Turning or revolving this part of the body around its long axis, taking the anterior surface of the limb closer toward the median plane (Moore, 1992).

**Joint Dysfunction**

Disturbance of function without structural changes, but affecting quality and range of joint motion (Bergmann *et al*., 1993), or simply a fixation (as above) with localized clinical signs and symptoms

**Joint Play**

Discrete short range movements of a joint independent of the action of voluntary muscles, determined by springing each vertebra in the neutral position (Haldemann, 1992).

**Manipulation**

A manual procedure that involves a direct thrust to move a joint past the physiologic range of motion without exceeding the anatomical limit (Gatterman, 1995:12). The joint must pass through the physiological range of movement, cross the elastic barrier and pass into the paraphysiological space, at which point a cavitation sound is heard, a sudden give is felt and range of motion is increased beyond the normal limits (Sandoz, 1976). The above mentioned definitions of manipulation focus on the range of motion and manipulation of normal joints, as opposed to the clinical situation in which there is joint dysfunction and reduced range of motion. This is addressed by Vernon and Mrozek (2005), who proposed that in a clinical situation, manipulation is only performed on joints whose motion is reduced, and the range of motion available in the clinical situation is called the "clinical physiological range." Actual manipulation is therefore not performed at the limit of the range of motion, for that would provoke pain. Rather, it is performed at a point slightly before this range (within the clinical physiological range of motion) and that the cavitation may originate from a source other than the formation of a gas bubble as advocated by Sandoz (1976) (Vernon and Mrozek, 2005).

**Median Plane**

Imaginary vertical plane passing longitudinally through the body from front to back, dividing it into right and left halves (Moore, 1992)

**Mobilization**

A form of manipulation applied within the physiological passive range of joint motion and is characterized by non-thrust passive joint manipulation, in an attempt to make a fixed part movable (Haldemann, 1992).

**Motion Palpation**

A palpatory diagnosis of passive and active segmental joint range of motion (Haldemann, 1992).

**Muscle Strength**

A measure describing an individual's ability to exert maximum muscular force, statically or dynamically (De Ste Croix *et al*., 2003)

**Osteokinematics**

Refers to the gross movements of bone rather than the movement of the articular surfaces.

**Subluxation**

An aberrant relationship between adjacent articular structures that may have functional or pathological sequelae, causing an alteration in the biomechanics and / or neurophysiological reflections of these articular structures, their proximal structures, and / or body systems that may be directly or indirectly affected by them (Haldemann, 1992). It can also be described as a joint dysfunction (as described above) with added peripheral signs and symptoms.

**Torque**

Torque is the turning effect of a force on an object (Chan and Maffulli, 1996:110). It is calculated by multiplying the force produced (newtons) with the length of the moment arm (metres) (www.rcmicroflight.com, 2005). It is measured in Newton meters (Nm).

# CHAPTER ONE

## 1.1 Introduction

A review of the literature on manipulation clearly showed that reflex responses are associated with spinal manipulative treatments (Herzog *et al*, 1999), and that these reflex responses have been hypothesized to cause the clinically beneficial effects of decreasing hypertonicity in muscles and pain. However, there is a paucity of literature regarding the peripheral effects of manipulation in particular with respect to the peripheral muscular effects, as very few studies have been conducted on the manipulation induced peripheral changes in muscles, and even fewer on the effect of manipulation on peripheral muscular strength. Furthermore, of the studies (Rebechini-Zasadny *et al*, 1981, Bonci *et al*, 1990 and Naidoo, 2002) which have been completed in this respect, most exhibited many of the same inconsistencies with respect to small sample sizes, lack of placebo control and the extrapolation of strength values from surface EMG readings, which therefore has left the effect of manipulation of peripheral muscular strength as inconclusive.

A further review of the literature with regard to muscle rehabilitation after injury revealed that one of the most important aims of any muscle rehabilitation protocol is to strengthen the muscles involved. Thus with a focus on rehabilitation of the rotator cuff of the shoulder, it was found that increasing strength was very important during this rehabilitation because it prevented recurrent subluxations, dislocations and helped to provide dynamic stability during functional activities.

With rehabilitation in mind, as well as the possibility that manipulation could increase peripheral muscular strength, this research was undertaken to address some of the inconsistencies in the current research with regards to the effects of manipulation on peripheral muscle strength. This could potentially indicate another beneficial effect of manipulation if the results showed an increase in peripheral muscle strength. Resultant inferences could then be used to implement more effective treatment and rehabilitation protocols following rotator cuff injuries.

## 1.2 Aim Of The Study

Therefore the aim of this study was to assess the short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction.

The 3 main objectives were to :

1.2.1 Evaluate the short-term effect of manipulation of the cervical spine on the peak torque of the rotator cuff muscles, utilising the Cybex Orthotron II Isokinetic Rehabilitation Device.

The first hypothesis :

Indicated that there would be an increase in the short term peak torque generated by the rotator cuff, following manipulation.

1.2.2 Establish whether manipulation of a particular cervical spinal level creates a greater improvement in the peak torque than manipulation of a different level of the cervical spine.

The second hypothesis:

Indicated that there should only be a difference in the peak torque generated by the muscle / muscle group which is innervated by the cervical spinal level which was manipulated.

1.2.3 Establish whether the presence or absence of a fixation has any change on peak torque, following manipulation.

The third hypothesis:

Indicated that manipulation would cause an increase in the peak torque generated by the rotator cuff, regardless of whether there was a fixation present prior to manipulation or not.

The aims and objectives of this study were achieved by taking 25 asymptomatic (except for fixations) male participants which were divided evenly into 5 groups according to the level of fixation found in their cervical spines. All participants had been manipulated at selected cervical spinal levels 24 hours prior to the collection of objective measurements for this study. A control group was included, whereby participants without any cervical fixations were also manipulated 24 hours prior to this study. Each participant under went peak torque testing 24 hours post manipulation for internal rotation, external rotation, abduction and adduction, using the Cybex Orthotron II Isokinetic Dynamometer.

Data was then captured in MS Excel and exported into SPSS version 12 (SPSS inc. Chicago, Ill) for analysis, which included descriptive analysis for categorical variables. In the case of quantitative variables, the assumption of normality was checked using the skewness statistic and its standard error.

Comparison of categorical variables between independent groups included the chi square or Fisher's exact tests where appropriate. Comparison of quantitative variables between independent groups : t-test in the case of two groups and ANOVA with Bonferroni post hoc tests for more than two groups. Repeated measures ANOVA was used to compare the treatment groups over the three time periods with regards to quantitative outcomes.

Hypothesis testing decision rule: a two tailed p value of $<0.05$ was considered statistically significant.

### 1.3 Limitations

At the outset of this study it was recognised that the sample and allocation of patients in this study would at best reflect a pilot investigation with indications for further study. Thus the inferences made could not be definitive in nature but only give rise to suggestion of possible associations / inferences.

### 1.4 Conclusion

Therefore it can be seen that there is a need for the development of further research into the area of reflex effects of spinal manipulation and thus the following chapters are designed to reveal a far more detailed account of current literature, the research design and the results and conclusions achieved, with :

Chapter 2 providing a detailed review of the related literature, covering anatomy, neuro-physiology, reflexogenic effects of manipulation, the logic behind segmental manipulation, and the evaluation of muscle strength.

Chapter 3 explaining the materials and methods used in the study, which includes the study design, sampling size and allocation, inclusion and exclusion criteria, objective measurements and the statistical analysis utilized.

In chapter 4, presenting the results of this study and the discussion of the results.

And chapter 5 summarising the final conclusions, with recommendations given for future research into this field.

# CHAPTER TWO

## Review Of Related Literature

### 2.1 Introduction

The following chapter will describe the relevant anatomy of the cervical spine and rotator cuff musculature of the shoulder with an emphasis on the neurological link between these two areas of the body. Research will be presented on the theorized reflex effects of manipulation, as well as discussing the possibility of increasing peripheral muscle strength through manipulation. Some of the inconsistencies and common flaws in the current research will also be highlighted. Furthermore this chapter will show the clinical significance of increasing muscle strength for shoulder rehabilitative purposes and the possible role manipulation could play in that rehabilitation protocol, and lastly, the concept of isokinetic muscle testing, and why it was utilized as the measurement tool in this study to evaluate the peak torque produced by the rotator cuff, will be discussed.

### 2.2 Anatomy And Innervation Of The Cervical Spine

The vertebral column consists of seven cervical vertebra, and these vertebrae form the bony skeleton of the neck (Kieser & Allen, 1999). C1 and C2 are atypical vertebrae, and as they have no relevance to this study, will not be discussed.

The remaining lower cervical vertebra (C3-7) have the typical vertebral structure, which includes a body and a vertebral arch (Moore, 1992). The body makes up the larger anterior part and its function is to support weight of the head and neck above that vertebra. The vertebral arch is formed by two pedicles which project posteriorly to meet two laminae which in turn meet posteriorly to form the spinous process. Four articular processes and two transverse processes also arise from the vertebral arch. The space enclosed by the body and the vertebral arch is the vertebral foramen. The succession of the vertebral foramina in the vertebral column forms the vertebral canal, which contains the spinal cord and its nerve roots. (Moore, 1992; www.sprojects.mmi.mcgill.ca, 2005).

The lower cervical vertebrae form a three joint complex with adjacent vertebrae - the first being the joint formed between the bodies of the vertebra and the intervertebral disc. The fibrocartilagenous disc, serves to unite as well as keep the vertebra apart (Gatterman, 1990). They provide the strongest attachment between the vertebral bodies, playing a major role in weight-bearing, and are composed of an external annulus fibrosus surrounding a gelatinous nucleus pulposus (Moore, 1992).

The other two joints between the lower cervical vertebrae are the posterior facet joints. Articular processes arise from the junctions of the pedicles and laminae, with the paired superior articular processes projecting superiorly and the paired inferior processes projecting inferiorly. Each process has an articular facet, and the articulation between the superior and inferior articular facets is known as the zygopophyseal facet (Moore, 1992, Kieser & Allen, 1999, www.sprojects.mmi.mcgill.ca, 2005). This joint is a true diarthrodial joint, has articular cartilage, a loose capsule lined with a synovial membrane, reinforced with ligaments and related muscles (Gatterman, 1990).

Ligaments are fibrous bands of connective tissue that attach to bone, connect two or more bones together and also help to stabilize joints at rest and during movement. The system of ligaments in the cervical spine helps provide a natural brace to protect the spine from injury (www.scoliosisassociates.com, 2005). The main cervical spinal ligaments are summarized in the following table :

| Ligament | Attachment |
|---|---|
| Anterior Longitudinal Ligament (ALL) | Runs the entire length of the spine from the base of the skull to the sacrum, and connects the anterior surface of the vertebral bodies and intervertebral discs. |
| Posterior Longitudinal Ligament (PLL) | Runs the entire length of the spine from the base of the skull to the sacrum, and connects the posterior surface of the vertebral bodies and intervertebral discs. |
| Ligamenta Flava | Joins the laminae of adjacent vertebral arches. |
| Ligamentum Nuchae | Extends posteriorly along the spinous processes from the base of the skull to the 7th cervical vertebra. |

(Gray, Pickering Pick & Howden, 1974; www.sprojects.mmi.mcgill.ca, 2005 and www.scoliosisassociates.com, 2005).

There are various mechano and nociceptive receptors in the facet joints, surrounding ligaments and intervertebral discs. Of these, the intrinsic (Wyke) receptors of the facet joints are important, as these are the joints which were manipulated 24 hours prior to this study. The classification of the Wyke receptors is summarized in the table below :

| Type | Location | Characteristics |
|---|---|---|
| I | Fibrous capsules of joints in the superficial layers | Static and dynamic mechanoreceptors, low threshold, slowly adapting. |
| II | Fibrous capsules of joints in the deep layers | Dynamic mechanoreceptors, low threshold, rapidly adapting. |
| III | Surfaces of joint ligaments (collateral and intrinsic) | Dynamic mechanoreceptors, very high threshold, slowly adapting. |
| IV | Fibrous capsule of joints | Nociceptive mechanoreceptors, very high threshold, non-adapting. |

(Colloca, 1997; Leach, 1994)

From the above mentioned cervical anatomy, the facet joints and their intrinsic (Wyke) receptors are the most important structures to this study, as these were the joints which were manipulated 24 hours prior to follow up readings being taken, thereby stimulating the Wyke receptors. This is relevant to this research because stimulation of the type I, II and III Wyke receptors through manipulation have been associated with reflexogenic performance effects (Wyke, 1985).

### 2.3 Anatomy And Function Of The Rotator Cuff

The supraspinatus, infraspinatus, teres minor and subscapularis muscles are referred to as the rotator cuff of the shoulder joint, because all the muscles (except supraspinatus) are rotators of the humerus at the shoulder joint (Moore, 1992). The following table illustrates the attachments of these rotator cuff muscles :

| Muscle | **Origin** | **Insertion** |
|---|---|---|
| Subscapularis | Arises from the medial and lower two-thirds of the axillary border of the subscapular fossa. | Fibres converge in a tendon which is inserted into the lesser tubercle of the humerus. |
| Infraspinatus | Arises from fibers on the medial two-thirds of the infraspinatus fossa. | Fibres converge to a tendon and are inserted into the middle impression on the greater tubercle of the humerus. |
| Teres Minor | Arises from the dorsal surface of the axillary border of the scapula. | Fibres end in a tendon which is inserted into the lowest of the three impressions on the greater tubercle of the humerus. |
| Supraspinatus | Arises from the medial two-thirds of the supraspinatus fossa. | Fibres converge to a tendon, which is inserted into the highest of the three impressions on the greater tubercle of the humerus. |

(Table information from Gray, Pickering Pick & Howden, 1974; Moore, 1992 and Kieser & Allen, 1999)

More specifically, the infraspinatus and teres minor muscles are the chief external rotators of the shoulder (Norkin and Levangie, 1992; Boublik *et al* 1993 and Moore and Dalley, 1999) whereas; the subscapularis muscle is involved mainly in internal rotation and adduction (Moore, 1992). The supraspinatus assists the deltoid to abduct the arm and in conjunction with the other rotator cuff muscles viz. infraspinatus, teres minor and subscapularis, helps hold the humeral head in the glenoid cavity (Norkin and Levangie, 1992; Moore 1992 and Moore and Dalley, 1999).

Adduction, although produced by the subscapularis muscle at the shoulder joint, is not a primary movement of the rotator cuff and is assisted by various muscles, namely; Pectoralis major, Latissimus dorsi and Teres major, all of which serve to adduct the humerus at the shoulder joint and assist in internal rotation of the upper limb (Gray, Pickering Pick & Howden, 1974; Moore, 1992 and Kieser & Allen, 1999). The attachments of these muscles are summarized in the following table.

| **Muscle** | **Origin** | **Insertion** |
|---|---|---|
| Pectoralis major | Anterior medial part of clavicle, anterior sternum, superior six costal cartilages and aponeurosis of external oblique muscle. | Lateral lip of Intertubercular groove of humerus. |
| Latissimus dorsi | Spinous processes of inferior six thoracic vertebra, thoracolumbar fascia , iliac crest and inferior 3-4 ribs. | Intertubercular groove of humerus. |
| Teres major | Dorsal surface of inferior angle of scapula. | Medial lip of Intertubercular groove of humerus. |

(Gray, Pickering Pick & Howden, 1974; Moore, 1992 and Kieser & Allen, 1999)

The free movement of the shoulder joint, as well as the shallowness of the glenoid cavity and the laxity of the fibrous capsule, leads to considerable loss of stability in the shoulder. By holding the humeral head in the glenoid cavity (Norkin and Levangie, 1992; Moore, 1992 and Moore and Dalley, 1999), the rotator cuff provides dynamic stability to the shoulder, which would otherwise be unstable (Reid, 1992).

This is important to note, as it has been shown that strength of the rotator cuff muscles form an integral part of any rehabilitation programme for the shoulder after injury (Reid, 1992 and Kamkar *et al*, 1993). Wilk and Arrigo (1993) found that shoulder rehabilitation programmes, which incorporate early motion and emphasize strengthening, have a lower incidence of recurrent dislocations, and also state that the aim of shoulder rehabilitation must be to enhance the efficiency of contraction of the muscular force couples, which provide dynamic stability during functional activities.

Thus it is clear that the rotator cuff and surrounding muscles are vital to the proper movement and stability of the shoulder joint. Weakness in the rotator cuff and surrounding muscles can lead to instability and improper shoulder movement, which is why strengthening, is emphasized in rehabilitation protocols. If muscle strength could be increased through the reflexogenic effects of manipulation, then manipulation could be recommended as part of the rehabilitation process after rotator cuff injury.

### 2.4 The Reflex Effects of Manipulation

In this respect Herzog *et al* (1999) found consistent reflex responses associated with spinal manipulative treatments. These reflex responses have been hypothesized to cause the clinically beneficial effects of decreasing hypertonicity in muscles, pain reduction and reflex activation of skeletal muscles. The reflex reduction in muscle spasm is supported by Korr (1975), who sees the aberrant muscle spindle activity as the cause of intersegmental muscle spasm and resultant joint fixation. His theory states that if the vertebral attachments of the short spinal muscles are brought together by unguarded movement, the resultant silencing of the annulospiral nerve ending and the related decrease in neural activity would cause a lack of input into the central nervous system. In order to restore this, the central nervous system resets and thereby turns up the “gamma gain” as controlled by the gamma motor neurons, thus increasing the intensity of the muscle spasm as the vertebral attachments of the spinal muscles are taken back to their anatomical normal positions. Stimulation of the joints mechanoreceptors (Wyke receptors) by manipulation is hypothesized to reduce this muscle spasm and restore joint movement, by causing the central nervous system to reset the gain to a less sensitive level and restoring a more normal homoeostatic relationship between the intrafusal and extrafusal muscle fibre ratios.

The reduction of pain through manipulation is supported by Melzack and Wall (1965), who proposed the “Gate Control Mechanism” whereby impulses travelling in the larger myelinated mechanoreceptor fibres take precedence over the small diameter nociceptive fibres, and act to inhibit nociceptor activity. Thus, a decrease in mechanoreceptor activity through joint dysfunction, could lead to an increase in pain, and likewise, stimulation of the mechanoreceptors through manipulation, could cause presynaptic inhibition of the pain.

However, of most importance to this study is the hypothesis that manipulation causes reflex activation of skeletal muscles. This is supported by Wyke (1985), who discussed the central affects of articular mechanoreceptor activity, and determined that since the articular mechanoreceptor’s afferent nerve fibres give off collateral branches that are distributed segmentally as well as intersegmentally throughout the neuraxis, manipulation of an individual joint should not only affect motor unit activity in the muscles operating over the manipulated joint, but also in more distant muscles. This was confirmed by Nansel (1993), who set out to determine the effect of cervical adjustments on lumbar muscle tone in asymptomatic subjects. The results of this study showed that lower cervical manipulations induced a significant decrease in lumbar muscle tone, possibly due to reflexes involving intersegmental pathways.

Wyke (1985), goes on to say that dysfunction adversely affects nerve endings, causing inhibition of nerve function. These findings are congruent with Homewood (1977), who described how there could be a decrease in muscular activity due to interference with the nerve supply of a muscle by means of a fixation. The nerve supply to the rotator cuff muscles as well as the muscles contributing towards adduction, whose function could possibly be compromised by a fixation, are summarized in the table below :

| **Nerve** | **Vertebral Origin** | **Muscles Innervated** |
|---|---|---|
| Suprascapular nerve | C5, C6, and often C4 | Supraspinatus and Infraspinatus |
| Subscapular nerve | C5, C6 | Subscapularis |
| Lateral and Medial Pectoral nerves | C5, C6 | Pectoralis major |
| Thoracodorsal nerve | C6, C7, C8 | Latissimus dorsi |
| Lower Subscapular nerve | C6, C7 | Teres major |
| Axillary nerve | C5, C6 | Teres minor |

(Moore, 1992; Kieser & Allen, 1999)

Therefore, in light of the work done by Homewood (1977), Wyke (1985) as well as the above mentioned Herzog *et al* (1999) study, one could hypothesize that removal of a joint dysfunction by manipulation could reduce pain and muscle hypertonicity as well as increase functional muscle activity by increased motor unit recruitment and muscular activity (as measured by EMG) (Rebechini-Zasadny *et al*, 1981), and therefore theoretically strengthening the muscles involved (Suter, 1999 and 2000 and Naidoo, 2002).

## 2.5 The Effects Of Spinal Manipulation On Muscle Strength

The mechanism by which spinal manipulation affects muscle strength has not been extensively researched, but Rebechini-Zasadny *et al* (1981) reported an increase in muscle activity and strength of the first interosseous muscle of the hand following cervical manipulation when compared to subjects who received only passive cervical spine movements. Rebechini-Zasadny *et al* (1981) came to the conclusion that the increased activity within a muscle, equated to increased strength of that muscle. However, in this research the muscle activity and strength was measured by using a surface EMG reading. Since the surface EMG only measures muscle activity, it cannot be assumed that there is also an increase in muscle strength.

Naidoo (2002) found increases in grip strength in all four treatment groups following cervical manipulation at all the relevant spinal levels (C4/C5, C5/C6, C6/C7, C7/T1). However, the sample groups were not compared to a control, and therefore the reported findings may have had interference by uncontrolled variables (atmospheric noise), which would have reduced the sensitivity and accuracy of the surface EMG readings and could have resulted in inaccurate conclusions being drawn from the results.

The results obtained from the Rebechini-Zasadny *et al* (1981), and Naidoo (2002) studies reveal the possible value of manipulation in generating muscle activity, and although positive, were inconclusive to the effect of manipulation on muscle strength. Therefore, further research into the manipulation induced strength changes in muscles was recommended. Thus this study aimed to address these inconsistencies by measuring peak torque with an isokinetic dynamometer, as opposed to a surface EMG, as this tool provides valuable information for the evaluation of strength (Scotville *et al*, 1997).

## 2.6 Clinical Significance Of Increasing Muscle Strength Through Manipulation

As muscle activity is dependent on the integrity of its innervation (Rebechini-Zasadny *et al*, 1981), it could then be extrapolated that any factor which interferes with the nervous system at a particular level, could affect the muscular activity supplied by that level (Naidoo, 2002), and therefore possibly prevent optimal rehabilitation of that muscle. If manipulation of a fixation was shown to increase muscle strength, then this could be used to develop and implement more effective treatment and rehabilitation protocols for patients with musculoskeletal painful shoulders and rotator cuff pathologies, and therefore provide future patients with more effective health care. However, there is a possibility that a fixation does not necessarily need to be present to in order for the patient to have a deranged neurological output, and the reflex effects as described by Herzog *et al* (1999) could also possibly occur following manipulation, regardless of whether there is a fixation present at the time of manipulation or not.

Therefore the aim of this research was to determine the short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction. These results were measured by the use of isokinetic muscle testing, which is discussed below.

## 2.7 Isokinetic Muscle Testing

### 2.7.1 Introduction

Power is determined by the force (strength) of the muscle multiplied by its contraction velocity (Bloomfield, 1995). When utilizing the Cybex orthotron II isokinetic dynamometer, the speed of movement is controlled whilst resistance is variable according to the amount of force throughout the range of movement (www.isokinetics.net, 2005). This means that the motion of the body segment being tested is kept at a predetermined velocity no matter how much force the individual applies to the machine, and therefore power could not be measured in this study.

However, this tool was able to assess the strength of the rotator cuff muscles by measuring torque, as strength can be defined as the amount of force a muscle can exert against a resistance (Bloomfield, 1995) or the ability to exert maximum muscular force, statically or dynamically (De Ste Croix *et al*., 2003), and torque is simply the turning effect of that force (Chan and Maffulli, 1996). Strength can then be deduced from this torque measure (Hamilton, 2004).

### 2.7.2 Reliability Of Isokinetic Muscle Testing

The reliability of isokinetic dynamometers is extremely high. The studies which have examined the accuracy of peak torque, work and power have shown correlation coefficients between 0.93 and 0.99 (Magnusson *et al* 1990).

Chan and Maffuli (1996) have concluded that more advanced isokinetic machines do not produce higher reliability, and variables with greater numerical values e.g. peak torque of the knee show higher reliability than ones with lower values e.g. peak torque of the shoulder. Also, concentric results tend to show greater reliability than eccentric ones.

### 2.7.3 Validity Of Isokinetic Muscle Testing

Bernard (2000:46) defines validity as the "accuracy and trustworthiness of instruments, data and findings that ensures that future research utilizing that particular tool is accurate".

Isokinetic dynamometry has content validity with respect to specific aspects of muscle performance (www.isokinetics.net, 2005), which means that the clinical setting of the isokinetic muscle testing, can sometimes be comparable to real life situations (Terblanche, 2004).

Convergent validity has also been established by recognition of the relationship that exists between isokinetic testing and numerous other factors.

These include :

**Age**

Strength normally reaches its peak in the third decade and then declines slowly with age until the seventh decade, where there is a sharper decline there after (www.isokinetics.net, 2005).

**Gender differences**

Isokinetic studies have shown that men are significantly and consistently stronger than women (www.isokinetics.net, 2005).

**Body weight**

The relationship between isokinetic values and body weight has been shown to rise proportionately, and although this relationship is not linear, heavier subjects tend to produce higher isokinetic values (www.isokinetics.net, 2005).

**Motivational Factors**

The maximal effort of a test subject during isokinetic testing is influenced by motivational factors like verbal and visual encouragement, whereby more of their maximum potential was reached when these motivational factors were present (De Ste Croix *et al* 2003).

In summary, this form of testing allows for maximum muscle contraction throughout the full range of shoulder joint movement (www.isokinetics.net, 2005), and therefore Isokinetic evaluation using the Cybex orthotron II isokinetic dynamometer, provides valuable information for the evaluation of shoulder peak torque values and by inference strength (Scotville *et al*, 1997), and renders objective, reliable, and valid data (Davies, 1992).

## 2.8 Conclusion

It has therefore been shown above that there are consistent reflex responses associated with spinal manipulative treatments, and evidence does exist, indicating that manipulation of the spine has reflexogenic effects on muscles both locally and elsewhere in the body via the joint mechanoreceptors, by means of intersegmental pathways.

Thus if a decrease in muscular function were to occur due to interference with the nerve supply of that muscle by means of a fixation, then it is theoretically possible that by removing that fixation through manipulation, one could increase functional muscle activity, motor unit recruitment and therefore strengthen the muscles involved. Unfortunately, results obtained from previous studies were inconclusive to the effect of manipulation on muscle strength and therefore no inferences could be drawn from their results.

Furthermore if muscle strength could be increased through the reflex effects of manipulation, then manipulation could be recommended as part of the rehabilitation process after rotator cuff injury, due to the importance of increasing strength during rehabilitative protocols in this context.

Therefore, further research into the manipulation induced strength changes in muscles was recommended and required, which this study aimed to address by determining the short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction. Isokinetic evaluation using the Cybex orthotron II isokinetic dynamometer, provides valuable information for the evaluation of shoulder strength, and renders objective, reliable, and valid data, and for these reasons, it was utilized in this study.

# CHAPTER THREE

## Materials And Methods

### 3.1 Design

Quantitative, quasi-experimental design, which supported the need for a pre-post intervention study, as this was the most appropriate method for data generation and analysis in order to capture the short term reflex effects of cervical spine manipulation on the shoulder girdle musculature (Mouton, 1996). Furthermore the quantitative analysis allows for objective and accurate numerical recording of the potentially small changes which could have been seen as a result of the reflex effects of manipulation, which would not be possible in asymptomatic patients if qualitative methods were utilised.

In this context of this quantitative quasi-experimental study the independent variable is identified as the intervention received by the participants (manipulation) with the dependant variables being:

- Cybex readings / isokinetic measures of the rotator cuff (internal and external rotation, abduction and adduction)
- Fixation levels pre intervention and post intervention (i.e. changes) as well as the presence / absence of cavitations and their number (if present) elicited with the intervention.

### 3.2 Sampling

#### 3.2.1 Recruitment

Participants for this study were recruited from a concurrent study, which used convenience sampling. Participants were asked to join this study after their completion of the concurrent study (Dixon, 2005). Only English speaking participants were considered, as verbal encouragement was needed during the isokinetic testing procedure to ensure maximal effort. English is the researcher's first language and thus this reduced possible linguistic confusion between the participants and the researcher.

### 3.2.2 Size and Allocation

As indicated by the following table, 25 participants were divided evenly into 5 groups according to the level of fixation found in their cervical spines (C4/C5, C5/C6 or C6/C7, no fixation and random fixation at these levels), which is keeping with the levels of innervation of the rotator cuff (Moore 1992). All participants were manipulated at selected cervical spinal levels, 1 day / 24 hours prior to the collection of objective measurements for this study. A control group was also included, whereby participants without any cervical spine dysfunction were manipulated 1 day / 24 hours prior to this study.

Schematically the groups are represented as follows:

| | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** |
|---|---|---|---|---|---|
| **Level of Fixation** | None | Anywhere between C4-7 | C4/5 | C5/6 | C6/7 |
| **Group Size** | 5 | 5 | 5 | 5 | 5 |
| **Level of Adjustment 1 day / 24 hrs Prior to Study** | Randomly between C4-7 | Randomly between C4-7 | C4/5 | C5/6 | C6/7 |

## 3.3 Procedures

A description of the study was given to the participants, and exactly what was expected of them was addressed in the letter of information (appendix A). Participants who accepted the terms were expected to complete an indemnity form (Informed Consent Form) (appendix B) and their details were recorded for future reference.

Participants then underwent a case history, research physical examination, regional examination of the cervical spine and shoulder regional examination prior to their acceptance into this study and complied with the following inclusion and exclusion criteria.

### 3.3.1 Inclusion Criteria

- All subjects chosen were between the ages of 18 and 45. This was to reduce the risk of chronic degenerative diseases. (Naidoo 2002, O'Connor 2001).
- Principles of motion palpation followed the guidelines set out by Schafer and Faye (1990).
  - Motion palpation

    During motion palpation, each cervical motion unit (three articulations including: two posterior zygopophyseal joints and the intervertebral disc between adjacent vertebra) was palpated in the following directions:

    - flexion
    - extension
    - rotation
    - and lateral flexion

    These were done in order to assess the joint play and the mobility of the joint segment. Starting at C7, the thumb and middle finger were placed on the lamina of each segment, a smooth forward push was carried out following which, the pressure was released and the hand slid upward to the next segment. This was continued up to the occipit. At no time did the hand leave the patient's skin, and a firm yet gentle stabilization of the patient's head was maintained at all times (Schafer and Faye 1990).
- All subjects selected were right-hand dominant to ensure consistency and homogeneity. Peak torque was measured on the dominant side only (i.e. right hand side).

- All subjects accepted into the study received a letter of information regarding the study (appendix A) and completed the informed consent document indicating that they understood and agreed to all documentation provided (appendix B).
- For sample homogeneity only males were used in the study.

### 3.3.2 Exclusion Criteria

Patients who presented with :

- Neurological deficits (Edmund 1993).
- History of fracture or trauma (Edmund 1993).
- Surgery in the cervical region.
- Systemic disorders affecting cervical region including arthritides, infections or malignancies (Edmund 1993).
- Any relevant relative contra-indications including disc prolapse, spondylolisthesis, severe scoliosis and vertebrobasilar insufficiencies will be excluded from the study (Edmund 1993).
- Hypertensive patients.
- Utilisation of medication or other treatment during the course of the study (Poul *et al* 1993).
- All patients who fail to complete the informed consent form.
- History of any injury or surgery to the shoulder.

Should any of the participants have failed to adhere to the follow up reading after their manipulation 1 day / 24 hour previously, then provisions were made in this study to replace all drop-outs until the data from 25 participants was collected.

### 3.4 Intervention

The purpose of this consultation was the collection of data as a result of the participants having received a manipulation 1 day / 24 hours prior (administered by a co-researcher in a concurrent study) (Dixon, 2005). The manipulation techniques employed were all performed on the right hand side of the cervical spine and were consistent with those techniques set out and suggested by Schafer and Faye (1990) (Appendix E) and were judged successful following a grade 5 mobilization with or without an audible cavitation.

The administration of the manipulation by a co-researcher, allowed for blinding of the researcher in this study as to the level manipulated, thereby decreasing the effects of bias and thus strengthening the study this study (Mouton, 1996).

### 3.5 Objective Measurements

The movements that were measured included:

- internal rotation,
- external rotation and
- abduction,

in keeping with the prime movements of the rotator cuff muscles (Moore 1992, Reid 1992), as well as adduction. (Appendix C: Cybex testing protocol)

Before testing began, the participant's cervical spines were motion palpated in the manner outlined in the above-mentioned inclusion criteria. Only after the patients were assessed, were these motion palpation findings compared to the pre manipulation findings conducted prior to manipulation by the co-researcher (Dixon, 2005), to observe if there was any return or change in the participant's fixations.

Participants then underwent a 3-minute rotator cuff warm up including stretches of the rotator cuff muscles. They were then positioned onto the cybex machine, where they underwent a ‘practise round’ in order to familiarise themselves with the procedure. The patient then performed 6 test contractions per movement on the affected side, with a four-minute rest in-between to avoid fatigue (Suter, 2000).

One reading (average of 6 repetitions) was recorded, with the patient receiving verbal encouragement from the researcher during the isokinetic contractions to ensure maximal effort.

The manipulation was then administered according to the motion palpation findings (Schafer and Faye, 1990) and cybex reading where then taken immediately after the manipulation and 1 day / 24hours later to determine if any changes had occurred. These readings were compared to the pre- and post manipulation findings conducted 1 day/24 hours prior to this study (Appendix D: data collection sheet) to observe the short - term effect of cervical manipulation on the peak torque of the rotator cuff.

### 3.6 Statistical Methods

Data was captured in MS Excel and exported into SPSS version 12 (SPSS inc. Chicago, Ill) for analysis.

Descriptive analysis for categorical variables was achieved by frequency tabulations. In the case of quantitative variables, the assumption of normality was checked using the skewness statistic and its standard error. Although the sample size was small, the quantitative variables all passed the normality test, and were thus represented by means and standard deviations.

Comparison of categorical variables between independent groups : chi square or Fisher’s exact tests where appropriate. Comparison of quantitative variables between independent groups : t-test in the case of two groups and ANOVA with Bonferroni post hoc tests for more than two groups.

Repeated measures ANOVA was used to compare the treatment groups over the three time periods with regards to quantitative outcomes.

Hypothesis testing decision rule: a two tailed p value of $<0.05$ was considered statistically significant.

# CHAPTER FOUR

## Presentation Of Results And Discussion

### 4.1 Introduction

This study was conducted alongside another study (Dixon, 2005) that aimed to investigate the immediate effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction. The objective data generated by that study (pre-manipulation and immediately post-manipulation), together with the objective data obtained from this study, was utilized to determine the short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction.

This is presented firstly by a discussion of the participant demographics followed by intra-group analysis and finally a comparison of the groups (inter-group analysis), in order to determine group differences with respect to the reflex changes that occurred.

### 4.2 Abbreviations in the Statistical Analysis

**Sd :** Standard Deviation
**Df :** Degrees of Freedom
**Sig :** Significance
**Vs :** Versus
**CI :** Confidence Interval

## 4.3 Results

### 4.3.1 Demographics

### 4.3.1.a Age

The ages of the 25 participants ranged from 20 to 41 years, with a mean age of 26.7 years and a standard deviation of 5.5 years (Figure 1). There was a statistically significant difference in mean age by grouping of the participants (p =0.005). Figure 1 shows the mean age of each group and the p values from the significant Bonferroni multiple comparison tests. It can be seen that groups 1 and 2 were significantly different from each other with regard to age (p = 0.012), as well as groups 2 and 3 (p = 0.005) (i.e. group 2 had a higher mean age than groups 1 and 3). No other groups differed in age.

Key to groups :

1 = no fixation, random adjustment, 2 = fixation, random adjustment,
3 = fixation, adjustment C4-C5, 4 = fixation, adjustment C5-C6,
5 = fixation, adjustment C6-C7.

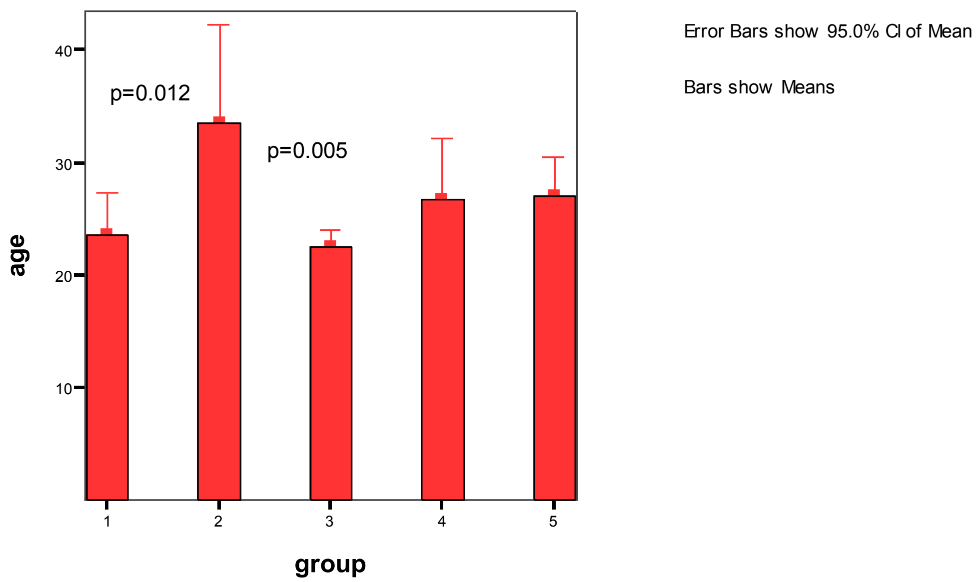



**Figure 1: mean and 95% CI age by group**

The fact that there was a statistically significant difference in mean age by grouping of the participants is a completely random event, as the method by which the participants were allocated to their groups was determined by the order in which they volunteered for the study and the level of fixation with which they presented.

It is however noted that this significant difference could have confounded the results as the responses per group (5 participants per group) could have been significantly different as the homogeneity of the groups was inconsistent (Mouton, 1996).

### 4.3.1.b Race

Only two race groups were represented in this study, Whites and Indians. Due to the sampling method there was a vast overrepresentation of whites (n=23, 92%), with only 2 Indian subjects. This breakdown by race is shown in Figure 2.

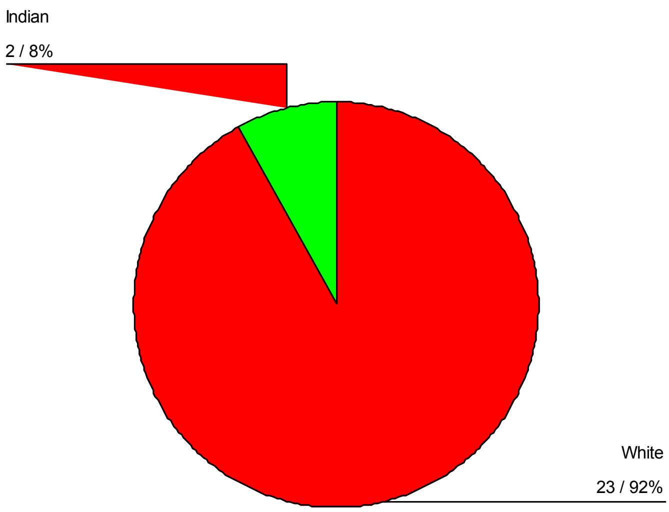



**Figure 2: Race groups in the study (n=25)**

It is however noted that this significant difference could have confounded the results as the responses per group (5 participants per group) could have been significantly different as the homogeneity of the groups was inconsistent (Mouton, 1996).

To assess whether age and race influenced the cybex readings, baseline cybex readings were compared between the age and race groups and this is discussed below.

#### 4.3.1.1 Comparison of cybex readings between the age and race groups

##### 4.3.1.1a Age

Table 1 shows that when the baseline Cybex readings were compared between the two age groups split at 25 years of age, there were no significant differences in any of the readings.

Table 1: Independent Samples T-Test for mean difference in baseline Cybex readings by age group.

| | Age group <=25 (n=15) mean (SD) | Age group >25 (n=10) mean (SD) | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|
| internal rotation pre | 44.73 (10.613) | 45.70 (18.613) | -.166 | 23 | .870 |
| external rotation pre | 35.40 (7.39) | 34.20 (11.04) | .327 | 23 | .747 |
| abduction pre | 45.73 (8.41) | 44.10 (10.43) | .432 | 23 | .670 |
| adduction pre | 81.20 (22.00) | 76.70 (16.87) | .547 | 23 | .590 |

Therefore it could be stated that although there could have been a difference in cybex readings as related to age, the comparative analysis revealed that this significance in terms of the recorded cybex readings (for internal, external, abduction and adduction readings pre manipulation), as according to means and SD, did not show a significant difference and therefore comparisons are not confounded by the lack of age homogeneity as defined by Mouton (1996).

#### 4.3.1.1b Race

Table 2 shows that there was a significant difference in all mean cybex readings at baseline between the two race groups. Indians scored lower on all readings than Whites. However, there were only two Indians in the group, thus results should be interpreted with caution.

**Table 2: Independent Samples T-Test for mean difference in baseline Cybex readings by race group**

| | Whites (n=23) mean (SD) | Indian (n=2) mean (SD) | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|
| internal rotation pre | 46.78 (13.31) | 26.00 (2.28) | 2.163 | 23 | .041 |
| external rotation pre | 36.48 (7.07) | 17.00 (8.49) | 3.702 | 23 | .001 |
| abduction pre | 46.35 (8.10) | 30.50 (9.19) | 2.641 | 23 | .015 |
| adduction pre | 82.13 (18.03) | 48.00 (12.73) | 2.596 | 23 | .016 |

There are three possible reasons why Indians may have scored lower on all readings than Whites, and they relate to body weight, motivational factors and sample size.

Firstly, the relationship between isokinetic values and body weight has been shown to rise proportionately, and although this relationship is not linear, heavier subjects tend to produce higher isokinetic values (www.isokinetics.net, 2005). The weight of the participants was not recorded in this study, but if one or both of the Indian participants was slightly smaller in statue, it may have produced the above mentioned lower readings.

The second reason could relate to motivational factors, as it has been shown that the maximal effort of a test subject during isokinetic testing is influenced by motivational factors like verbal and visual encouragement, whereby more of their maximum potential was reached when these motivational factors were present (De Ste Croix *et al*, 2003). It is however possible that perceptional differences between races occurred, where different cultures are not necessarily motivated by the same motivational factors, and the encouragement used to motivate the participants in this study may have been lost on one or the other race group.

Thirdly, the two Indian participants represented a very small percentage of the total sample size. So if one or both of the Indian participants offered sub-maximal exertion, it would dramatically lower the average readings for that race group, as opposed to the white participants who could have had many more lower readings without dramatically affecting the average torque produced by their race group, due to their greater number of participants.

Thus it could be inferred that the relative cybex readings obtained from this sample that was not homogenous could have affected the outcomes of this study and therefore it is recommended that future studies utilize stratification methods in order to homogenize the sample with respect to race.

### 4.3.2 Intra-group analysis

In order to establish the effect of manipulation within each group, each group was examined separately for descriptive purposes in order to describe each of the variable compositions (objective measurement compositions) that where appropriate to each group.

#### 4.3.2.1 Group 1:
#### No fixation between C4-7, random manipulation between C4-7

Group 1 all had many cavitations and none had fixations present after manipulation. One subject developed a fixation after 24 hours. This is shown in Table 3.

**Table 3: Cavitations and fixations in Group 1**

| | n (%) |
|---|---|
| Cavitation present | 5 (100%) |
| Many cavitations | 5 (100%) |
| Fixations after manipulation | 0 (0%) |
| Fixations 24 hours post | 1 (C4) (20%) |

The descriptive statistics for the cybex readings for Group 1 are shown in Table 4 over time. Internal rotation increased, external rotation decreased, abduction and adduction increased over time. This is also shown graphically in Figure 3.

**Table 4:**
**Descriptive statistics for Cybex measurements over time in Group 1: No fixation between C4-7, random manipulation between C4-7**

| | | internal rotation | | external rotation | | abduction | | adduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Range | Median | Range | Median | Range | Median | Range |
| TIME | pre | 49 | 31 | 42 | 15 | 46 | 18 | 81 | 62 |
| | post | 50 | 30 | 41 | 12 | 49 | 21 | 94 | 36 |
| | 24 hours post | 57 | 24 | 39 | 10 | 49 | 16 | 91 | 49 |

External rotation was the only movement where strength decreased over time. It is theoretically possible that the fixation which developed at C4 in one of the participants, 24 hours post manipulation, interfered with the nerve supply to the infraspinatus muscle (supplied by C4), therefore weakening this primary external rotator of the shoulder. These findings are congruent with Homewood (1977), who described how there could be a decrease in muscular activity due to interference with the nerve supply of a muscle by means of a fixation. The fact that only one of the participants developed this infraspinatus interference is still important, because the group only consisted of five people and therefore the fixated participant contributed 20% of the results.

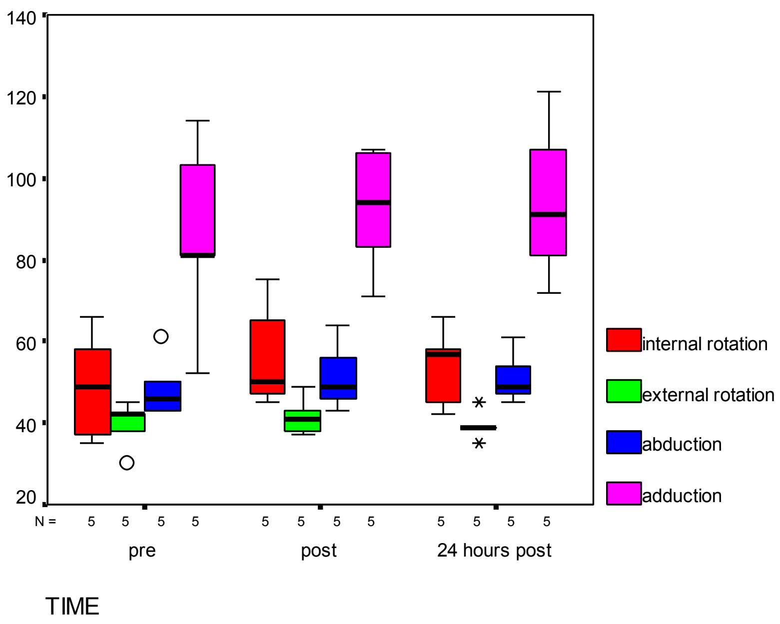



**Figure 3: Box plots of Group 1 over 3 time points**

#### 4.3.2.2 Group 2:

**Fixation between C4-7, random manipulation between C4-7**

Eighty percent of group 2 had cavitations, and of these 75% had many cavitations. All had no fixations present after manipulation or after 24 hours. This is shown in Table 5.

**Table 5: Cavitations and fixation in Group 2**

| | n (%) |
|---|---|
| Cavitation present | 4 (80%) |
| Many cavitations | 3 (75%) |
| Fixations present after manipulation | 0 (0%) |
| Fixations 24 hours post | 0 (0%) |

Table 6 shows that all cybex measurements increased in group 2 from pre to post and after 24 hours.

**Table 6:**

**Descriptive statistics for Cybex measurements over time in Group 2 : Fixation between C4-7, random manipulation between C4-7**

| | | internal rotation | | external rotation | | abduction | | adduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Range | Median | Range | Median | Range | Median | Range |
| TIME | pre | 37 | 31 | 35 | 16 | 42 | 23 | 77 | 15 |
| | post | 45 | 30 | 38 | 18 | 52 | 18 | 92 | 21 |
| | 24 hours post | 52 | 33 | 39 | 21 | 53 | 24 | 96 | 32 |

These results are supported by the work of Wyke (1985), who discussed the central affects of articular mechanoreceptor activity, and that manipulation of an individual joint should not only affect motor unit activity in the muscles operating over the manipulated joint, but also in more distant muscles. The increases in cybex measurements and lack of fixations 24 hours post manipulation is also congruent with the literature. Furthermore as Rebechini-Zasadny *et al*, (1981) state the removal of a joint dysfunction by manipulation could increase functional muscle activity by increased motor unit recruitment, and therefore possibly strengthen the muscles involved (Suter, 1999 and 2000 and Naidoo, 2002).

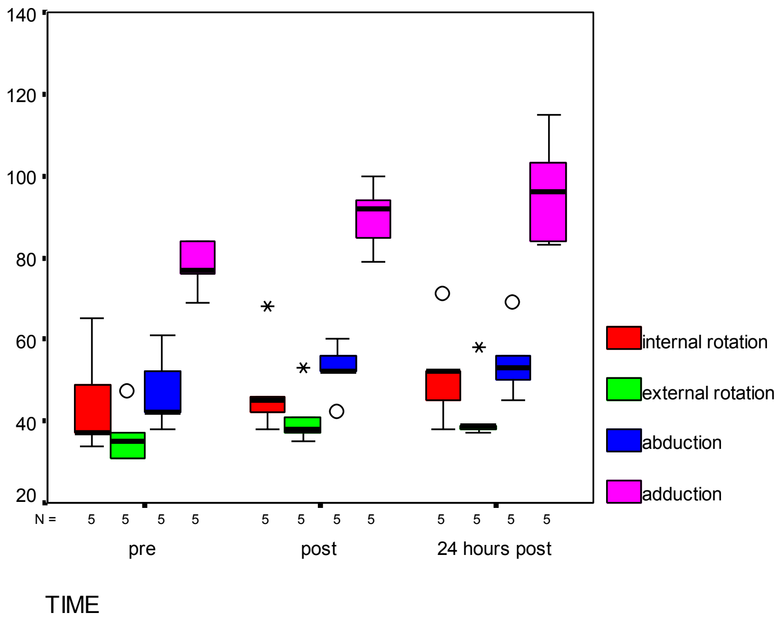



**Figure 4: Box plots of Group 2 over 3 time points**

**4.3.2.3 Group 3:**

**C4/5 fixation, manipulation at C4/5**

All of group 3 had cavitations, and 40% of them had many cavitations. None had fixations present after manipulation or post 24 hours.

**Table 7: Cavitations and fixations in Group 3**

| | n (%) |
|---|---|
| Cavitation present | 5 (100%) |
| Many cavitations | 2 (40%) |
| Fixations present after manipulation | 0 (0%) |
| Fixations post 24 hours | 0 (0%) |

Table 8 shows that internal rotation readings increased to a large extent between pre and post, and thereafter decreased. External rotation readings increased slightly, while abduction and adduction increased quite markedly in Group 3. This is shown in Figure 5.

**Table 8:**

**Descriptive statistics for Cybex measurements over time in Group 3 :**

**C4/5 fixation, manipulation at C4/5**

| | | internal rotation | | external rotation | | abduction | | adduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Range | Median | Range | Median | Range | Median | Range |
| TIME | Pre | 38 | 28 | 37 | 20 | 45 | 21 | 65 | 49 |
| | post | 47 | 29 | 39 | 19 | 47 | 31 | 87 | 46 |
| | 24 hours post | 37 | 28 | 39 | 24 | 50 | 32 | 91 | 59 |

Only 2 participants had many cavitations and therefore the majority of the group was manipulated specifically at C4/5, which was also the level of fixation pre-manipulation. The immediate increases seen in the cybex measurements for all movements may have been due to the immediate reflex effects of manipulation as described by Herzog *et al* (1999).

Internal rotation from the subscapularis muscle and assisted by pectoralis major, latisimus dorsi and teres major, was the only movement to decrease in strength 24 hours post manipulation. The decrease seen in internal rotation 24 hours post-manipulation could possibly be due to the fact that the majority of manipulations did not take place at C6 (specificity was achieved in 60% of the adjustments applied), which is the main segmental nerve supply for the muscles of internal rotation, due to the specificity of the adjustments at C4/5.

However, it has also been shown that the biomechanical changes which occur following manipulation at one level, could affect other levels as well without themselves having been manipulated, and thus restoring normalcy at those levels (Bergmann *et al* 1993; Leach, 1994). If these biomechanical changes occurred immediately post-manipulation, then this could explain why specifically manipulating levels unrelated to the main segmental innervation of the internal rotators, still caused a reflex increase in the peak torque of the internal rotators immediately post-manipulation. However because of the fact that the C6 mechanoreceptors were not adequately stimulated, due to the main forces of manipulation being directed at the joint receptors of C4/5, these reflex increases in torque were not sustained by the internal rotators 24 hours post-manipulation and returned to baseline. It could be argued that these biomechanical effects as described by Bergmann *et al* (1993) would only be evident after 24 hours and thus the improvement by the internal rotators immediately post-manipulation, should have been sustained at a similar level 24 hours later, but in this instance, this was not observed.

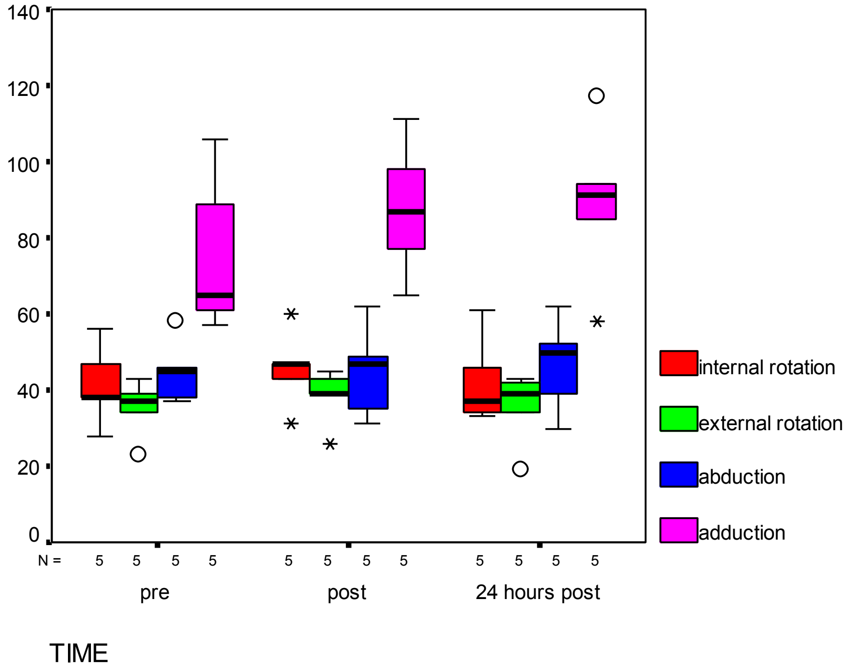



**Figure 5: Box plots of Group 3 over 3 time points**

#### 4.3.2.4 Group 4:
#### C5/6 fixation, manipulation at C5/6

Eighty percent of group 4 had cavitations, of which 75% had many cavitations. This is shown in Table 9. Two subjects (40%) developed fixations at 24 hours.

**Table 9: Cavitations and fixations in Group 4**

| | n (%) |
|---|---|
| Cavitation present | 4 (80%) |
| Many cavitations | 3 (75%) |
| Fixations present after manipulation | 0 (0%) |
| Fixations post 24 hours | 2 (C5) (40%) |

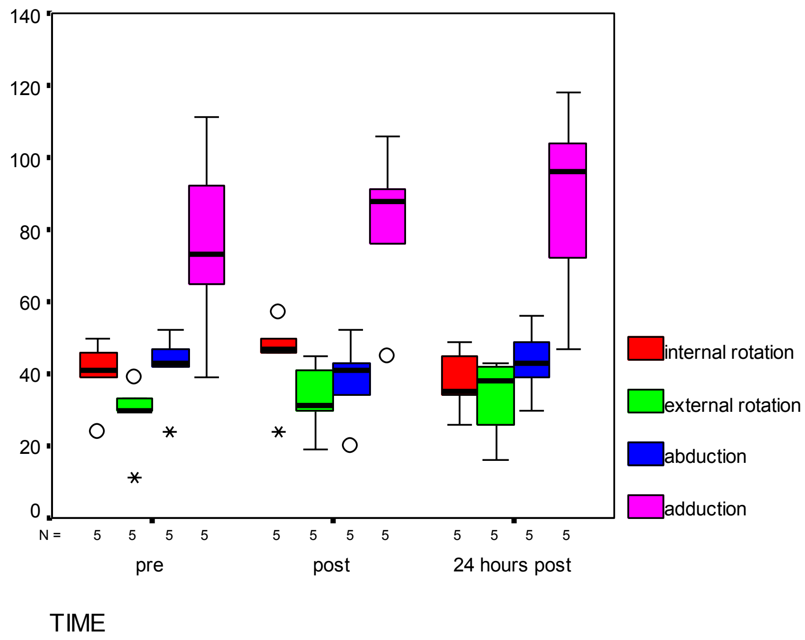
In group 4, there was an initial increase in internal rotation, followed by a decrease at 24 hours. External rotation showed an overall increase, as did adduction, while abduction remained quite constant. This is shown in Table 10 and Figure 6.

**Table 10:**
**Descriptive statistics for Cybex measurements over time in Group 4 : C5/6 fixation, manipulation at C5/6**

| | | internal rotation | | external rotation | | abduction | | adduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Range | Median | Range | Median | Range | Median | Range |
| TIME | pre | 41 | 26 | 30 | 28 | 43 | 28 | 73 | 72 |
| | post | 47 | 33 | 31 | 26 | 41 | 32 | 88 | 61 |
| | 24 hours post | 35 | 23 | 38 | 27 | 43 | 26 | 96 | 71 |

There were two participants who developed fixations at C5, 24 hours post-manipulation. This may have interfered with the innervation of the subscapularis muscle and pectoralis major, both of which are internal rotators and supplied by C5, and therefore caused a decrease in internal rotation strength, 24 hours post-manipulation. These findings are congruent with Homewood (1977), who described how there could be a decrease in muscular activity due to interference with the nerve supply of a muscle by means of a fixation.

A possible reason why this trend was not seen in external rotation and abduction, which are also mainly supplied by C5, is possibly due to the fact that larger musculature was involved in the internal rotation movement, and therefore the negative influence of the fixations at C5 had a amplified effect on the larger muscles causing decreases in their peak torque 24 hours post-manipulation.




**<u>Figure 6: Box plots of Group 4 over 3 time points</u>**

#### 4.3.2.5 Group 5:
#### C6/7 fixation, manipulation at C6/7

All of the subjects in group 5 had cavitations, and 40% of them had many cavitations. None developed fixations after 24 hours.

**Table 11: Cavitations and fixations in Group 5**

| | n (%) |
|---|---|
| Cavitation present | 5 (100%) |
| Many cavitations | 2 (40%) |
| Fixations present 24 hours | 0 (0%) |
| Fixations post 24 hours | 0 (0%) |

Group 5 internal rotation increased between pre and post, but levels fell back down to baseline levels at 24 hours. External rotation and abduction decreased over time, while adduction increased over time.

**Table 12:**
**Descriptive statistics for Cybex measurements over time in Group 5 :**
**C6/7 fixation, manipulation at C6/7**

| | | internal rotation | | external rotation | | abduction | | adduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Range | Median | Range | Median | Range | Median | Range |
| TIME | Pre | 43 | 60 | 37 | 33 | 46 | 30 | 81 | 49 |
| | post | 52 | 52 | 34 | 30 | 45 | 20 | 79 | 55 |
| | 24 hours post | 43 | 31 | 35 | 27 | 45 | 19 | 98 | 52 |

Only 2 participants had many cavitations and therefore the majority of the group was manipulated specifically at C6/7, which was also the level of fixation pre-manipulation.

The torque readings for external rotation from infraspinatus and teres minor, and abduction from the supraspinatus muscle remained the same, both immediately post and 24 hours post-manipulation. This could possible be due to the fact that the majority of manipulations did not take place at C5, which is the main segmental nerve supply for the muscles of external rotation and abduction, due to the specificity of the adjustments at C6/7. Therefore, due to the lack of mechanoreceptor stimulation at C5, the effects of manipulation as described by Wyke (1985), may not have adequately stimulated the external rotators and abductors to increase strength 24 hours post manipulation and therefore allowed them to remain within a narrow range (almost consistent) with pre-manipulation findings.

The increases seen in adduction at 24 hours post-manipulation are congruent with this study's hypothesis that manipulation and removal of fixations at a particular level (C6/7 in this case), removes interference of the nerve supply to the muscles supplied by that level, and therefore allows optimum functioning of that muscle. However, it is also acknowledged that changes in the biomechanics of the cervico-thoracic junction could have lead to sustaining the initial reflex effects of the manipulation at the 24 hour reading (Bergmann *et al* 1993; Leach, 1994).

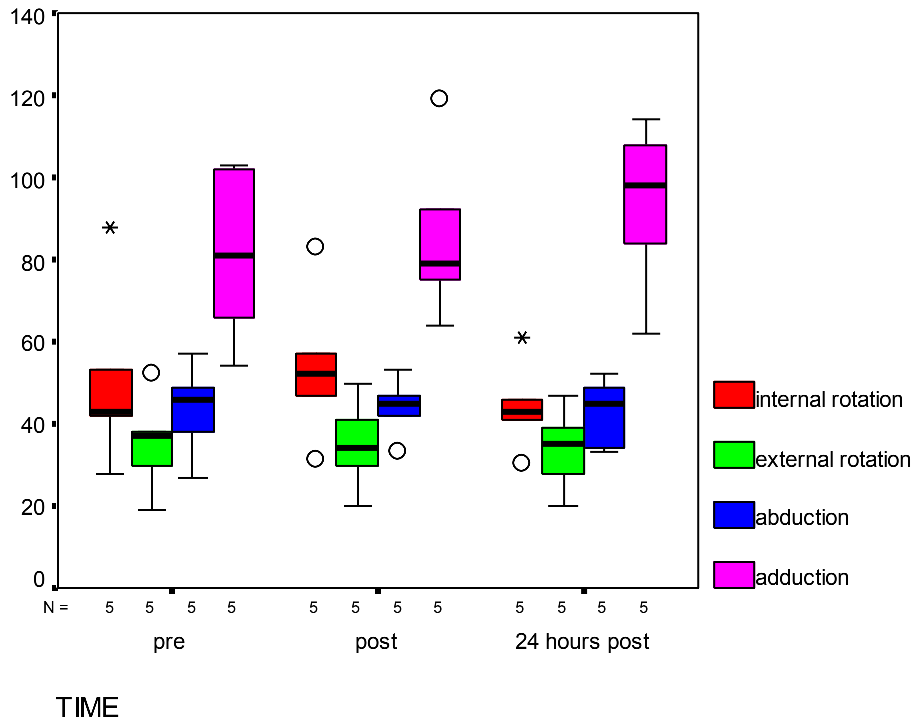



**Figure 7: Box plots of Group 5 over 3 time points**

#### 4.3.2.6 Intra-Group Analysis Summary

In Group 1 where there was no fixation and the application of a random adjustment, external rotation was the only movement where strength decreased over time. All other movements increased. Indicating that the presence of a fixation is not necessary for the stimulation of the rotator cuff musculature. The decrease in strength of the external rotators may be related to the levels that where randomly chosen within the group, such that there may and only have been 1 or no participants manipulated at the level which supplies the external rotators.

All cybex measurements increased in Group 2 (a fixation was present, however the adjustment was random and not necessarily at the level of the fixation), from pre to post and after 24 hours. These results indicate that there is a possibility that it does not matter which levels are manipulated and that it is more important the restoration of mechanics within the cervical spine is restored (Bergmann *et al* 1993; Leach, 1994).

In Group 3 (fixation at C4-C5 and adjustment C4-C5), internal rotation readings increased to a large extent between pre and post, and thereafter decreased, while abduction and adduction increased quite markedly. An initial increase in internal rotation was seen in Group 4 (fixation C4-C5 and adjustment C5-C6), followed by a decrease at 24 hours. External rotation showed an overall increase, as did adduction. In Group 5 (fixation C6-C7 and adjustment C6-C7), internal rotation increased between pre and post, but levels fell back down to baseline levels at 24 hours. External rotation and abduction decreased over time, while adduction increased over time.

The effects of the specific adjustments at specific levels indicated that there is a role for specific adjusting at specific levels, yielding specific results which was related for the most part to the level of neurological innervation of the rotator cuff muscle involved.

### 4.3.3 Inter-group comparisons

Repeated measures ANOVA was done for each Cybex measurement to assess if there was a significant change over time in all subjects, if there was a significant difference between the 5 groups at all time points and if there was an interaction between time and group (the levels changed over time to different extents in the different groups). The latter would be an indication of treatment effect difference in the groups. The effect of race, cavitations and fixation 24 hours post -manipulation were also assessed by using these as factors in the model. However, the study was underpowered to detect small differences between the groups due to small sample size. Thus the results should be interpreted with caution and more emphasis should be put on the trends which may emerge.

#### 4.3.3.1 Internal rotation

There was no significant change over time, nor between the groups. The effects of race, cavitation and fixations at 24 hours did not affect the change over time significantly. Figure 8 shows that for all groups there was an increase between pre and post manipulation, but in most groups it was not sustained over 24 hours. Only group 1 and 2 showed no decrease in internal rotation after 24 hours. Group 2 showed a continued increase at 24 hours post.

**Table 13:**
**Hypothesis tests for repeated measures ANOVA for Internal Rotation**

| | Statistic | p value |
|---|---|---|
| Time | Wilk's lambda 0.816 | 0.197 |
| Time *Group | Wilk's lambda 0.513 | 0.168 |
| Group | F =0.443 | 0.776 |
| Time* race | Wilk's lambda 0.856 | 0.289 |
| Race | F=2.956 | 0.104 |
| Time* cavitation | Wilk's lambda 0.991 | 0.932 |
| Cavitation | F=1.909 | 0.185 |
| Time*fixations 24 hours post | Wilk's lambda 0.906 | 0.453 |
| Fixations 24 hours post | F=2.505 | 0.132 |

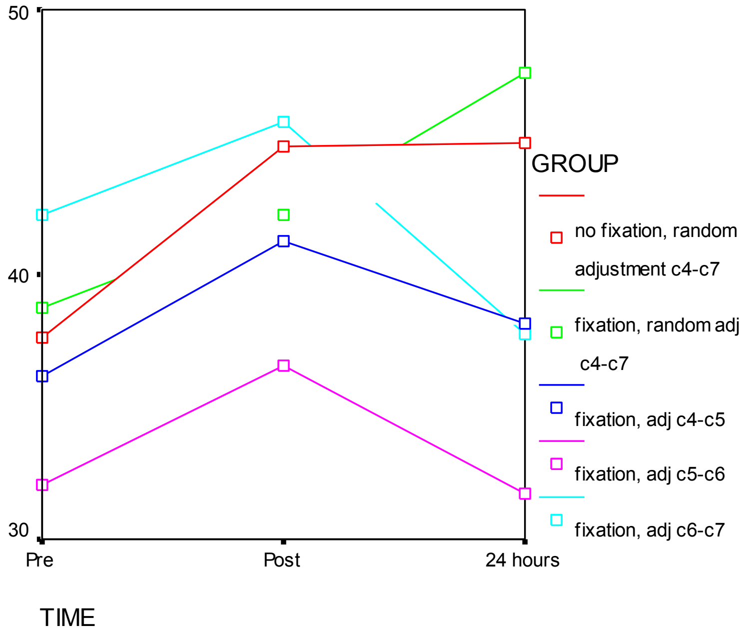



**Figure 8: Mean internal rotation over time by group**

#### 4.3.3.1.1 Interpretation Of Results

All groups showed an increase in peak torque between pre and post manipulation. This can be explained by Herzog *et al* (1999) who found consistent reflex responses associated with spinal manipulative treatments, and these reflex responses have been hypothesized to cause reflex activation of skeletal muscles. This is supported by Wyke (1985), who discussed the central affects of articular mechanoreceptor activity, and that manipulation of an individual joint should not only affect motor unit activity in the muscles operating over the manipulated joint, but also in more distant muscles, and removal of a joint dysfunction by manipulation could increase functional muscle activity by increased motor unit recruitment (Rebechini-Zasadny *et al*, 1981), and therefore possibly strengthen the muscles involved (Suter, 1999 and 2000; Naidoo, 2002).

These immediate increases seen in the torque measurements either continued to increase or were sustained 24 hour post manipulation in groups 1 and 2.

The reasons for this can possibly be explained by :

- The effect of adjusting the joints that had a high probability of allowing adjustments at the end range of motion in groups 1 and 2. This is as a result of the fact that group 1 had no fixations and groups 2 although they had fixations, could easily have been adjusted at a level that did not have a fixation.

  The effect of this adjustment at the end range of motion implies that the neurological stimulation of the respective levels that where adjusted was greater than those patients that where adjusted at the fixated level, whereby the degree of stretch applied to the muscles and ligaments would have been reduced as the patient would only have been adjusted at the end of the clinical physiological range of motion (e.g. restricted by scar tissue or adhesion formation) (Vernon and Mrozek, 2005).

  It is therefore implied in this discussion that there is a direct association between improvement of the peak torque in groups one and two which is related to the fact that the segments where not fixated at the time of the adjustment thereby allowing for a greater and sustained result as compared to the other 3 groups (3,4, and 5).

- This would be consistent with the “Neural Scar” Hypothesis as proposed by Patterson and Steinmetz (Leach, 1994), who suggested that if an initial stimulus is sufficient or lasts long enough, a “learned influence” in the spinal cord remains due to segmental facilitation, even though the influence of the instigating lesion has been removed. These authors go on to say that once this facilitation occurs, the abnormal reflex circuit in the spinal cord participates in maintaining the symptoms itself, due to hyper-excitable neurons, and may not be easily removed.

This concept of a “learned influence” in the spine as well as the fact that all participants in groups 3, 4 and 5 presented to this study with cervical facet dysfunction of unknown duration at the level manipulated, could explain why their torque readings decreased 24 hours post-manipulation, even though 13 out of the 15 participants manipulated in these three groups were fixation free and only two participants presented with fixations at their 24 hour post-manipulation reading.

The suggestion here is that there is still a neurological facilitation present even thought the fixation was no longer present at the 24 hour post-manipulation reading. This is congruent with the findings of Homewood (1977), who described that there could be a decrease in muscular activity due to interference with the innervation of muscle by means of a fixation. However Homewood (1977) based his theories on the presence of a fixation, when what is presented here seems to indicate that his theory stands, but that a role also needs to be attributed to the presence of a neural scar as suggested by Patterson and Steinmetz (Leach, 1994).

#### 4.3.3.2 External rotation

There was a significant interaction of time and group (p = 0.022). Thus we can say that the change over time of mean external rotation was dependant on the group in which the subject was. This is more easily interpreted by examining Figure 9 below. It can be seen that most groups increased mean external rotation between pre and post visits, but they mostly decreased at 24 hours post. This was not the case for group 2 which showed an increase between immediately post and 24 hours post-manipulation. Thus the intervention had a significantly different effect in group 2 compared with the other groups. There was also a significant difference overall between the race groups (p = 0.010). This can be seen in Figure 10 where at all time points the means for Whites are higher than those for Indians. This is due to the higher baseline readings in the whites and not due to treatment effect. Cavitations and fixations did not affect the mean external rotation over time.

**Table 14:**
**Hypothesis tests for repeated measures ANOVA for External Rotation**

| | Statistic | p value |
|---|---|---|
| Time | Wilk's lambda 0.663 | 0.069 |
| Time *Group | Wilk's lambda 0.289 | 0.022 |
| Group | F =0.646 | 0.639 |
| Time* race | Wilk's lambda 0.652 | 0.062 |
| Race | F=8.735 | 0.010 |
| Time* cavitation | Wilk's lambda 0.887 | 0.460 |
| Cavitation | F=1.873 | 0.193 |
| Time*fixations 24 hours post | Wilk's lambda 0.720 | 0.352 |
| Fixations 24 hours post | F=0.257 | 0.777 |

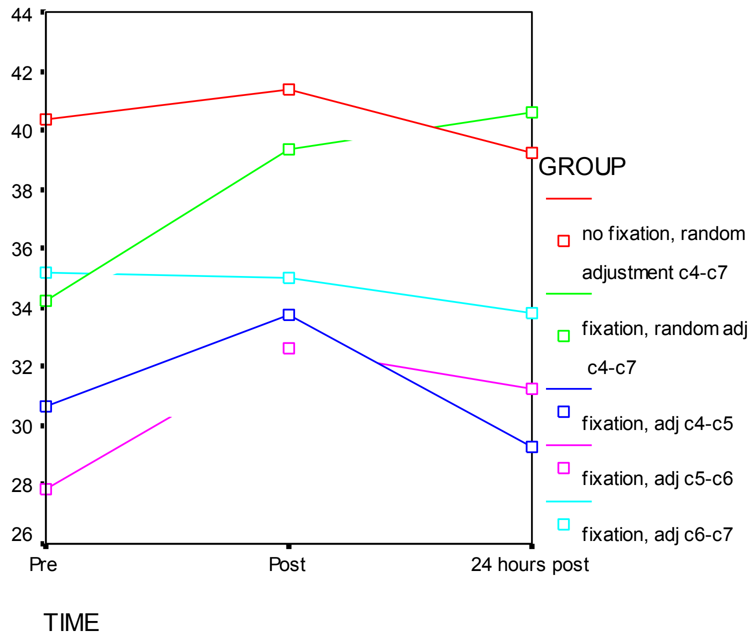



**Figure 9: Mean external rotation by group and time**

#### 4.3.3.2.1 Interpretation Of Results

Most groups showed an increase in peak torque between pre and post manipulation, the possible reason for which, was explained by reflex effects in 4.5.3.1.1 above.

These immediate increases seen in the torque measurements, continued to increase in group 2, 24 hours post-manipulation, which is consistent with the rationale for improvement as suggested under 4.5.3.1.1.

Groups 3, 4 and 5 all showed decreases in peak torque between immediately post-manipulation and 24 hours post-manipulation. The "Neural Scar" Hypothesis of Patterson and Steinmetz (Leach, 1994), used in 4.5.3.1.1 above to describe decreases in internal rotation strength 24 hours post-manipulation, relies on a history of cervical dysfunction in the study's participants, and therefore may be used to explain the decreases in torque produced by groups 3, 4 and 5.

But the hypotheses as indicated above cannot be used to explain this trend in external rotation for group 1, as all the participants in this group were fixation-free on the day that they were manipulated, and therefore the possibility of them having a neural scar is not appropriate.

However, another possible reason why these groups decreased in strength 24 hours post-manipulation, whether they were fixated prior to manipulation or not, relates to post exercise muscle pain and stiffness. Although it was not recorded objectively or subjectively in this study, it was however noted that numerous participants complained of post exercise muscle pain and stiffness as a result of the cybex testing protocol 24 hours previously. Painful muscular contractions may have contributed to decreases in torque production by the shoulder at the 24 hour post manipulation testing, but the stiffness described by the participants as, "in and around the shoulder joint", may have been more of a factor. This is due to the fact that the glenohumeral, scapulothoracic, sternoclavicular and acromioclavicular joints participate in shoulder movement in a smooth, co-ordinated pattern called "scapulohumeral rhythm" (Kamkar *et al*, 1993). One of the main purposes of this co-ordinated motion is to maintain the optimal length / tension relationship of the muscles acting on the humerus and therefore maximize their contraction efficiency (Norkin and Levangie, 1983). Further to this, Kamkar *et al*, (1993) states that disruption of motion at any of the joints involved in scapulohumeral rhythm, may affect the total motion produced at the shoulder.

Therefore, although these joints were not examined before the 24 hour post-manipulation testing procedure, it is possible that the stress applied to the glenohumeral and surrounding joints (i.e. scapulothoracic, sternoclavicular and acromioclavicular joints) during the cybex testing procedure 24 hours previously, led to the development of one or more fixations in these joints, especially due to the fact that as mentioned earlier, many participants complained of stiffness in and around the shoulder joint at their 24 hour post-manipulation testing. If fixations were present in these joints, they may have altered the scapulohumeral rhythm and decreased the contraction efficiency of the scapular muscles acting on the humerus, and therefore led to decreases in the torque readings.

However we also note that this theory related to the scapulohumeral effects of the manipulation should also be applicable to group 2, however this group shows an increase at 24 hours.

One possible reason for this could be that group 1 was only manipulated at a particular level which did not suit the external rotation level. For example, group 1 could have had C6 adjusted more often than C4, with the resultant effect of having less input into the external rotation in this group when compared to group 2 where C4 was adjusted more than C6. This, however, is an assumption as the level of adjustment in these groups was allocated as random and assumed to be such during the course of the study, but it is also acknowledged that different applications of adjustments and researcher preference for a particular adjustment may have allowed for gravitation towards a particular level in order to achieve the adjustment.

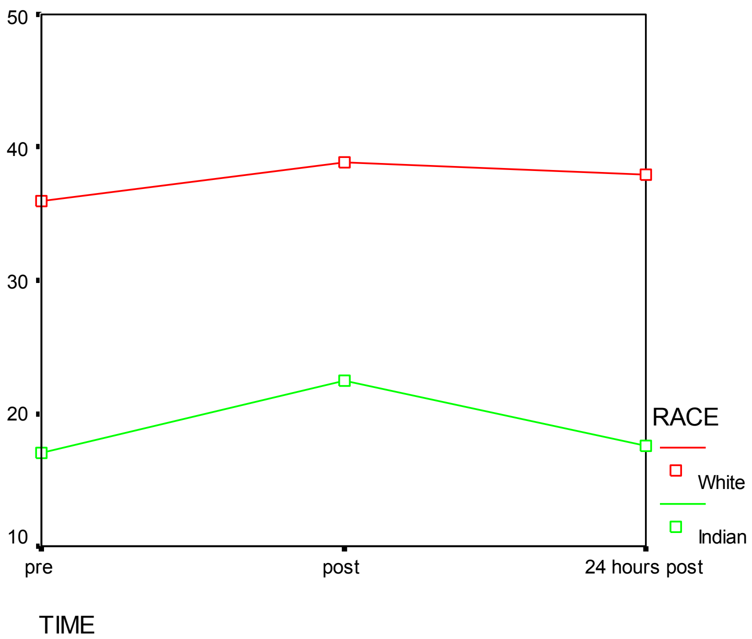



**Figure 10: Mean external rotation by time and race group**

At all time points the means for Whites are higher than those for Indians, due to the higher baseline readings in the whites, the possible reason for which was explained in 4.5.1.1 above.

#### 4.3.3.3 Abduction

There was no significant time*group interaction nor effect of time overall. Examination of Figure 11 shows that two of the groups initially increased between pre and immediately post manipulation. However, group 1 then decreased back down to baseline levels, while group 2 continued to increase until 24 hours post. Group 4 showed an initial decrease until post-manipulation, followed by a sharp increase between post and 24 hours post-manipulation. Only the effect of race group was statistically significant overall, meaning that the mean abduction for whites was at all times higher than that for Indians.

**Table 15:**
**Hypothesis tests for repeated measures ANOVA for Abduction**

| | Statistic | p value |
|---|---|---|
| Time | Wilk's lambda 0.922 | 0.590 |
| Time *Group | Wilk's lambda 0.622 | 0.554 |
| Group | F =1.112 | 0.390 |
| Time* race | Wilk's lambda  0.933 | 0.638 |
| Race | F=7.873 | 0.014 |
| Time* cavitation | Wilk's lambda 0.927 | 0.609 |
| Cavitation | F=3.859 | 0.070 |
| Time*fixations 24 hours post | Wilk's lambda 0.982 | 0.886 |
| Fixations 24 hours post | F=0.112 | 0.742 |

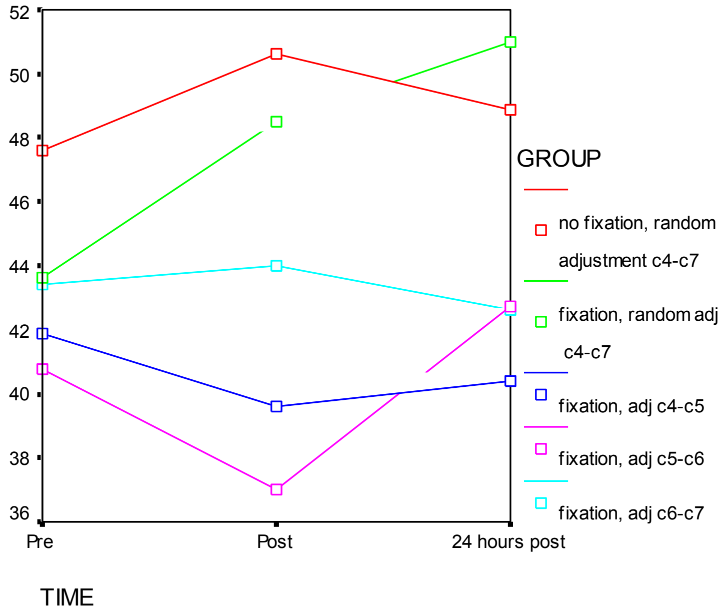



**Figure 11: Mean abduction by time and group**

#### 4.3.3.3.1 Interpretation Of Results

Group 1 and 2 follow the same trend as for external rotation above (Table 14).

Group 5 showed an increase in peak torque between pre and post manipulation, the possible reason for which, was explained by reflex effects in 4.5.3.1.1 above. The decreases in peak torque between immediately post-manipulation and 24 hours post-manipulation can be explained by the "Neural Scar" Hypothesis of Patterson and Steinmetz (Leach, 1994), used in 4.5.3.1.1 above, which relies on a history of cervical dysfunction in the study's participants, and therefore may be used to explain the decreases in torque produced by group 5.

Groups 3 and 4 showed decreases in peak torque immediately post-manipulation, followed by an increase with an attempt to return to baseline readings (or supersede these) 24 hours post-manipulation, even though no further intervention took place in the 24 hours following manipulation. A possible reason for this relates to the type of movement performed, the muscles involved in abduction, and the subsequent development of fatigue, as described below.

Firstly, the deltoid and supraspinatus muscles are the prime movers of glenohumeral abduction (Andrews and Wilk, 1994), but are relatively small in size in comparison with other muscles producing movement at the shoulder joint (e.g. the larger pectoral and latisimus dorsi muscles producing adduction and internal rotation). Secondly, a long lever manoeuvre was used to measure abduction during the isokinetic testing protocol, which means that the movement was performed further away from the centre of rotation than the short lever manoeuvre's utilized during internal and external rotation, and thus it would be harder to produce the equivalent effort, as compared with a short lever manoeuvre. Lastly, the side lying position used to test abduction, required the participants to contract the deltoid and supraspinatus muscles against gravity throughout the 90 degree range of motion tested, which is more difficult than contracting in the direction of gravity, as in adduction.

In light of the three above mentioned reasons as well as the fact that during abduction the deltoid and supraspinatus muscles contract with a slight mechanical disadvantage, due to their close attachment to the axis of rotation, one can see that the isokinetic testing of abduction is not an easy movement to perform, and the relatively small musculature may have a greater chance of becoming fatigued, as opposed to the larger muscles producing the other movements at the shoulder.

Therefore, it is possible that as glucose was broken down to provide the energy for the muscle contractions during the isokinetic testing procedure, there was a build-up of lactic acid as a by-product of glucose metabolism. It is this lactic acid which is said to cause extreme fatigue (Bloomfield *et al*, 1995). Muscle fatigue can possibly explain the trend seen in Group 3 and 4, as the decreases seen in peak torque immediately post-manipulation may have been due to the short rest period and inadequate recovery between the pre and post manipulation testing, leading to decreases in these readings. This possibility can also help explain the fact that the readings of the participants in group 3 and 4 returned to baseline 24 hours later, even though no further intervention took place, as they had had ample time to rest and recover from the previous days testing procedure.

However, it is also acknowledged that these effects should have been as prominent in the other groups 1, 2 and 5. The argument that suggests that the groups 3 and 4 suffered most is that these 2 groups had less neurological stimulation of the relevant levels (level of manipulation) and to a lesser degree (degree of neurological stimulation related to the presence / absence of a fixation), which could have negated the effects of the fatigue suggested above in the other groups.

In addition, movements at the glenohumeral joint do not occur in isolation and are associated with scapulothoracic movement (Kamkar *et al*, 1993). The normal biomechanics of the shoulder joint relies on the scapulothoracic articulation because it orientates the glenoid fossa so that it can provide a stable base for articulation with the humeral head and maintain optimal contact with the moving humerus (Norkin and Levangie, 1983). The scapulothoracic articulation is not a true joint as it lacks ligamentous restraints, which fully delegates the function of stability to the muscles that attach the scapula to the thorax, and therefore because certain muscles control the movement at the scapulothoracic articulation, their proper functioning is vital to the normal biomechanics of the shoulder (Kamkar *et al*, 1993).

Of the several muscles controlling movement at the scapulothoracic articulation, latisimus dorsi and the pectoral muscles have been discussed in 2.3 above, due to their role in this study as adductors of the humerus at the shoulder joint and their assistance in internal rotation of the upper limb (Gray, Pickering Pick & Howden, 1974; Moore, 1992 and Kieser & Allen, 1999), and therefore will not be discussed here any further. Serratus anterior, trapezius, levator scapulae and the rhomboids are the remaining muscles controlling the scapulothoracic articulation and are important in this explanation as they were not monitored in this study, yet clearly play a role in shoulder movement and all have segmental nerve origins which relate to the vertebral levels which were manipulated 24 hours prior to this study. These muscles of the scapulothoracic articulation, their nerves and segmental origin are summarized in the following table :

| Muscle | Nerve | Vertebral Origin |
|---|---|---|
| Serratus Anterior | Long Thoracic Nerve | C5, C6, C7 |
| Trapezius | Accessory Nerve | C3, C4 |
| Levator Scapulae | Dorsal Scapular Nerve | C3, C4, C5 |
| Rhomboid Major | Dorsal Scapular Nerve | C4, C5 |
| Rhomboid Minor | Dorsal Scapular Nerve | C4, C5 |

(Moore, 1992; Kieser & Allen, 1999)

By viewing the vertebral origins of the muscles controlling movement at the scapulothoracic articulation, it is clear that manipulation was inadvertently directed at these levels and the peripheral effects of manipulation as described by Herzog *et al* (1999) in 4.5.3.1.1 above, could have produced their effects by either reducing pain, hypertonicity or by reflex activation of these muscles. All participants in this study were pain free in the cervical and shoulder regions prior to manipulation, therefore by possibly reducing hypertonicity and / or by reflex activation of one or more scapulothoracic muscles, the manipulation 24 hours prior to this study may have improved the functioning of the scapulothoracic articulation and therefore the biomechanics of the entire shoulder, leading to sustained or improved strength 24 hours post-manipulation.

These effects could have been more marked in the groups 1,2 and 5 when compared to 3 and 4, thus allowing for an over-riding of the specific shoulder effects (fatigue) on groups 3 and 4.

This would be congruent with the effects as discussed by Vernon and Mrozek's (2005) article, where reading 2 should be at minimum, better than reading 1 (i.e. irrespective of the degree of stimulation there should still be improvement as a result of neurological input). However this neurological input is determined by the degree of stimulation (presence or absence of the fixation) and the level of the stimulation (cervical level) as well as the peripheral effects described by Herzog *et al* (1999). This would imply that the greater the degree of stimulation at a particular level affecting more muscles will have a greater effect, where the converse would also hold true. Thus if groups 1, 2 and 5 fell into the former, the degree of fatigue affecting the readings would have been less, whereas if groups 3 and 4 had lesser stimulation at an inappropriate level as well as affecting fewer muscles, the nett effect of fatigue would not as easily have been masked and thus resulted in a decreased reading (reading 2), which would have resolved over the 24 hours showing a normalization or improvement to pre treatment readings.

### 4.3.3.4 Adduction

All groups showed an increase in adduction over time, but this was not statistically significant (p =0.086). There was no differences between the groups, nor time*group interaction. Thus all groups behaved in the same manner over time. The only effect which was significant was the effect of race (p=0.008), which was constant across time (p = 0.259).

**Table 16:**
**Hypothesis tests for repeated measures ANOVA for Adduction**

| | Statistic | p value |
|---|---|---|
| Time | Wilk's lambda 0.686 | 0.086 |
| Time *Group | Wilk's lambda 0.855 | 0.972 |
| Group | F =0.209 | 0.929 |
| Time* race | Wilk's lambda 0.813 | 0.259 |
| Race | F=9.468 | 0.008 |
| Time* cavitation | Wilk's lambda 0.855 | 0.362 |
| Cavitation | F=0.587 | 0.456 |
| Time*fixations 24 hours post | Wilk's lambda 0.761 | 0.170 |
| Fixations 24 hours post | F=2.701 | 0.123 |

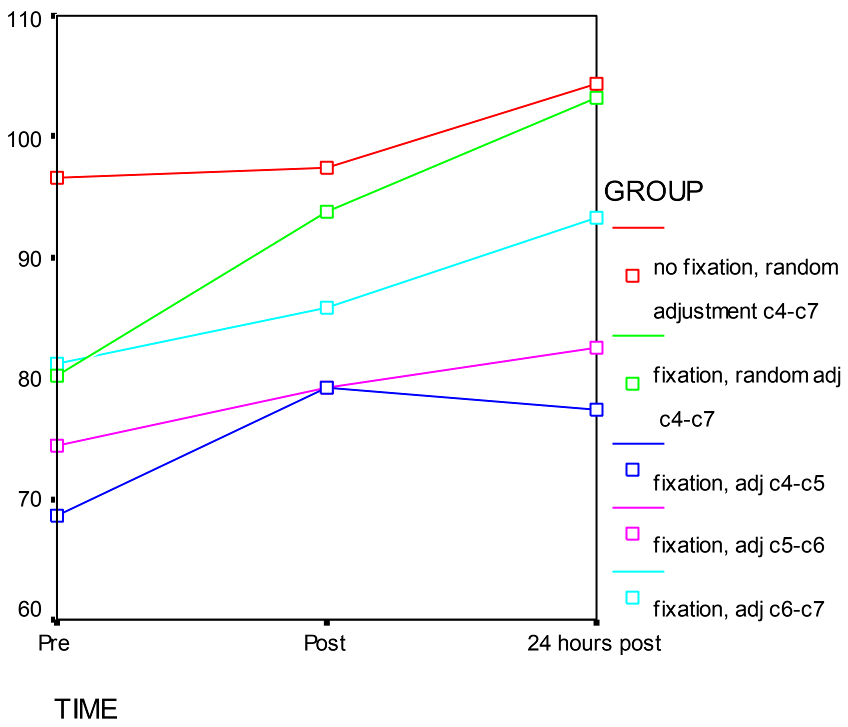



**Figure 12: Mean adduction by time and group**

#### 4.3.3.4.1 Interpretation Of Results

All groups showed increased peak torque between pre and immediately post-manipulation, the possible reason for which was explained by reflex effects in 4.5.3.1.1 above. However, all groups showed an increase in adduction over 24 hours as well, even though manipulation may have in some groups been directed at levels unrelated to the innervation of the adductors.

One possible reason for this could be due to the fact that the biomechanical changes which occur at one vertebral level following manipulation, may affect other levels as well, without themselves having been manipulated (Bergmann *et al*, 1993; Leach, 1994). This could explain why adjusting levels unrelated to the innervation of the adductors, still caused an increase in their torque readings, 24 hours post-manipulation. This coupled with the fact that out of all the movements tested, adduction had the largest size and number of muscles contributing towards its movement, and therefore the reflex activation of so many large muscles, as described earlier by Wyke (1985) and Herzog *et al*, (1999) had the greatest potential for increases in torque.

#### 4.3.3.5 Inter-Group Analysis Summary

With internal rotation it was found that there was no significant change over time, nor between the groups. For all groups there was an increase between pre and post manipulation, but in most groups it was not sustained over 24 hours (especially 4 and 5 with groups 1 and 2 showing no decrease in internal rotation after 24 hours). Only group 2 (fixation, random adjustment) showed a continued increase / sustained response at 24 hours post, which indicates that internal rotation is seemingly independent of level affected by the manipulation intervention.

In congruence with internal rotation, external rotation was found to have most groups showing an increased mean external rotation between pre and post visits, but they mostly decreased at 24 hours post. This was not the case for group 2 which showed an increase between immediately post and 24 hours post-manipulation. Thus the intervention had a significantly different effect in group 2 compared with the other groups. This seems to shadow the results of in the internal rotation and speaks to the theory proposed by Bergmann (1993) and Leach (1994) in respect of the normalisation of mechanics more so than the stimulation of receptors as proposed by Wyke (1985).

In contrast to this abduction had a confounding variable as it related to race group with the abduction related to White participants being higher than that of the Indian participants. Even in the face of this, groups 1 and 2 follow the same trend as for external rotation above with a decrease in group 1 and an increase in group 2. Group 5 showed an increase in peak torque between pre and post manipulation and a decrease in peak torque between immediately post- manipulation and 24 hours post-manipulation, which supports the "neural scar theory" (Leach, 1994) and the adhesion hypothesis (Vernon and Mrozek (2005). Whereas groups 3 and 4 showed decreases in peak torque immediately post- manipulation, followed by an increase with an attempt to return to baseline readings (or supersede these) 24 hours post-manipulation, even though no further intervention took place in the 24 hours following manipulation, which supports the theories proposed by Bergmann (1993) and Leach (1994).

In the movement of adduction, all groups showed an increase in adduction over time, but this was not statistically significant. These results could have been confounded by the presence of gravity assisting all groups irrespective of the effect of the manipulation that was administered.

**4.4 Conclusion**

There appeared to be a beneficial short term effect of the treatment in group 2 relative to the other groups. Although the other groups also improved between pre and immediately post-manipulation, this was not sustained to the same degree as that in group 2. However, since the sample sizes were small this could have happened by chance, since the p values were not statistically significant (except for external rotation). Thus the results should be interpreted with caution. A larger study would help to rule out the role of chance and increase the power to reject a false null hypothesis.

Another interesting and often statistically significant trend was the racial differences in peak torque, which also could have been due to chance since this was based on only 2 Indian subjects. Again a larger study with a more representative racial composition would be indicated to substantiate this.

In light of the results found, the following hypotheses, which were developed at the outset of this study, can either be accepted or rejected.

> The first hypothesis indicated that there would be an increase in the short term peak torque generated by the rotator cuff, following manipulation. This hypothesis was rejected, because although most of the groups improved between pre and immediately post-manipulation, this was generally not sustained for 24 hours post-manipulation, except for group 2.

The second hypothesis indicated that there should only be a difference in the peak torque generated by the muscle / muscle group which is innervated by the cervical spinal level which was manipulated. This hypothesis was rejected, because most groups showed increases in peak torque immediately post-manipulation and this was sustained for 24 hours in some groups, especially group 2, whether the cervical spinal level of the movement being tested was manipulated or not.

The third hypothesis indicated that manipulation would cause an increase in the peak torque generated by the rotator cuff, regardless of whether there was a fixation present prior to manipulation or not. This hypothesis was accepted, because group 1 increased peak torque immediately post-manipulation and in some instances sustained these increases for 24 hours, even though they were fixation free prior to manipulation.

# CHAPTER FIVE

## Conclusions and Recommendations

### 5.1 Conclusions

It has been shown above that there are consistent reflex responses associated with spinal manipulative treatments, and evidence does exist, indicating that manipulation of the spine has reflexogenic effects on muscles both locally and elsewhere in the body via the joint mechanoreceptors and the related intersegmental pathways.

Thus if a decrease in muscular function were to occur due to interference with the nerve supply of that muscle by means of a fixation, then it is theoretically possible that by removing that fixation through manipulation, one could increase functional muscle activity, motor unit recruitment and therefore strengthen the muscles involved. Unfortunately, results obtained from previous studies were inconclusive to the effect of manipulation on muscle strength and therefore no inferences could be drawn from their results.

Furthermore if muscle strength could be increased through the reflex effects of manipulation, then manipulation could be recommended as part of the rehabilitation process after rotator cuff injury, due to the importance of increasing strength during rehabilitative protocols in this context.

Therefore, further research into the manipulation induced strength changes in muscles was recommended and required, which this study aimed to address by determining the short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction.

The Intra-Group Analysis did not reveal any significant results other than the fact that all cybex measurements increased in Group 2 from pre to post and after 24 hours which supports the theories proposed by Bergmann (1993) and

Leach (1994), whereby it would seem that it is not as important to adjust the level with the fixation (with the resultant neurological consequences), but rather more important to restore the normal biomechanics within the given region of the spine in order to affect a change in the rotator cuff musculature.

The Inter-Group Analysis revealed that most groups increased mean internal rotation, external rotation, abduction and adduction between pre and post visits, but they mostly decreased at 24 hours post manipulation. Only group 1 and 2 showed no decrease in internal rotation after 24 hours, with group 2 showing a continued increase at 24 hours post. Group 2 showed a similar trend in external rotation. Even with the effect of race group 2 showed consistently increasing results in the face of the other groups (1,3,4 and 5) and all groups showed an increase in adduction over time, but this was not statistically significant and may have been related to the confounding variable or gravity. This again seems to favour the theories proposed by Bergmann (1993) and Leach (1994), whereby it would seem that it is not as important to adjust the level with the fixation (with the resultant neurological consequences), but rather more important to restore the normal biomechanics within the given region of the spine in order to affect a change in the rotator cuff musculature.

Thus with the purpose of this study having been to evaluate the short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction, the results from this study showed a significant rise in peak torque immediately following manipulation, but these increases were generally not sustained for 24 hour post-manipulation, and therefore the ***first hypothesis*** which indicated that there would be an increase in the short term peak torque generated by the rotator cuff, following manipulation, was rejected.

The ***second hypothesis*** which indicated that there should only be a difference in the peak torque generated by the muscle / muscle group which is innervated by the cervical spinal level which was manipulated. This hypothesis was rejected, because most groups showed increases in peak torque immediately post- manipulation and in some groups, this was sustained for 24 hours, whether the cervical spinal level of the movement being tested was manipulated or not.

The ***third hypothesis*** which indicated that manipulation would cause an increase in the peak torque generated by the rotator cuff, regardless of whether there was a fixation present prior to manipulation or not. This hypothesis was accepted, because participants in group 1 increased peak torque immediately post- manipulation and in some instances sustained these increases for 24 hours, even though they were fixation free prior to manipulation. Also, groups 2, 3, 4 and 5 all showed increases in peak torque during certain movements regardless of whether they were manipulated at the level of a fixation or not.

### 5.2 Recommendations

At the outset of this study it was recognised that the sample and allocation of patients in this study would at best reflect a pilot investigation with indications for further study. Thus the inferences made could not be definitive in nature but only give rise to suggestion of possible associations / inferences. Therefore, should this or a similar study be repeated, a larger sample size should be utilized in order to increase the validity of the study and power of the statistics. It could be inferred that the relative cybex readings obtained from this sample that was not homogenous (race) and could have affected the outcomes of this study and therefore it is recommended that future studies utilize stratification methods in order to homogenize the sample with respect to race.

Although the immediate and short term effects of cervical manipulation on rotator cuff strength was observed in this study, a further time course of the treatment effects on the peripheral musculature is suggested in future research. One week and one month post-manipulation isokinetic testing should be included to establish the intermediate and long term effects of manipulation on rotator cuff strength.

Lastly, as the aim of this study was to evaluate the effect of cervical manipulation on rotator cuff strength for the purpose of implementing more effective rehabilitative protocols for the shoulder, further research should evaluate the effect of cervical manipulation on participants with rotator cuff pathologies, to asses whether the same results are achieved in a clinical situation.

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# APPENDIX A

## Letter Of Information

Dear patient. Welcome to my research study. My study will be running concurrently with a study by Tamsyn Dixon. Tamsyn will be determining the immediate effect of adjusting the neck (cervical spine) on the strength of the muscles of the shoulder, while I will be determining the short – term effects. Only once you have completed her study, will you be accepted into mine. You will then be required to attend a follow – up visit at the Medigate Medical Centre.

**Title Of Study :**

The short-term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without mechanical cervical spine dysfunction.

| | | |
|---|---|---|
| **Supervisors :** | Dr. C.M. Korporaal | (031) 2042611 |
| | Mr. D. Jackson | (031) 5662165 |
| **Research Student :** | Warrick Botha | (031) 2093442 / 0723673643 |
| **Institution:** | Durban Institute of Technology | |

**Purpose of the study:**
The purpose of this study is to determine the short – term effect that adjusting the neck (cervical spine) has on the strength of the muscles of the shoulder.

**Procedures:**
The consultation for this appointment will take place at the Medigate Medical Centre in Umhlanga Rocks (directions attached). At this consultation, you will be required to undergo the same testing procedure as with Tamsyn the previous day. This appointment will be approximately half an hour long.

**Risks / Discomfort:**
The testing of your muscle strength is relatively harmless. However, some may experience some muscle stiffness after testing.

**Benefits:**
Your contribution to this study, by volunteering to partake, will help us as chiropractors to build on our knowledge. This will benefit you as a patient in the long run, as we will be able to provide you with more effective health care in the future. On the completion of your participation in this study, you will be eligible to 2 free treatments at the Durban Institute of Technology Chiropractic Day Clinic.

**New Findings:**
You will be made aware of any new findings during the course of this study

**Reasons why you may be withdrawn from this study without your consent :**

You may be removed from this study without your consent for the following reasons:

- If you are unable to attend your follow – up appointment.
- If you have changed any lifestyle habits during your participation in this study that may effect the outcome of this research (e.g. Medication, supplements or treatment).

AS A VOLUNTARY PARTICIPANT IN THIS RESEARCH STUDY, YOU ARE FREE TO WITHDRAW FROM THE STUDY AT ANY TIME, WITHOUT GIVING A REASON.

**Remuneration:**

You will **NOT** be receiving a travel allowance in order to attend your appointment at the Medigate Medical Centre in Umhlanga Rocks.

**Cost of the study:**
The testing procedure will be free of charge and your participation in this study is voluntary.

**Confidentiality:**
All patient information is confidential. The results from this study will be used for research purposes only. Only individuals that are directly involved in this study and Tamsyn's study (Dr. C.M. Korporaal, Mr D. Jackson, Tamsyn Dixon and myself) will be allowed access to these records.

**Persons to contact should you have any problems or questions:**
Should you have any problems or questions that you would prefer being answered by an independent individual, feel free to contact my supervisors on the above numbers. If you are not satisfied with a particular area of this study, please feel free to forward any concerns to the Durban Institute of Technology Research and Ethics Committee.

Thank you for participating in my research study.

| | | |
|---|---|---|
| ______________ | ______________ | ______________ |
| **Warrick Botha** | **Dr. C.M. Korporaal** | **Mr D. Jackson** |
| **(Researcher)** | **(Supervisor)** | **(CoSupervisor)** |

**APPENDIX B**

# INFORMED CONSENT FORM

(To be completed by patient / subject )

| | |
|---|---|
| **Date** | **:** |
| **Title of research project** | **:** The short - term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymtomatic patients with and without mechanical cervical spine dysfunction. |
| **Name of supervisor** | **:** Dr. C.M. Korporaal |
| **Tel** | **:** (031) 2042611 |
| **Name of research student** | **:** Warrick Botha |
| **Tel** | **:** (031) 2042205 |

**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?<br>at any time<br>without having to give any a reason for withdrawing, and<br>without affecting your future health care. | Yes | No |
| 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:**

Patient /Subject Name:__________________________________Signature: _______

Parent/ Guardian:______________________________________Signature:_______

Witness Name:________________________________________Signature:_______

Research Student Name:_________________________________Signature:_______

# APPENDIX C

## CYBEX TESTING PROTOCOL

Internal rotation

The patient is supine with arm abducted to 90 degrees at the shoulder, elbow flexed to 90 degrees and hand is pronated. The patient is then asked to apply their greatest effort internally (ie attempt to bring the palm of the hand to the table).

External rotation

The patient is supine with arm abducted to 90 degrees at the shoulder, elbow flexed to 90 degrees and hand is pronated. The subject is asked to apply their greatest effort against the machine but this time externally (ie attempt to bring the back of the hand to table).

Abduction

The patient is side-lying on the uninvolved side, with tested arm at side, elbow extended and hand in the neutral position. The subject is asked to lift the arm away from the body with the greatest possible effort.

Adduction

The patient is side-lying on the uninvolved side, with tested arm in abduction, elbow extended and hand in the neutral position. The subject is asked to pull the arm towards the body with the greatest possible effort.

## APPENDIX D

## Data Collection Sheet

Patient name :
Date :

| Group 1 | Group 2 | Group 3 | Group 4 | Group 5 |
|---|---|---|---|---|
| No Fixation | Random Fixation C4-C7 | Specific Fixation C4-C5 | Specific Fixation C5-C6 | Specific Fixation C6-C7 |
| Level Of Prior Adjustment : | Level Of Prior Adjustment : | Level Of Prior Adjustment : C4-C5 | Level Of Prior Adjustment : C5-C6 | Level Of Prior Adjustment : C6-C7 |
| Cavitation :<br>• Yes / No<br>• 1 / Many | Cavitation :<br>• Yes / No<br>• 1 / Many | Cavitation :<br>• Yes / No<br>• 1 / Many | Cavitation :<br>• Yes / No<br>• 1 / Many | Cavitation :<br>• Yes / No<br>• 1 / Many |
| Was fixation present after manipulation : Yes / No | Was fixation present after manipulation : Yes / No | Was fixation present after manipulation : Yes / No | Was fixation present after manipulation : Yes / No | Was fixation present after manipulation : Yes / No |

Motion Palpation Findings 1 day / 24 hours Post Manipulation

Return / Change / Absence of fixation :

Cybex Measurements

| | **Pre Manipulation** | **Post Manipulation** | **1 day / 24 hours Post Manipulation** |
|---|---|---|---|
| **Internal Rotation** | | | |
| **External Rotation** | | | |
| **Abduction** | | | |
| **Adduction** | | | |

# APPENDIX E

## MANIPULATION PROTOCOL

1) Thumb-web for loss of posterior rotation

Patient is supine, examiner stands at the cephald end of the bed facing caudad. The posterior aspect of the articular pillar of the vertebra on the side of the fixation is contacted with the palmer aspect of the thumb. The hand is pronated and the fingers are placed on the mandible of the patient on the same side as the fixation. Indifferent hand is supporting the cranium and the cervical spine by contacting the cranium with fingers running down the side of the cervicals. The patients head is rotated away till resistance if felt and an impulse thrust into the fixation, from posterior to anterior, is administered.

2) Supine-index for loss of lateral flexion

Examiner position, patient position and indifferent hand contact is the same as for 1) above. Contact is taken with the index finger at the posterior-lateral aspect of the transverse process of the vertebra on the side of the fixation. The patients' head is laterally flexed over the contact until resistance is felt and an impulse thrust into the fixation is given.

3) Tissue pull for loss of anterior-posterior rotation.

Examiner position, patient position and indifferent hand contact is the same as for 1) above. Patients head is rotated toward the side of fixation, the index of the contact hand reaches under the patients neck and contacts the fixation. Tissue pull and slack is taken out from anterior to posterior until the thumb of the contact hand can contact the patient's mandible on the side opposite to the fixation. The neck is laterally flexed away from the fixation until resistance is felt and an impulse thrust into the fixation is administered.

4) <u>Loss of extension</u>

Examiner position, patient position and indifferent hand contact is the same as for 1) above. Contact hand is the same as for 2) above. The patients head is extended and slightly laterally flexed till resistance is felt and an impulse thrust into the fixation is given.

## Title Page

1) Title:

The short term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without a mechanical cervical spine dysfunction.

2) Authors:

Warrick Jon Botha M.Tech Chiropractic.

Supervisor: Dr Charmaine Korporaal M.Tech Chiropractic, CCFC (SA), CCSP (USA), ICCSD (FICS)

Co-Supervisor: Mr Dennis Jackson Bsc (HMS), HonsB(Biok)

3) Institution where work is attributed:

Department of Chiropractic, Durban Institute of Technology South Africa.

4) Source of support:

Funding was through Durban Institute of Technology

## Abstract

*Design:* This study was a post experimental investigation.

*Objective:* To determine the short term effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff in asymptomatic patients with and without a mechanical cervical spine dysfunction.

*Background**:*** Research has shown a consistent reflex response associated with spinal manipulative treatments and manipulation induced peripheral changes in muscles, but due to the inconclusive nature of the current research, further research was needed to investigate the peripheral muscular effects of manipulation.

*Methods:* 25 asymptomatic (except for fixations) male participants were divided evenly into 5 groups according to the level of fixation found in their cervical spines. All participants had been manipulated at selected cervical spinal levels 24 hours prior to the collection of objective measurements for this study. A control group was included, whereby participants without any cervical fixations were also manipulated 24 hours prior to this study. Each participant under went peak torque testing 24 hours post manipulation for internal rotation, external rotation, abduction and adduction, using the Cybex Orthotron II Isokinetic Dynamometer.

*Results:* There appeared to be a beneficial short term effect of manipulation in group 2 relative to the other groups. Although the other groups also increased their peak torque between pre and immediately post manipulation, this was not sustained for 24 hours to the same degree as that in group 2. Presence and number of cavitations did not statistically affect the change in peak torque over time, nor did the level of the manipulation. There was a significant difference in all mean Cybex readings at baseline between the two race groups.

*Conclusion:* The results found that manipulation did have an effect on peak torque immediately post manipulation, but this effect was generally not sustained for 24 hours post manipulation. The torque increases which did occur were shown to increase whether the cervical spinal level of the movement being tested was manipulated or not, and whether there was a fixation present prior to manipulation or not. However, since the sample sizes were small this could have happened by chance, and thus the results should be interpreted with caution. A larger study would help to rule out the role of chance and increase the power of the statistics to reject a false null hypothesis.

*Keywords*: Manipulation, Cervical spine, Rotator cuff, Isokinetic muscle testing, Peak torque

**Introduction**

Herzog et al. (1999) [1] found consistent reflex responses associated with spinal manipulative treatments. These reflex responses have been hypothesized to cause the clinically beneficial effects of decreasing hypertonicity in muscles, pain reduction and increasing the functional ability of muscles.

The above-mentioned reflex effects, as well as increasing strength and functional ability of the rotator cuff muscles are important in any rehabilitative programme of the shoulder [2,3], as they assist in preventing recurrent subluxations, dislocations and help provide dynamic stability during functional activities [4]. However, no definite recommendations have been made with regards to cervical manipulation during shoulder rehabilitation, due to the inconclusive nature of previous studies.

In this respect, one study by Rebechini-Zasadny et al, (1981) [5], in which manipulation of certain cervical spinal levels increased grip strength and strength of the 1st interosseous muscle of the hand, there where inconsistencies with respect to small sample sizes, lack of placebo control and the extrapolation of strength values from surface EMG readings. This is consistent in similar studies [6,7]. Therefore suggestions were made in the above studies for further research to be done into the manipulation induced peripheral changes in muscles.

Thus this research was undertaken to address some of the inconsistencies of the current research by measuring the effect of cervical spine manipulation on the peak torque of the rotator cuff. Furthermore, the aims of this study included looking at whether manipulation of specific cervical levels increased the peak torque of the specific muscle groups innervated by those levels and whether or not manipulation could cause these increases regardless of whether there was a fixation present prior to manipulation or not.

**Materials and Methods**

*Sampling and Allocation*

25 Participants were recruited from a concurrent study, which used convenience sampling, and were asked to join this study after their completion of the concurrent study. Only right handed, english speaking males between the ages of 18 and 45 with cervical spine dysfunction, but no current pain or history of trauma and surgery to the right shoulder or cervical spine, were accepted into this study. The 25 participants were divided evenly into 5 groups according to the level of fixation found in their cervical spines (C4/C5, C5/C6 or C6/C7), which is keeping with the levels of innervation of the rotator cuff [8]. All participants were manipulated at selected cervical spinal levels, 1 day / 24 hours prior to the collection of objective measurements for this study. A control group was also included, whereby participants without any cervical spine dysfunction were manipulated 1 day / 24 hours prior to this study. Participant allocation, level of cervical dysfunction and level of manipulation is summarized in the table below :

| | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** |
|---|---|---|---|---|---|
| **Level of Fixation** | None | Anywhere between C4-7 | C4/5 | C5/6 | C6/7 |
| **Group Size** | 5 | 5 | 5 | 5 | 5 |
| **Level of Adjustment 1 day / 24 hrs Prior to Study** | Randomly between C4-7 | Randomly between C4-7 | C4/5 | C5/6 | C6/7 |

*Measurement Tool*

Peak torque of the rotator cuff muscles was measured using the Cybex Orthotron II Isokinetic Dynamometer. This tool was able to assess the strength of the rotator cuff muscles by measuring torque, as strength can be defined as the ability to exert maximum muscular force, statically or dynamically [9], and torque is simply the turning effect of that force [10]. Strength can then be deduced from this torque measure [11]. This form of testing allows for a maximum muscle contraction throughout the full range of shoulder joint movement [12], and therefore Isokinetic evaluation using the Cybex orthotron II isokinetic dynamometer, provides valuable information for the evaluation of shoulder strength [13], and renders objective, reliable, and valid, data [14].

*Testing Procedure*

Before testing began, the participant's cervical spines were motion palpated in the manner outlined by Schafer and Faye (1990) [15], to asses for the presence of fixations. Participants then underwent a 3 minute rotator cuff warm up including stretches of the rotator cuff muscles. They were then positioned onto the cybex machine, where they underwent a 'practise round' in order to familiarise themselves with the procedure. The movements that were measured included internal rotation, external rotation and abduction, in keeping with the prime movements of the rotator cuff muscles [3,8], as well as adduction. The patient then performed 6 test contractions per movement on the right hand side, with a 4 minute rest interval between, to avoid fatigue [16].

*Data Analysis*

One reading (average of the 6 repetitions performed) was recorded per movement and these readings were compared to the pre – and post – manipulation findings conducted 1 day/24 hours prior to this study to observe the short - term effect of cervical manipulation on the peak torque of the rotator cuff. The motion palpation findings were also compared to the pre manipulation findings of the concurrent study conducted 1 day/24 hours prior to this study, to observe if there was any return or change in the participant's fixations. The data from this study was analyzed using the SPSS statistical package (version 12). Comparison of categorical variables between independent groups utilized chi square or Fisher's exact tests where appropriate. Comparison of quantitative variables between independent groups utilized the t-test in the case of two groups, and ANOVA with Bonferroni post hoc tests for more than two groups. Repeated measures ANOVA was used to compare the treatment groups over the three time periods with regards to quantitative outcomes. A two tailed p value of $<0.05$ was considered statistically significant.

## Results

There appeared to be a beneficial short term effect of the treatment in group 2 relative to the other groups. Although the other groups also improved between pre and immediately post manipulation, this was not sustained to the same degree as that in group 2. However, since the sample sizes were small, the results observed in Group 2 could have happened by chance, because except for external rotation where $p = 0.022$, the $p$ values for all other movements were not statisticially significant (internal rotation $p = 0.168$, abduction $p = 0.554$, adduction $p = 0.972$), and thus the results should be interpreted with caution. A larger study would help to rule out the role of chance and increase the power to reject a false null hypothesis.

Another interesting and often statistically significant trend was the racial differences in peak torque, with Indians scoring lower on all readings than whites, which also could have been due to chance since this was based on only 2 Indian subjects. Again a larger study with a more representative racial composition would be indicated to substantiate this.

Finally, the results showed that age did not significantly influence the peak torque readings, and cavitations, whether present or absent, one or many, did not statistically affect the change in torque over time. The level of the cervical manipulation also did not appear to influence the results significantly.

**Discussion**

Table 1 shows that there was a significant difference in all mean cybex readings at baseline between the two race groups. Indians scored lower on all readings than whites, but due to the sampling method there was a vast overrepresentation of whites (n=23, 92%), and therefore with only two Indians in this study, the results should be interpreted with caution.

**Table 1: Independent Samples T-Test for mean difference in baseline Cybex readings by race group**

| | Whites (n=23) mean (SD) | Indian (n=2) mean (SD) | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|
| internal rotation pre | 46.78 (13.31) | 26.00 (2.28) | 2.163 | 23 | .041 |
| external rotation pre | 36.48 (7.07) | 17.00 (8.49) | 3.702 | 23 | .001 |
| abduction pre | 46.35 (8.10) | 30.50 (9.19) | 2.641 | 23 | .015 |
| adduction pre | 82.13 (18.03) | 48.00 (12.73) | 2.596 | 23 | .016 |

Table 2 shows that during the intra-group comparison all cybex measurements increased in group 2 from pre to post and after 24 hours. These results are supported by the work of Wyke (1985) [17], who discussed the central affects of articular mechanoreceptor activity, and that manipulation of an individual joint should not only affect motor unit activity in the muscles operating over the manipulated joint, but also in more distant muscles. The increases in cybex measurements and lack of fixations 24 hours post manipulation is also congruent with the literature, as Rebechini-Zasadny et al., (1981) [5] state that removal of a joint dysfunction by manipulation could increase functional muscle activity by increased motor unit recruitment, and therefore possibly strengthen the muscles involved [7,16].

**Table 2: Descriptive statistics for Cybex measurements over time in Group 2 : Fixation between C4-7, random manipulation between C4-7**

| | | Internal rotation | | external rotation | | abduction | | adduction | |
|---|---|---|---|---|---|---|---|---|---|
| | | Median | Range | Median | Range | Median | Range | Median | Range |
| TIME | pre | 37 | 31 | 35 | 16 | 42 | 23 | 77 | 15 |
| | post | 45 | 30 | 38 | 18 | 52 | 18 | 92 | 21 |
| | 24 hours post | 52 | 33 | 39 | 21 | 53 | 24 | 96 | 32 |

The study was underpowered to detect small differences in the Inter-group comparisons, so the trends that were observed must be interpreted with caution, due to the small sample size of this study. One such trend which was generally observed during the testing of internal rotation, external rotation and abduction can be explained here by using internal rotation as the example (Figure 1). Another trend was observed in adduction (Figure 2), and will be explained separately.

Using internal rotation as the example, all groups showed an increase in peak torque between pre and immediately post manipulation. This can be explained by Herzog et al. (1999) 1 who found consistent reflex responses associated with spinal manipulative treatments, and these reflex responses have been hypothesized to cause reflex activation of skeletal muscles. The torque increases observed in this study are supported by the above mentioned work done by Rebechini-Zasadny et al., (1981) [5], Wyke (1985) [17], Suter, (2000) [16] and Naidoo, (2002) [7]. These immediate increases seen in the torque measurements either continued to increase or were sustained 24 hour post manipulation in groups 1 and 2.

The reasons for this can possibly be explained by :

- The effect of adjusting the joints that had a high probability of allowing adjustments at the end range of motion in groups 1 and 2. This is as a result of the fact that group 1 had no fixations and groups 2 although they had fixations, could easily have been adjusted at a level that did not have a fixation.

  The effect of this adjustment at the end range of motion implies that the neurological stimulation of the respective levels that where adjusted was greater than those patients that where adjusted at the fixated level, whereby the degree of stretch applied to the muscles and ligaments would have been reduced as the patient would only have been adjusted at the end of the clinical physiological range of motion (e.g. restricted by scar tissue or adhesion formation) [18].

  It is therefore implied in this discussion that there is a direct association between improvement of the peak torque in groups one and two which is related to the fact that the segments where not fixated at the time of the adjustment thereby allowing for a greater and sustained result as compared to the other 3 groups (3,4, and 5).

- This would be consistent with the “Neural Scar” Hypothesis as proposed by Patterson and Steinmetz [19], who suggested that if an initial stimulus is sufficient or lasts long enough, a “learned influence” in the spinal cord remains due to segmental facilitation, even though the influence of the instigating lesion has been removed. These authors go on to say that once this facilitation occurs, the abnormal reflex circuit in the spinal cord participates in maintaining the symptoms itself, due to hyperexcitable neurons, and may not be easily removed.

This concept of a “learned influence” in the spine as well as the fact that all participants in groups 3, 4 and 5 presented to this study with cervical facet dysfunction of unknown duration at the level manipulated, could explain why their torque readings decreased 24 hours post manipulation, even though 13 out of the 15 participants manipulated in these three groups were fixation free and only two participants presented with fixations at their 24 hour post manipulation reading.

The suggestion here is that there is still a neurological facilitation present even thought the fixation was no longer present at the 24hour post manipulation reading. This is congruent with the findings of Homewood (1977) [20], who described that there could be a decrease in muscular activity due to interference with the innervation of muscle by means of a fixation. However Homewood (1977) [20] based his theories on the presence of a fixation, when what is presented here seems to indicate that his theory stands, but that a role also needs to be attributed to the presence of a neural scar as suggested by Patterson and Steinmetz [19].

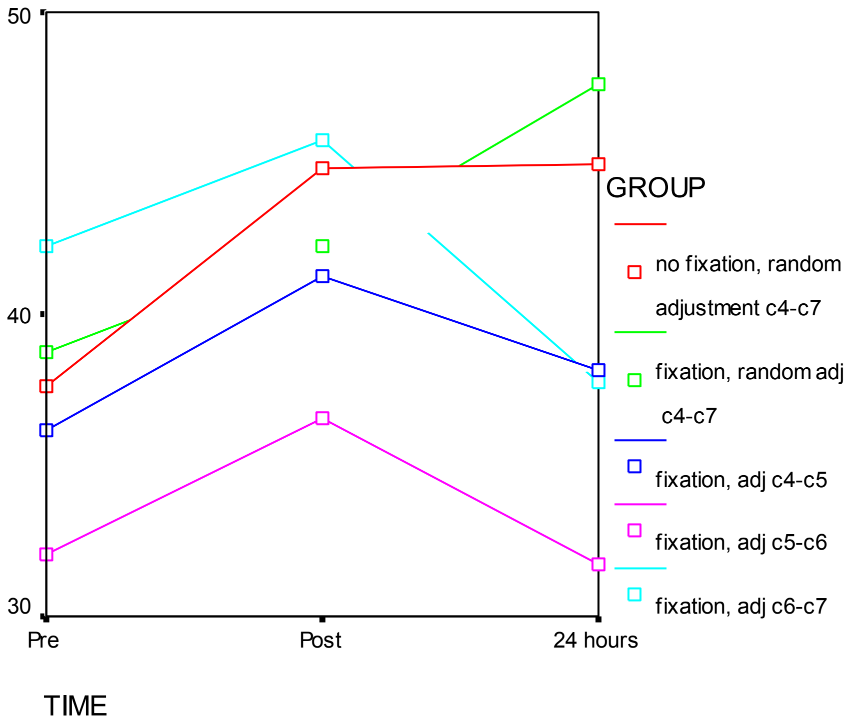
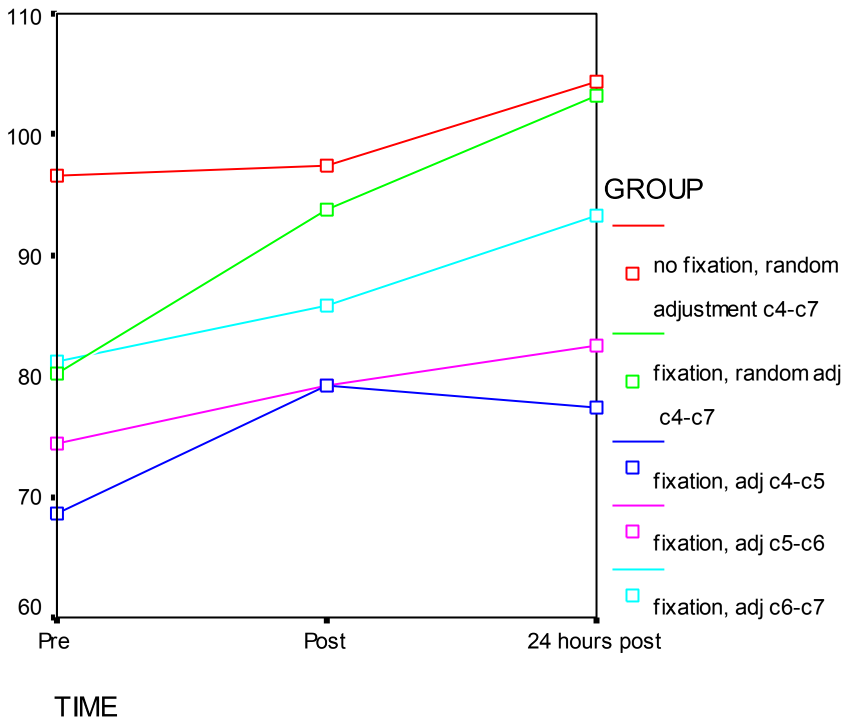



**Figure 1: mean internal rotation over time by group**

During adduction, all groups showed increased peak torque between pre and immediately post manipulation, the possible reason for which, was explained above by the works of Rebechini-Zasadny et al. (1981) [5], Wyke (1985) [17], Herzog et al. (1999) [1], Suter (2000) [16] and Naidoo (2002) [7]. However, all groups showed an increase in adduction over 24 hours as well, even though manipulation may have in some groups been directed at levels unrelated to the innervation of the adductors.

One possible reason for this could be due to the fact that the biomechanical changes which occur at one vertebral level following manipulation, may effect other levels as well, without themselves having been manipulated [19,21]. This could explain why adjusting levels unrelated to the innervation of the adductors, still caused an increase in their torque readings, 24 hours post manipulation. This coupled with the fact that out of all the movements tested, adduction had the largest size and number of muscles contributing towards its movement, and therefore the reflex activation of so many large muscles, as described earlier by Wyke (1985) [17] and Herzog et al., (1999) [1] had the greatest potential for increases in torque.

**Figure 2: mean adduction by time and group**



**Conclusion**

The hypothesis that there would be an increase in the short term peak torque generated by the rotator cuff, following manipulation, was rejected, because although most of the groups improved between pre and immediately post manipulation, this was generally not sustained for 24 hours.

The hypothesis that there should only be a difference in the peak torque generated by the muscle / muscle group which is innervated by the cervical spinal level which was manipulated, was rejected, because most groups showed increases in peak torque either immediately post manipulation or after 24 hours, whether the cervical spinal level of the movement being tested was manipulated or not.

The last hypothesis that manipulation would cause an increase in the peak torque generated by the rotator cuff, regardless of whether there was a fixation present prior to manipulation or not, was accepted, because group 1 increased peak torque immediately post manipulation and in some instances sustained these increases for 24 hours, even though they were fixation free prior to manipulation.

Further studies should utilize larger sample sizes in order to increase the validity of the study and power of the statistics. Inclusion of an equal number of participants per race group would also allow for a more effective comparison between different races.

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