The Immediate Effect of Manipulation of Selected Cervical Spinal Segments on the Peak Torque of the Rotator Cuff Muscles in Asymptomatic Patients with and without a Mechanical Cervical Spine Dysfunction.

Tamsyn Louise Dixon

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A dissertation in partial compliance with the requirements for a Master's Degree in Technology: Chiropractic, submitted to the Faculty of Health at the Durban Institute of Technology.

By

Tamsyn Louise Dixon

I solemnly declare this work to be my own in compilation and execution.

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DEDICATION

This work is dedicated to my mum and dad, Judith and Jonathan Dixon. Mum, for never letting me loose touch of the grander picture and continually reassuring me with that love you radiate. Dad, for grounding me with your support and encouragement while allowing me the freedom to discover my own path.

With my deepest, fondest love I thank you both.

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Dr Charmaine Korporaal, I'm not sure you will ever begin to realize how inspiring it is to observe the dedication with which you undertake your work. It leaves me in complete awe! It has been an honor to have you as my Supervisor. Thank you, thank you, thank you for your time and never-ending energy reserves!

Dennis Jackson, thank-you for your time, your patience and the willingness to provide the tools for this research.

Thank-you to the **Patients** without whom this study could not have taken place.

Mrs Ireland for your encouragement's when the research hills seemed like mountains.

Tonja Esterhuizen for your professional and efficient contributions to the statistics section.

To my **Nana**, what a treat to have such a wonderful grandmother! Thank you for all the laughs, encouragement's and love which you have so generously offered to me.

Timo, you're a treasure…. Your unfailing support and love will always be an inspiration for me.

To my precious **Shamwari's** for the joys, the tears, and the unbelievable adventures we have undertaken together, you are with me always.

Torin, our paths crossing has been a touch of magic. Thank you for sharing this journey with me. I love you.

And lastly but certainly not least, to the **Great Stillness** within us all, which has guided my wondrous path and allowed me to see the beauty and fragility in all life…. Thank you.

ABSTRACT

Although studies of manipulation-induced peripheral changes in the muscles have been done, inconsistencies noted by the author's call for further investigation into the reflex effects of manipulation. Additionally, according to the literature, no effective treatment protocol for the painful shoulder has been found. Therefore this research aimed at addressing these discrepancies by quantifying the immediate effect of cervical spine manipulation in terms of peak torque on rotator cuff musculature in asymptomatic patients with both a cervical spine dysfunction and without. And thus by investigating cervical manipulation to the C4-C7 spinal segment, as a possible added intervention for improving rotator cuff muscle peak torque, a more efficient and effective management protocol for the painful shoulder could be attained.

Twenty-five asymptomatic patients, barring a cervical spine dysfunction, between the ages of 18-45, were selected following a screening examination for exclusion criteria. Once selected the individuals were divided into 5 groups of 5 subjects depending on the level of fixation found. These were defined as follows: group 1 (no fixation present), group 2 (fixation present anywhere between C4-C7), group 3 (fixation present at C4-C5), group 4 (fixation present at C5-C6) and group 5 (fixation present at C6-C7). Each individual under went peak torque testing both pre and post manipulation. An average of 6 readings from the following movements – internal rotation, external rotation, abduction and adduction - were taken using the Cybex Orthotron II for torque assessment. These measurements formed the objective data for the study.

Data was captured in MS Excel and exported into SPSS (Statistical Package for Social Sciences) version 12 (SPSS inc. Chicago, Ill) for analysis. A brief outline of the demographics of the sample in terms of age and race was followed by both Intragroup and Intergroup analysis.

The results showed that age did not significantly influence the Cybex readings. There was a significant difference in all mean Cybex readings at baseline between the two race groups. Due to the vast overrepresentation of whites (n=23, 92%), no generalization for the Indian population in terms of reduced Cybex readings can be made due to the small group size and results should be interpreted with caution. Additionally the group to which the subject belonged did not seem to significantly affect the increase or change in Cybex measurements immediately after manipulation. Groups 2 and 3 showed increased peak torque values in all four movements measured. Groups 1 and 4 improved in all movements barring external rotation and abduction respectively. Group 5 only increased peak torque for internal rotation. Cavitations, whether absent, present, one or many, did not statistically affect the change over time significantly. And the level of the manipulation did not appear to influence the results significantly. Intergroup analysis revealed internal rotation, external rotation and adduction increased overall between pre and post manipulation. For abduction there was no significant increase over time because two groups showed a decrease over the time period, two groups an increase and one group had no change. The role of chance cannot, unfortunately, be excluded due to the small sample size and thus a larger study should be done to fully explore the statistical significance of the above trends.

In conclusion manipulation did have an effect on peak torque and thus Hypothesis 1 is accepted. Hypothesis 2 was rejected as the results of this study where inconclusive as to the relationship of the neurological level and its effect of the innervated structures at that level. Lastly a fixation did not necessarily need to be present for manipulation to raise the peak torque and thus Hypothesis 3 was accepted.

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Thus the aims for this study included: 1) To evaluate whether manipulation has an effect on rotator cuff peak torque or not, utilizing the Cybex Orthotron II Isokinetic Rehabilitation System; 2) To ascertain whether manipulation of the specific levels has an effect on the rotator cuff peak torque or not and 3) To ascertain whether the presence or absence of a fixation has any change on peak torque following a manipulation or not.

Twenty-five asymptomatic patients, barring a cervical spine dysfunction, between the ages of 18-45, were selected following a screening examination for exclusion criteria. Once selected the individuals were divided into 5 groups of 5 subjects depending on the level of fixation found. These were defined as follows: group 1 (no fixation present), group 2 (fixation present anywhere between C4-C7), group 3 (fixation present at C4-C5), group 4 (fixation present at C5-C6) and group 5 (fixation present at C6-C7). Each individual under went peak torque testing both pre and post manipulation. An average of 6 readings from the following movements – internal rotation, external rotation, abduction and adduction - were

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Data was captured in MS Excel and exported into SPSS (Statistical Package for Social Sciences) version 12 (SPSS inc. Chicago, Ill) for analysis. A brief outline of the demographics of the sample in terms of age and race was followed by both Intragroup and Intergroup analysis.

The results showed that age did not significantly influence the Cybex readings. There was a significant difference in all mean Cybex readings at baseline between the two race groups. Due to the vast overrepresentation of whites (n=23, 92%), no generalization for the Indian population in terms of reduced Cybex readings can be made due to the small group size and results should be interpreted with caution. Additionally the group to which the subject belonged did not seem to significantly affect the increase or change in Cybex measurements immediately after manipulation. Groups 2 and 3 showed increased peak torque values in all four movements measured. Groups 1 and 4 improved in all movements barring external rotation and abduction respectively. Group 5 only increased peak torque for internal rotation. Cavitations, whether absent, present, one or many, did not statistically affect the change over time significantly. And the level of the manipulation did not appear to influence the results significantly. Intergroup analysis revealed internal rotation, external rotation and adduction increased overall between pre and post manipulation. For abduction there was no significant increase over time because two groups showed a decrease over the time period, two groups an increase and one group had no change. The role of chance cannot, unfortunately, be excluded due to the small sample size and thus a larger study should be done to fully explore the statistical significance of the above trends.

In conclusion manipulation did have an effect on peak torque and thus Hypothesis 1 is accepted. Hypothesis 2 was rejected as the results of this study where inconclusive as to the relationship of the neurological level and its effect of the innervated structures at that level. Lastly a fixation did not necessarily need to be present for manipulation to raise the peak torque and thus Hypothesis 3 was accepted.

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CHAPTER ONE

1.1 Introduction

Certain reflex responses following manipulation have been hypothesised to have an increasing effect on functional ability of the patient, pain reduction and inhibition of hypertonic muscles (Herzog *et al.* (1999) and Nansel *et al.* (1993)). These three reflex effects as well as improvement in strength in the rotator cuff muscles are vital in any rehabilitative programme of the shoulder (Green *et al.* 1998, Kamkar *et al.* 1993, Wilk *et al.* 1993).

Strength is defined as the rotational effect of the force, generated by a single muscle or muscle group, about the joint under consideration, and is also termed the moment (Dvir, 2004). The common understanding of strength is the point in the range of motion where strength reaches its maximum, hence the term peak moment or peak torque is used in the literature to describe strength (Dvir, 2004). Isokinetic testing, using the Cybex Orthotron II, may be performed as a screening technique to determine any weakness or imbalance of the peak torque [force (in Newton's) x radius (in meters)] of any of the major peripheral joints (Krukner *et al.* 2001, Maffulli 1996, Siqueira *et al.* 2002). Additionally isokinetic testing has provided valuable information for the evaluation of shoulder strength assessment (Scotville *et al.* 1997).

Although studies of manipulation-induced peripheral changes in the muscles have been done, Rebechini-Zasadny *et al.* (1981), Bonci *et al.* (1990) and Naidoo (2002) all have made suggestions for further studies due to inconsistencies in these studies.

Thus this research aims to address these inconsistencies by quantifying the immediate effect of cervical spine manipulation in terms of peak torque on rotator cuff musculature in asymptomatic patients with both a cervical spine dysfunction and without. Hence by investigating cervical manipulation to the C4-C7 spinal segment, as a possible added intervention for improving rotator cuff muscle peak torque, a more efficient and effective management protocol for the painful shoulder could be attained.

1.2 The Aims

1. To evaluate whether manipulation has an effect on rotator cuff peak torque or not, utilizing the Cybex Orthotron II Isokinetic Rehabilitation System.

   <u>Hypothesis 1</u>

   Manipulation did have an effect on peak torque.

2. To ascertain whether manipulation of the specific levels has an effect on the rotator cuff peak torque or not.

   <u>Hypothesis 2:</u>

   Manipulation of specific levels could raise the peak torque of the specific muscle innervated by those levels.

3. To ascertain whether the presence or absence of a fixation has any change on peak torque following a manipulation or not.

   <u>Hypothesis 3:</u>

   A fixation would not necessarily have to be present for manipulation to raise the peak torque.

1.3 Rationale / Need for the study

1. Rebechini-Zasadny *et al.* (1981) and Naidoo (2002) demonstrated and inferred that manipulation to the cervical spine does influence muscle strength but suggested further studies of manipulation-induced peripheral

changes in the muscles are needed, due to unaccounted for variables and small sample sizes in their respective studies.

2. Herzog *et al.* (1999) showed a consistent reflex response associated with spinal manipulative treatments, which have been hypothesized to have a beneficial effect on functional ability, reducing pain and inhibiting hypertonic muscles. All three noted reflexes are essential in the establishment of treatment and rehabilitation protocols for musculoskeletal painful shoulders and rotator cuff pathologies (Green *et al.*, 1998).
3. Wilk *et al.* (1993) goes further to emphasize rotator cuff strength as well as balance of the muscular force couples created by the rotator cuff muscles, as imperative in the treatment and rehabilitative program of the shoulder in order to restore functional ability. Wilk *et al.* (1993) also suggests that a cervical spine evaluation be included as part of the treatment and rehabilitation protocols to improve and normalize the osteokinematics[1] of the glenohumeral joint and related biomechanics.

[1]Osteokinematics refers to the gross movements of bone rather than the movement of the articular surfaces. The glenohumeral joint has 3º of freedom: flexion-extension, abduction-adduction, medial-lateral rotation shoulder

CHAPTER TWO

2.0 Review of the Literature

2.1 Introduction

This chapter aims at informing the reader of the relative effects that manipulation has on peripheral musculature. Relevant anatomy of the cervical spine and the rotator cuff musculature will also be reviewed as well as the role of isokinetic muscle testing used in this study.

2.2 Anatomy

2.2.1 Rotator Cuff Musculature of the Shoulder

The supraspinatus, infraspinatus, teres minor and subscapularis are the muscles comprising the rotator cuff of the shoulder joint and whose tendons blend with the articular capsule of the shoulder joint (Moore and Dalley, 1992 and 1999). Although the glenohumeral joint is an inherently unstable joint (Wilk and Arrigo, 1993), the musculotendinous rotator cuff protects and gives stability. This is achieved by holding the head of the humerus in the glenoid cavity of the scapula, which prevents excessive humeral head translation (Moore and Dalley, 1992 and 1999; Norkin and Levangie, 1992). Additionally, the rotator cuff adds power to the glenohumeral elevation and rotation (Kamkar *et al.* 1993).

2.2.2 Attachments of the Rotator Cuff Muscles

Attachments of the rotator cuff muscles are summed up in the table 2.2.2 below:

Table 2.2.2: Attachments of the Rotator Cuff Muscles

MUSCLE	PROXIMAL ATTACHMENT	DISTAL ATTACHMENT
Supraspinatus	Supraspinous fossa of scapula	Superior facet on greater tubercle of humerus
Infraspinatus	Infraspinous fossa of scapula	Middle facet on greater tubercle of humerus
Teres minor	Superior part of lateral border of scapula	Inferior facet on greater tubercle of humerus
Subscapularis	Subscapular fossa	Lesser tubercle of humerus

(Table abridged from Moore, 1992)

2.2.3 Actions and Innervation of the Rotator Cuff Muscles

Table 2.2.3 below outlines the three main movements of the rotator cuff, the muscles responsible for this movement and the relevant innervation for each muscle. Adduction, although not a movement performed by the rotator cuff muscles, was necessary to analyze due to the operative methods of the measurement tool (Cybex Orthotron II). The Cybex Orthotron II measures both the peak torque for abduction and adduction simultaneously and thus needed to be included in this study and therefore appears in the table below.

Table 2.2.3: Actions and Innervation of the Rotator Cuff Muscles

MOVEMENT AT THE SHOULDER JOINT	MUSCLES PERFORMING THE MOVEMENT	INNERVATION
Abduction	Supraspinatus	Suprascapular nerve C4, **C5** an C6
External rotation	Infraspinatus Teres minor	Suprascapular nerve **C5** and C6 Axillary nerve **C5** and C6
Internal rotation	Subscapularis	Upper and lower Subscapular nerve C5, **C6** and C7
Adduction	Latissimus dorsi Teres major Pectoralis major Subscapularis	Thoracodorsal nerve **C6**, **C7**, C8 Lower Subscapular nerve **C6** and C7 Lateral and Medial Pectoral nerves C5 and **C6** Upper and Lower Subscapular nerves C5, **C6** and C7

Boldface indicates the main spinal cord segmental innervation.

(Kamkar *et al.* 1993; Moore and Dalley, 1999; Norkin and Levangie, 1992; Boublik *et al.* 1993)

2.2.4 The Cervical Spine

The cervical spine consists of two functionally distinct components: the upper cervical spine, which includes articulations between the occiput, atlas and axis (C0-C1 and C1-C2 respectively); and the lower cervical spine which includes the articulations C2-C3 continuing to C7-T1 (Haldeman, 1992). For the purpose of this study only the relevant anatomy of the lower cervical spine will be covered, more specifically from the C3-C4 articulation to the C6-C7 articulation, this being the levels for the emergence of the spinal roots which innervate the rotator cuff musculature.

2.2.4.1 Bony Anatomy

The vertebrae of C3-C6 are classified as ‘typical vertebra’ and have many distinctive features including an oval foramen transversarium, which allows for the passage of the vertebral arteries (Moore, 1992; Gray *et al*. 1980). The spinous processes of C3-C6 are short and bifid (divided into two parts) in comparison to the C7 vertebra which has a very long spinous process and its transverse foramina do not transmit vertebral arteries and thus is characterized as ‘atypical’ (Moore, 1992; Gray *et al*. 1980). The superior surface of each vertebra from C3-C7 is concave and raised laterally to form the uncinate processes, which articulate with the inferior lateral plateau of the vertebra above to form the joints of Von Luschka. The lamina is angled medially while the pedicles project laterally and backward. The articular pillar extends from the lamina-pedicle junction to the cartilage lined facet joints. (Cramer *et al.* 1995, Gray *et al*. 1980)

There are two sets of facet joints: superior and inferior. The superior facet joints are oval and flat in shape and are directed backward and upward where as the inferior facet joints face downward and forward. These joints are angled at 45° to the horizontal and thus tend to lie in the coronal plane. (Cramer *et al.* 1995)

2.2.5 The Neurological Link Between the Cervical Spine and the Shoulder Musculature

The three nerves responsible for the innervation of the rotator cuff muscles namely: the suprascapular nerve, the axillary nerve and the subscapular nerve, form part of the Brachial Plexus of the upper limb. The plexus forms from the vental rami of C5-T1 nerve roots merging into three main trunks-superior, middle and inferior. It is further divided into supraclavicular and infraclavicular branches. The infracavicular branch is then further divided into lateral, medial and posterior cords (Moore, 1992, Gray *et al*. 1980).

The suprascapular nerve arises from the supraclavicular division, while the subscapular nerve and axillary nerve arise from the posterior cord of infraclavicular division (Moore, 1992, Gray *et al*. 1980).

2.2.5.1 The Suprascapular Nerve

The suprascapular nerve receives fibers from C5, C6 and, in 50% of people, C4. It arises from the posterior aspect of the superior trunk of the brachial plexus, passes laterally across the posterior triangle of the neck, superior to the brachial plexus, and then passes through the scapular notch to supply the supraspinatus and infraspinatus muscles (Moore, 1992, Gray *et al*. 1980).

2.2.5.2 The Subscapular Nerve

The subscapular nerve arises from the posterior cord of the infraclavicular division and receives fibers from C5 and C6. It is a small nerve that innervates the subscapularis muscle (Moore, 1992, Gray *et al*. 1980).

2.2.5.3 The Axillary Nerve

This nerve receives fibers from C5 and C6 and is a large terminal branch of the posterior cord of the brachial plexus. The axillary nerve passes through the quadrangular space to the posterior aspect of the arm, where it winds around the neck of the humerus to supply the teres minor and deltoid muscles. It terminates as the upper lateral brachial cutaneous nerve where it supplies the skin over the inferior half of the deltoid as well as adjacent areas of the arm (Moore, 1992, Gray *et al*. 1980).

2.3 Cervical Spine Dysfunction

2.3.1 Definition

Joint dysfunction is described as an area of disturbance of function without structural changes yet affecting quality and range of joint motion (Bergmann *et al.* 1993). Similarly joint fixation is the state whereby an articulation has become temporarily immobilized in a position that it may normally occupy during any phase of physiologic movement (Bergmann *et al.* 1993). Both fixation and dysfunction are used to describe a state of altered function commonly described as a subluxation in chiropractic terms. Haldeman (1992) defines the subluxation as 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.

Bergmann *et al.* (1993) explains that a large percentage of dysfunction is self-limiting or in fact so minor that the individual adapts and compensates to the change with limited structural and functional alteration. Therefore although a fixation is present the patient is asymptomatic. This asymptomatic patient with a cervical dysfunction was the subject group selected for this study.

2.3.2. Causes of Dysfunction

Bergmann *et al.* (1993) mentions soft tissue derangement's to be responsible for mechanical dysfunction and may be initiated by: trauma, repetitive motion injuries, postural decompensation, developmental anomalies, immobilization, reflex changes, psychosocial factors, aging and degenerative disease.

2.4 Diagnosing dysfunction: Motion Palpation

Bergmann *et al.* (1993) defines palpation as the application of variable manual pressure through the surface of the body for the purpose of determining the shape, size, consistency, position, inherent motility, and health of the tissues beneath. He further describes motion palpation as being a palpatory diagnosis of passive and active segmental joint range of motion.

Clinical features of joint dysfunction, which may or may not be present as indicated above, are listed below (From Bergmann *et al.* 1993):

1. Local pain: commonly changes with activity
2. Local tissue hypersensitivity
3. Altered alignment
4. Decreased, increased or aberrant joint movement
5. Altered joint play[2]
6. Altered end-feel resistance[3]
7. Local palpatory muscle rigidity

For further detail on motion palpation, please see chapter 3: Inclusion Criteria.

[2] Joint play: Discrete, short range movements of a joint independent of the action of voluntary muscles, determined by springing each vertebrae in the neutral position.

[3] End Feel: Discrete, short range of movements of a joint independent of the action of voluntary muscles, determined by springing each vertebrae at the limit of its passive range of motion.

2.5 Removal of the Dysfunction: Manipulation

2.5.1 Definition

Joint manipulation is defined by Edmond (1993) as a manual therapeutic technique which involves the movement of one articular surface in relation to another that is performed on an articular structure that has been shown to be in dysfunction on physical examination.

Bergamnn (1993) further characterizes manipulation by having a specific joint contact involving a dynamic thrust of a high-velocity and low-amplitude, delivered within the boundaries of the joint's anatomic integrity and usually associated with an audible articular click with subsequent improved joint mobility.

2.5.2 The Effects of Manipulation on Peripheral Musculature

Rebechini-Zasadny *et al.* (1981) state that muscle activity is dependent on the integrity of its innervation. One could reasonably argue then that any factor, which impacts on the nervous system at these levels, could affect the muscular activity supplied by those levels (Naidoo, 2002).

In this regard and with respect to compromised spinal joint motion, Homewood (1977) described that a fixation may interfere with the nerve supply and result in a decrease in muscular activity. He hypothesized that removal of the subluxation could restore:

- Normal physiological processes,
- Increase muscle activity and
- Improve functional ability and normalize the torque ratios.

This is supported by Korr (Leach 1994), who proposed that manipulation of the spine could relax muscle spasm by affecting the central nervous system input into a muscle spindle. This is further supported by Herzog *et al.* (1999) and Nansel *et al.* (1993) who hypothesized that certain reflex responses following manipulation have been attributed to having an increasing effect on functional ability of the patient, pain reduction and inhibition of hypertonic muscles. Similarly Haldeman (1992) refers to Vernon *et al.* (1986) who states evidence that sensorimotor reflex connections are influenced by manipulation via stimulation of segmental motor pools, which in turn could reduce both pain and muscle hypertonicity. Herzog *et al.* (1999) describes these reflexes as "spatially and temporally nonsynchronised motor unit action potentials".

Hamilton *et al.* (2004) correlated that the number of motor-units innervating a muscle relates positively to the strength[4] of that muscle. Thus it could be hypothesized that manipulation could have a positive effect on the motor units, by applying the theories proposed by Homewood (1977), Korr (Leach, 1994) and Vernon *et al.* (1986). This could in turn mean that manipulation may have an affect on the strength of the muscle innervated by those motor units. It should be noted however that there is a possibility that a fixation does not necessarily need to be present to derange neurological output. And the reflex effects as described by Herzog *et al.* (1999), Korr (Leach, 1994), Vernon (1986) and Homewood (1977) could occur regardless of whether there is a fixation present at the time of manipulation or not.

[4] Strength is defined by Lewis *et al.* (1991) as being a function of muscle cross-sectional area, motor-unit recruitment and neuromuscular coordination, which has the ability to develop force in a maximal-effort voluntary contraction of rested muscle. Isokinetic testing, using the Cybex Orthotron II, may be performed as a screening technique to determine any weakness or imbalance of the torque (force (in Newton's) x radius (in meters)) ratios of any of the major peripheral joints (Krukner *et al.* 2001, Maffulli 1996, Siqueira *et al.* 2002). Additionally it has provided valuable information for the evaluation of shoulder strength assessment (Scotville *et al.* 1997).

In addition Rebechini-Zasadny *et al.* (1981), Bonci *et al.* (1990) and Naidoo (2002) have all made suggestions for further studies of manipulation-induced peripheral changes in the muscles.

Errors arising from these authors research include:

- Small sample size and extrapolation of strength values from EMG readings (Rebechini-Zasadny *et al.* 1981).
- The reported interference of atmospheric noise that could have interfered with the sensitivity and thus with the accuracy of the surface EMG readings in Naidoo's (2002) study, as there was no placebo control.
- The use of a single diagnostic measure, which was also used as a measurement tool in assessing the presence and severity of the vertebral subluxation complex and investigation of strength (Bonci *et al.* 1990).

Kamkar *et al.* (1993), Reid (1992), Scotville *et al.* (1997), Wilk and Arrigo (1993) and Green *et al.* (1998) all recommend research in this field for the following reasons:

- Adequate strength provides dynamic stability to the glenohumeral joint by controlling excessive humeral head migration, as well as decreasing impingement by depressing the humeral head.
- A proper ratio of the eccentric antagonist to the concentric agonist muscles is critical for dynamic stability and optimal function of the shoulder.
- Strengthening enhances the efficacy of the glenohumeral joint force couples and thus lowers the incidence of recurrent subluxations and dislocations.
- The cervical spine, along with the sternoclavicular, acromioclavicular, scapulothoracic joints and thoracic spine should be assessed to improve and normalize the overall osteokinematics[1] at the glenohumeral joint.
- Green *et al.* (1998) were unable to draw firm conclusions about the efficacy of any of the common interventions currently being used to treat painful shoulders.

Hence by investigating cervical manipulation to the C4-C7 spinal segment, as a possible added intervention for improving rotator cuff muscle peak torque, a more efficient and effective management protocol for the painful shoulder could be attained.

2.6 Isokinetic Muscle Testing

2.6.1 Introduction

'Isokinetic' refers to a muscle group contracting against a controlled accommodating resistance, which in turn causes a limb to move at a constant angular or linear velocity within a prescribed sector of its range of motion (Dvir, 2004).

Strength is defined as the rotational effect of the force, generated by a single muscle or muscle group, about the joint under consideration, and is also termed the moment. The common understanding of strength is the point in the range of motion where strength reaches its maximum, hence the term peak moment or peak torque is used in the literature to describe strength (Dvir, 2004).

2.6.2 Reliability and validity of isokinetic testing

2.6.2.1 Reliability

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 (www.isokinetics.net).

Callaghan *et al.* (2000) performed a test re-test reliability designed study to determine a reproducible protocol for multijoint isokinetic assessments on both a healthy and patient population. They concluded that isokinetic testing for peak torque, average power and total work using dynamometery is highly reliable in both healthy subjects and patients.

2.6.2.2 Validity

Certain factors have been recognised as establishing convergent validity due to the relationship they have with isokinetic testing. These factors include:

- **Gender differences**

Many isokinetic studies have shown that men are significantly and consistently stronger than women [(www.isokinetics.net) and De Ste Coix *et al.* (2003)].

- **Effect of Age**

Strength normally reaches its peak in the third decade and there after declines moderately with age until the seventh decade where there is a steeper decline (www.isokinetics.net)

- **Body weight**

Muscle mass rises proportionately with body weight. Hence heavier subjects produce higher isokinetic moments. However, this relationship is not linear and is one of the reasons for normalizing strength to body weight using Newton meter per kilogram body weight [www.isokinetics.net and De Ste Croix *et al.* (2003)].

- **Muscle characteristics**

The slope of moment angular velocity curve changes with age in that children cannot utilize stretch shortening cycles as adults can, possibly because of softer muscles (i.e. they are more flexible). This is seen in isokinetics especially in adolescents who generate more moment at slower speeds (www.isokinetics.net).

2.7 Conclusion

A review of the literature revealed that manipulation does in fact have an effect on peripheral musculature. Herzog *et al.* (1999) showed a consistent reflex response associated with spinal manipulative treatments, which have been hypothesized to have a beneficial effect on functional ability, reducing pain and inhibiting hypertonic muscles. This is supported by Nansel *et al.* (1993), Korr (Leach, 1994), Vernon (1986) and Homewood (1977) who all noted similar reflex effects following manipulation. According to Green *et al.* (1998) the above noted reflexes are essential in the establishment of treatment and rehabilitation protocols for musculoskeletal painful shoulders and rotator cuff pathologies.

Rebechini-Zasadny *et al.* (1981) and Naidoo (2002) demonstrated and inferred that manipulation to the cervical spine does influence muscle strength but suggested further studies of manipulation-induced peripheral changes in the muscles are needed, due to unaccounted for variables and small sample sizes in their respective studies.

Lastly, isokinetic dynamometers can effectively and accurately measure the true maximal capacity of muscles (Dvir, 2004). Isokinetic testing, using the Cybex Orthotron II, may be performed as a screening technique to determine any weakness or imbalance of the peak torque [force (in Newton's) x radius (in meters)] of any of the major peripheral joints (Krukner *et al.* 2001; Maffulli, 1996; Siqueira *et al.* 2002). Further more it has provided valuable information for the evaluation of shoulder strength assessment (Scotville *et al.* 1997).

CHAPTER THREE

3.0 Material and Methods

3.1 Introduction

This chapter contains an overview of how the study was carried out. Included here are the study design, the subjects (patients) used, the interventions (treatment) they received as well as a discussion of the collected data and the statistical procedures performed on that data.

3.2 Study Design

This study was a pre and post experimental investigation (Nansel *et al.* 1993 and Naidoo, 2002).

3.2.1 Sampling

Participants were recruited by word of mouth on the Durban Institute of Technology campus, surrounding gyms and clubs.

To those responding, an initial telephonic interview with the researcher was undertaken to establish whether the patient was suitable for the study. Only English speaking patients 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 patients and the researcher.

Once initial suitability was established, applicants were screened for inclusion to the study during an initial consultation. During this consultation the patient received a short description of the study (letter of information: Appendix A), they were requested to complete an informed consent form (Appendix B) prior to admission into the study and their details were recorded for future reference.

All participants then underwent a case history (Appendix C), physical examination (Appendix D) as well as a regional cervical and shoulder examination (Appendix E and F respectively) in order to ensure that the applicant would comply with the inclusion and exclusion criteria listed below to be selected for the study.

3.2.2 Sample size

The first twenty-five patients who complied with the inclusion and exclusion criteria were invited to participate in the study. Budget restrictions necessitated the sample size.

3.2.3 Sample allocation

Table 3.2.3 indicates the sample allocation into the 5 groups.

Table 3.2.3: Sample allocation

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**
Fixation	No fixation present	Fixation present between C4-C7	Fixation present specific to the C4-C5 level	Fixation present specific to the C5-C6 level	Fixation present specific to the C6-C7 level
Manipulation	Randomly at the levels C4-C7	Randomly at the levels C4-C7	Specific at the level C4-C5	Specific at the level C5-C6	Specific at the level C6-C7
Sample size	5	5	5	5	5

Bergmann *et al.* (1993) explains that a large percentage of dysfunction is self-limiting or in fact so minor that the individual adapts and compensates to the change with limited structural and functional alteration. Therefore although a fixation is present the patient is asymptomatic. This asymptomatic patient with a cervical dysfunction was the subject group selected for this study.

It was recognized at the outset of the study that there would be a possibility that 10 individuals could have been manipulated at a segment that was not fixated (i.e. a normal joint). This in contrast to current literature which suggests that only dysfunctional joints be manipulated (Vernon Mrozek 2005), however this assumes that dysfunction is only related to motion and therefore can only be assessed by motion palpation. It was therefore acknowledged that this assessment is unable to fully assess for dysfunction and therefore by inference we cannot assume that the joint is normal or abnormal. However for this study what has been defined as a normal joint is based on the current understanding of motion parameters only.

3.2.4 Inclusion and Exclusion Criteria

3.2.4.1 Inclusion Criteria

- All subjects chosen were between the ages of 18 and 45. This is 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 apophyseal joints and the intervertebral disc between adjacent vertebra) was individually 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 then continued up to the occiput. At no time did the hand leave the patients skin, and a firm yet gentle stabilization of the patient's head was maintained at all times (Schafer and Faye 1990).

- Subjects selected were right hand dominant. Peak torque was measured on the dominant side only (i.e. right hand side)
- For sample homogeneity only males were used in the study
- All subjects accepted into the study received a letter of information regarding the study (Appendix A) and must have completed the informed consent form document indicating that they understood and agreed to all documentation provided (Appendix B).

3.2.4.2 Exclusion Criteria

Patients were excluded from the study who presented with:

- a history of fracture or acute trauma to the cervical or shoulder region (Edmund, 1993; Bergmann *et al.* 1993)
- any relevant relative contraindications to manipulation including:
    - disc prolapse,
    - neurological deficits,
    - spondylolisthesis,
    - severe scoliosis,
    - systemic disorders affecting the cervical region including arthritides, infections or malignancies
    - vertebrobasilar insufficiencies

  (Edmund, 1993; Bergmann *et al.* 1993; Gatterman, 1990).
- Hypertensive patients (Bergmann *et al.* 1993).
- Utilisation of medication or other treatment during the course of the study (Poul *et al.* 1993)
- Any contraindications to isokinetic testing (Jackson, 2004 and www.isokinetictesting.com) (Appendix K)
- All patients who failed to complete the informed consent form.

All dropouts were replaced until 25 participants were recruited.

3.3 Clinical Intervention

The initial consultation took place at the Chiropractic Day Clinic on the Durban Institute of Technology campus and included applicant screening and establishment of suitability for the study. No treatment or isokinetic measurements were performed on the initial consultation. The patients were then approved and signed for by a clinician at the Chiropractic Day Clinic before a second appointment was scheduled.

The second consultation took place at the Medigate Medical center in Umhlanga. Here the patients underwent isokinetic testing of their rotator cuff muscles on the Cybex Orthotron II, the isokinetic device used to measure peak torque. The isokinetic testing was done with a registered biokineticist, who agreed to work with the researcher on this study (Appendix I).

3.3.1 Measurements

3.3.1.1 Patient and Testing Procedure

The patients underwent a 3-minute rotator cuff warm up including stretches of the rotator cuff muscles. They were positioned onto the Cybex where they underwent a ‘practice round’ in order to familiarize them with the procedure. The patients then performed 6 test contractions per movement on the affected side, with a four-minute rest in between to avoid fatigue (Suter *et al.* 2000).

The movements measured included

- Internal rotation,
- External rotation,
- Adduction,
- Abduction in keeping with the prime movements of the rotator cuff muscles. (Moore, 1992; Reid, 1992).

See Appendix G: Cybex Testing Protocol for patient positioning.

The patient received verbal encouragement from the researcher during the isokinetic contractions to ensure maximal effort.

Measurements were obtained from the experimental group prior and following the manipulation.

Two sets of readings were recorded:

1. One reading (an average of 6 repetitions) prior to manipulation was recorded.
2. One reading (an average of 6 repetitions) immediately following the manipulation. Not more than 1 minute was allowed to elapse between the time the adjustment had been administered and the device was reset for the second test. (The time suggestion correlates to the study by Bonci *et al.* 1990).

Manipulation followed the techniques set out by Schafer and Faye (1990) (Appendix H: Protocol for Manipulations) and was judged successful following a grade 5 mobilization with or without an audible cavitation.

3.4 The Data

The data used in this study was both primary and secondary data.

3.4.1 The Primary Data- Objective Data

3.4.1.1 Cybex Orthotron II: Isokinetic Muscle Testing

The Cybex Orthotron II Isokinetic Rehabilitation System was used to gather the objective measurements of the peak torque of the rotator cuff muscles. Davies (1992) states that several studies have been conducted confirming the reliability and validity of the Cybex.

Torque is measured in Newton meters and comparisons of rotator cuff peak torque before and after manipulation were represented graphically. Comparisons were made using a normal reference range (Appendix L) (Krukner *et al.* 2001).

3.4.1.2 Record of Fixations Pre and Post Manipulation

A record of where the fixation was located and whether the fixation remained following the manipulation was kept.

3.4.1.3 Record of Audibles Following Manipulation

A record of whether or not the cavitation following manipulation was audible or not was held. Additionally if an audible was heard it was noted whether there was one or many.

3.4.2 Secondary Data

This incorporated literature from current journal articles, books and related Internet sites. The source of this data was found in the library of the Durban Institute of Technology campus.

3.5 Statistical Methods

Data was captured in MS Excel and exported into SPSS (Statistical Package for Social Sciences) 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.

3.6 Statistical analysis

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 were used. Repeated measures ANOVA were used to compare the treatment groups over the two 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

4.0 Results and Discussion

4.1 Introduction

This chapter includes the statistical analysis of the 5 groups allocated to this study. A brief outline of the demographics of the sample in terms of age and race, is followed by both Intragroup and Intergroup analysis.

Key for Abbreviations in Tables and Graphs:

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

Key to groups:

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

4.2 Demographic Data

4.2.1 Age

The ages of the 25 participants ranged from 20 to 41 years, the mean age was 26.7 years and a standard deviation of 5.5 years was noted. There was a statistically significant difference in mean age by group of the participant ($p = 0.005$). 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 significantly in terms of age, however it should be noted that the sample was not representative of the population and thus more emphasis was placed on observing the trends rather than the p values.

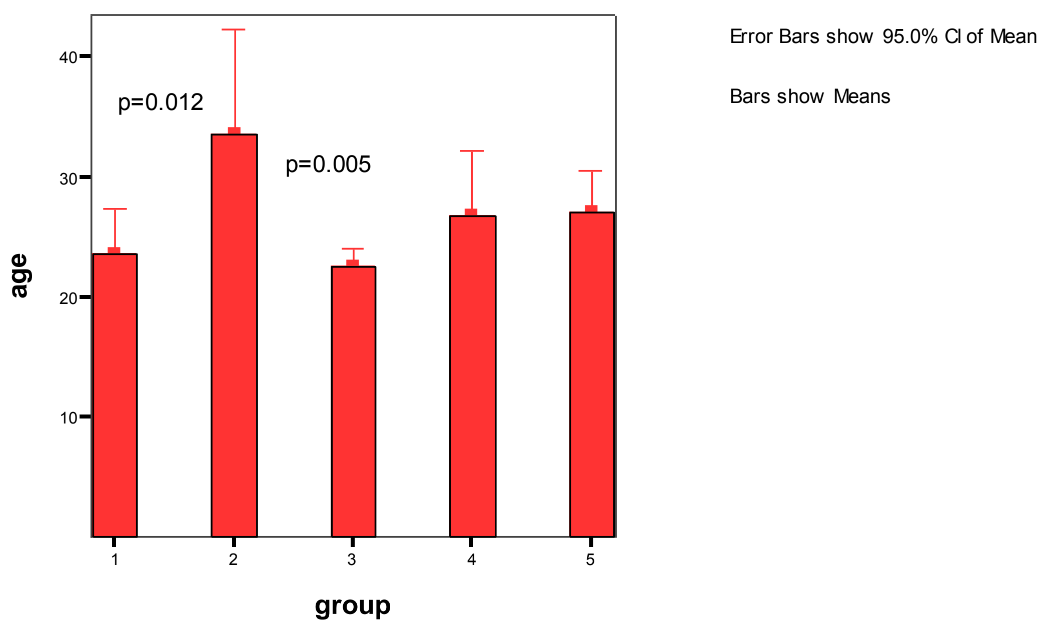


Figure 1: Mean and 95% CI Age by Group

4.2.2 Ethnicity

Only two race groups were represented in this study, Whites and Indians. Due to the consecutive convenient sampling method, no stratification in terms of age or race was executed and thus there was a vast overrepresentation of whites (n=23, 92%), with only 2 Indian subjects represented. This breakdown by race is shown in Figure 2.

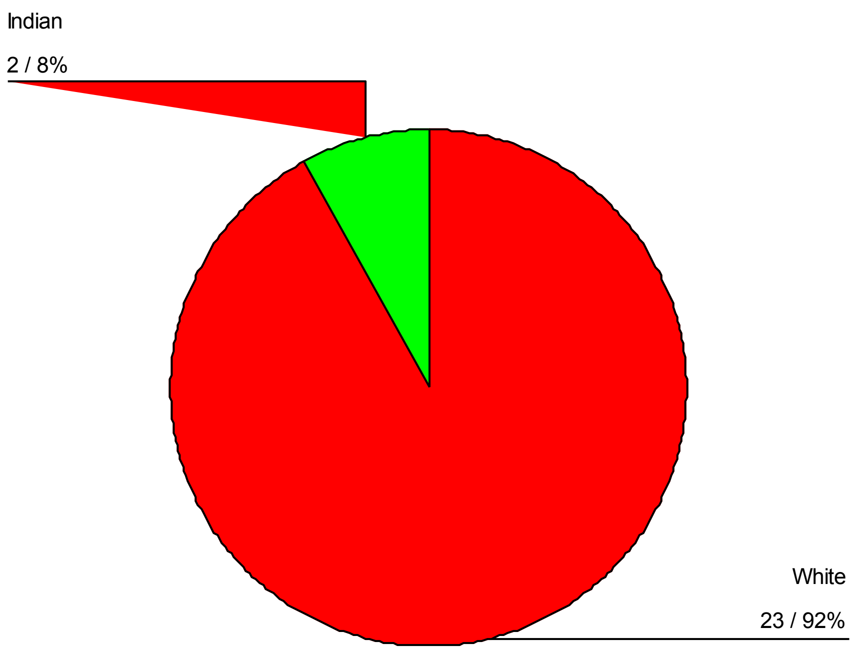


Figure 2: Race Groups in the Study (n=25)

4.2.3 Comparison of Cybex Readings Between the Age and Ethnic Groups:

To assess whether age and race influenced the Cybex readings, baseline Cybex readings were compared between the age and race groups.

4.2.3.1 Age vs Cybex Readings

Table 4.2.3.1: Independent Sample T-Tests 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

Table 4.2.3.1 shows that when the baseline Cybex readings were compared between the two age groups arbitrarily split at 25 years of age to allow for roughly equal groups, no significant differences in any of the readings was noted. This correlates to the fact that as the individuals were being compared to themselves, no significant difference should have been recorded.

4.2.3.2 Ethnicity vs Cybex Readings

Table 4.2.3.2: Independent Sample T-Tests 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 4.2.3.2 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. Possible reasons for the lower Cybex readings could have included as mentioned in Chapter Two:

1) Gender differences [(www.isokinetics.net) and De Ste Coix *et al.* (2003)]. This study however utilized male subjects only, to create a homogenous sample, therefore this option did not influence the results seen here.
2) Age: Strength normally reaches its peak in the third decade and thereafter declines moderately with age (www.isokinetics.net). However 4.2.3.1 above indicates that no significant difference was found when the baseline Cybex readings were compared to age.
3) Body Weight: Muscle mass rises proportionately with body weight. Hence heavier subjects produce higher isokinetic moments and similarly lighter subjects would produce lower isokinetic moments. However, this relationship is not linear and is one of the reasons for normalizing strength to body weight using Newton meter per kilogram body weight [(www.isokinetics.net) and De Ste Coix *et al.* (2003)]. No body weight measurements were taken in this

study therefore no extrapolations can be made to its possible relationship to ethnicity.

4) Muscle characteristics: The slope of moment angular velocity curve changes with age in that children cannot utilize stretch shortening cycles as adults can, possibly because of softer muscles (i.e. they are more flexible). This is seen in isokinetics especially in adolescents who generate more moment at slower speeds (www.isokinetics.net). No adolescents were utilized in this study and thus no extrapolations can be made as to whether muscle characteristics played a part in the ethnicity differences.
5) Effort: Although verbal encouragement was given to all subjects, it is possible that if just one of the two Indian subjects represented, offered a reduced effort, it would reflect a marked reduction in peak torque overall for that group. In comparison to one of the White subjects offering a reduced effort in a group of 23 representatives, which would possibly affect the peak torque less significantly. Thus no generalization for the Indian population in terms of reduced Cybex readings can be made due to the small group size and results should be interpreted with caution.

4.3 Intragroup Analysis

Each group was examined separately for descriptive purposes.
The following were noted in each group:

1) Whether a cavitation was heard following manipulation,
2) Whether it was one or many cavitations that were heard,
3) Whether or not the fixation remained following manipulation, and
4) Descriptive statistics for the Cybex measurements over time were done for each group.

4.3.1 Group 1: No Fixation with Random Manipulation between C4-C7

4.3.1.1 Cavitations and Fixations in Group 1

Table 4.3.1.1 shows that all subjects in Group 1 had many cavitations and none had fixations present after manipulation.

Table 4.3.1.1: Cavitations and fixations in Group 1

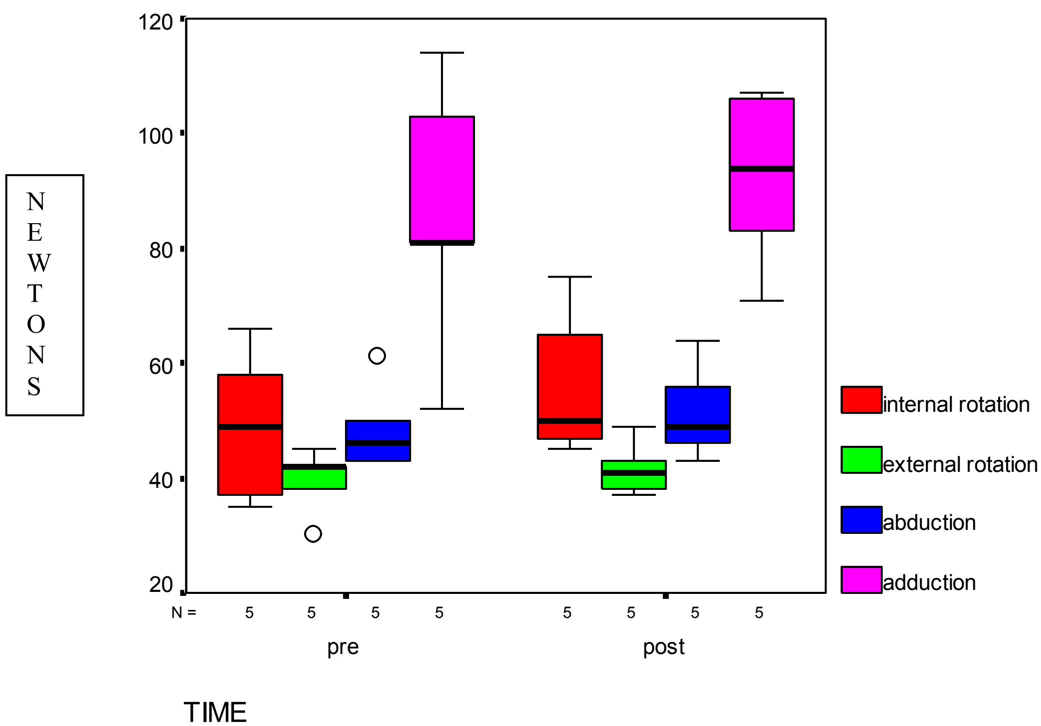
	n (%)
Cavitation present	5 (100%)
Many cavitations	5 (100%)
Fixations after manipulation	0 (0%)

4.3.1.2 Descriptive Statistics for Cybex Measurements Over Time in Group 1

The descriptive statistics for the Cybex readings for Group 1 are shown in Table 4.3.1.2 over the two time intervals. Internal rotation increased, external rotation decreased, abduction and adduction increased over time. This is also shown graphically in Figure 3.

Table 4.3.1.2: Descriptive statistics for Cybex measurements over time in Group 1

		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



The black line denotes the median, O represents the outliers

Figure 3: Boxplots of Group 1 over Two Time Points

4.3.2 Group 2: Fixation with Random Manipulation Between C4-C7

4.3.2.1 Cavitations and Fixation in Group 2

It was noted that 80% of Group 2 had cavitations, and of these 75% had many cavitations. All had no fixations present after manipulation. This is shown in Table 4.3.2.1

Table 4.3.2.1: Cavitations and fixation in Group 2

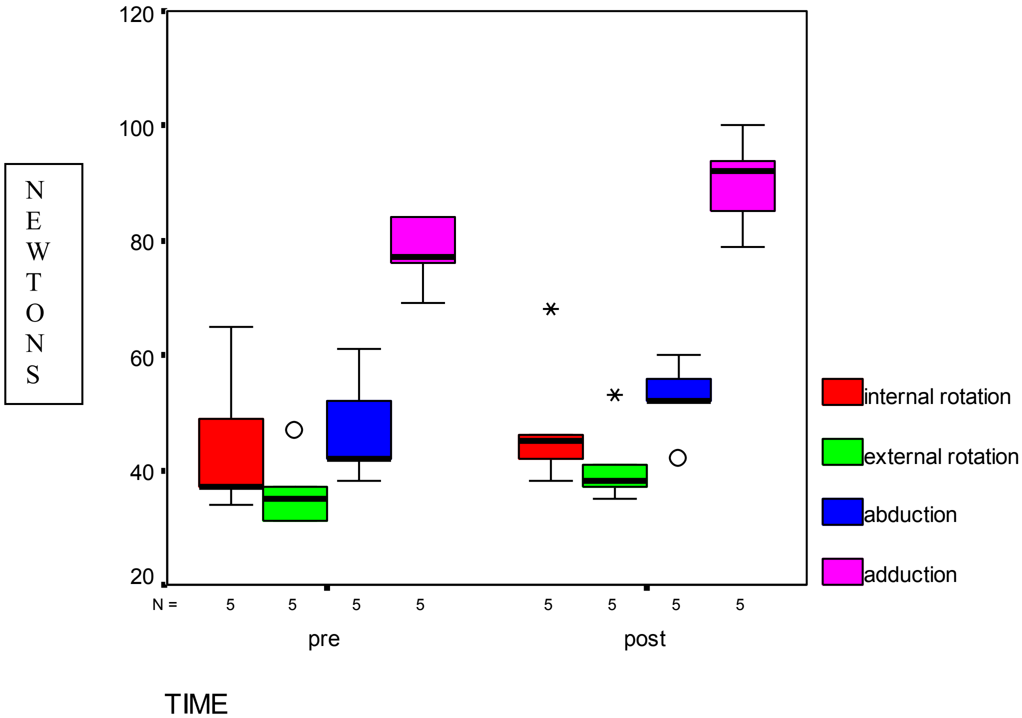
	n (%)
Cavitation present	4 (80%)
Many cavitations	3 (75%)
Fixations present after manipulation	0 (0%)

4.3.2.2 Descriptive Statistics for Cybex Measurements Over Time in Group 2

Table 4.3.2.2 shows that all Cybex measurements increased in Group 2 from pre to post manipulation. This is similarly reflected in Figure 4.

Table 4.3.2.2: Descriptive statistics for Cybex measurements over time in Group 2

		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



The black line denotes the median, O represents the outliers and the * represents the extreme values

Figure 4: Boxplots of Group 2 over Two Time Points

4.3.3 Group 3: Fixation with Specific Manipulation C4-C5

4.3.3.1 Cavitations and Fixations in Group 3

Table 4.3.3.1 indicates that all 5 subjects in Group 3 had cavitations following manipulation, however only 40% had many cavitations. None had fixations present after manipulation.

Table 4.3.3.1: Cavitations and fixations in Group 3

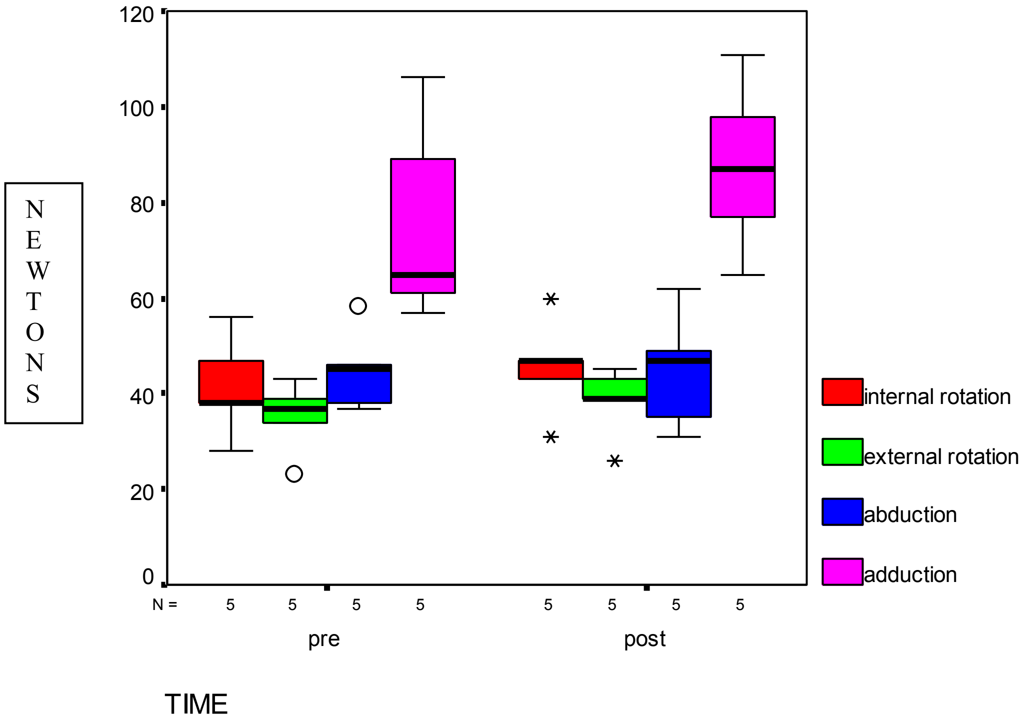
	n (%)
Cavitation present	5 (100%)
Many cavitations	2 (40%)
Fixations present after manipulation	0 (0%)

4.3.3.2 Descriptive Statistics for Cybex Measurements Over Time in Group 3

Table 4.3.3.2 shows that all Cybex readings increased between pre and post manipulation in group 3. This is shown in Figure 5.

Table 4.3.3.2: Descriptive statistics for Cybex measurements over time in Group 3

		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



The black line denotes the median, O represents the outliers and the * represents the extreme values

Figure 5: Boxplots of Group 3 over Two Time Points

4.3.4 Group 4: Fixation with Specific Manipulation at C5-C6

4.3.4.1: Cavitations and Fixations in Group 4

In Group 4, 80% of the subjects had cavitations, of which 75% had many cavitations. No fixations remained following the manipulation. This is shown in Table 4.3.4.1.

Table 4.3.4.1: Cavitations and fixations in Group 4

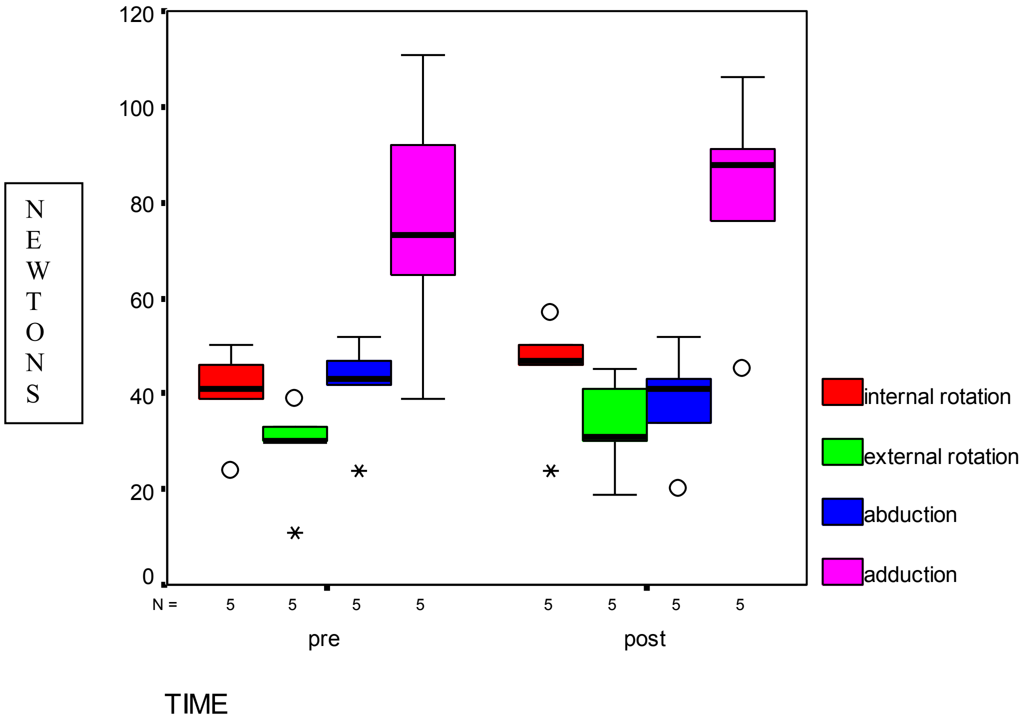
	n (%)
Cavitation present	4 (80%)
Many cavitations	3 (75%)
Fixations present after manipulation	0 (0%)

4.3.4.2 Descriptive Statistics for Cybex Measurements Over Time in Group 4

In group 4, there was a slight increase in all measurements after manipulation, barring abduction. This is shown in Table 4.3.4.2 and Figure 6.

Table 4.3.4.2: Descriptive statistics for Cybex measurements over time in Group 4

		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



The black line denotes the median, O represents the outliers and the * represents the extreme values

Figure 6: Boxplots of Group 4 over Two Time Points

4.3.5 Group 5: Fixation with Specific Manipulation at C6-C7

4.3.5.1 Cavitations and Fixations in Group 5

All of the subjects in Group 5 had cavitations, however only 40% of them had many cavitations. As was the trend in all the Groups thus far no fixations remained following manipulation. This can be seen in Table 4.3.5.1below:

Table 4.3.5.1: Cavitations and fixations in Group 5

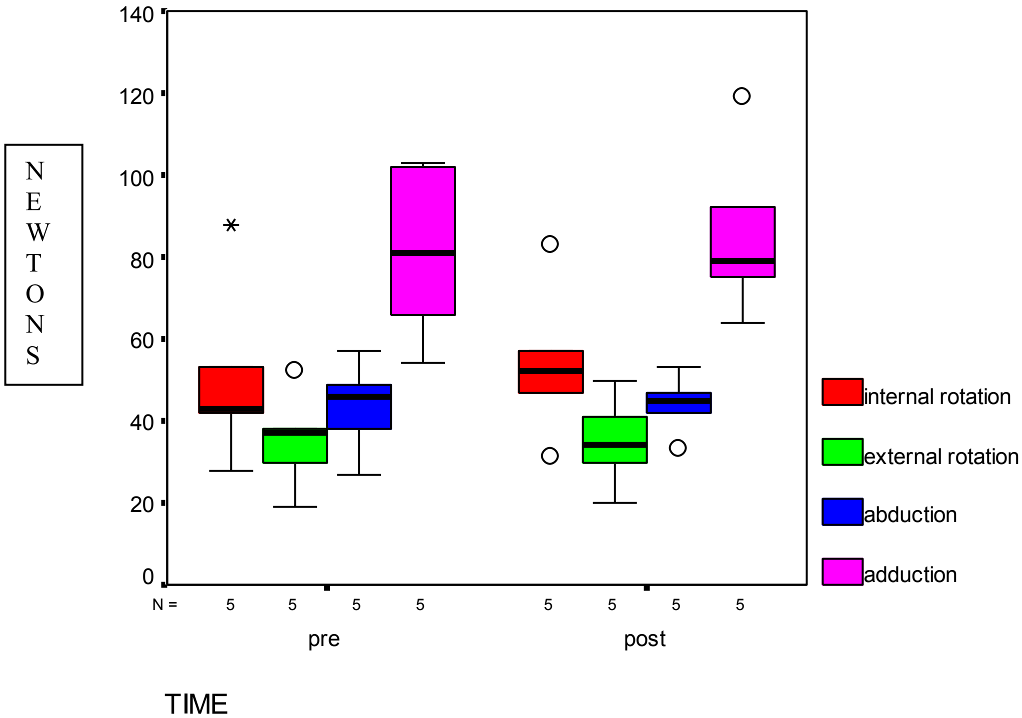
	n (%)
Cavitation present	5 (100%)
Many cavitations	2 (40%)
Fixations present post manipulation	0 (0%)

4.3.5.2 Descriptive Statistics for Cybex Measurements Over Time in Group 5

Internal rotation was the only muscle in Group 5 which increased in peak torque between pre and post manipulation. External rotation, abduction and adduction all decreased post manipulation. This can be observed in Table 4.3.5.2 and Figure 7 below.

Table 4.3.5.2: Descriptive statistics for Cybex measurements over time in Group 5

		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



The black line denotes the median, O represents the outliers and the * represents the extreme values

Figure 7: Boxplots of Group 5 over Two Time Points

4.3.6 Conclusion

Of the 25 subjects manipulated 2 did not cavitate, 7 only had one cavitation and 15 had many cavitations. It is noted in the descriptive statistics for the Cybex readings in each group that Group 2 and Group 3 improved in all readings between pre and post manipulation. Although these values were not statistically analyzed against the number of cavitations it appeared that regardless of whether there were cavitations or not, the trend was toward peak torque improvement post manipulation.

In this light a cavitation is described by Leach (1994) as a process by which manipulation enables the range of motion of a joint to enter the paraphysiological space and by doing so a 'crack' is heard. 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. This in turn is hypothesiszed to have a reflex effect on the neuromuscular system by inhibiting pain, increasing range of motion and causing relaxation of spastic muscles (Herzog 1996). Thus one could suggest that with an increase in the number of cavitations one hears, there is a more significant increase in the reflex effects on the joint and peripheral musculature. However further studies into the role of cavitations would be of much value in widening our understanding of manipulation induced effects of peripheral musculature.

4.4 Intergroup comparisons

Repeated measures ANOVA (Analysis of variance) was done for each Cybex measurement to assess three hypotheses:

1) If there was a significant change over time in all subjects,
2) If there was a significant difference between the 5 groups at both time points, and
3) 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 being different in the five groups.

Using these as factors in the model the effects of race and cavitations were also assessed. 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.

4.4.1 Internal rotation

Table 4.4.1: Hypothesis Tests for Repeated Measures ANOVA for Internal Rotation

	Statistic	p value
Time	Wilk's lambda 0.701	***0.019***
Time *Group	Wilk's lambda 0.825	0.515
Group	F =0.156	0.958
Time* race	Wilk's lambda 0.944	0.344
Race	F=3.518	***0.079***
Time* cavitation	Wilk's lambda 0.985	0.633
Cavitation	F=0.648	0.433

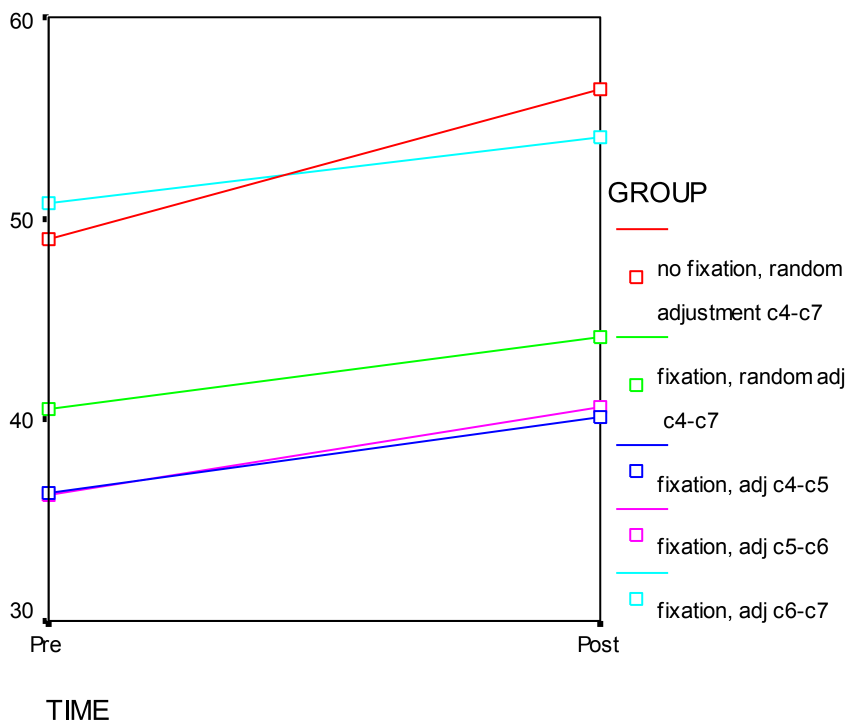


Figure 8: Mean Internal Rotation by Group over Time

Table 4.4.1 shows a significant increase over time in all groups (p = 0.019), however the change over time was not different between the groups. The effects of race and cavitations did not affect the change over time significantly. As mentioned above in 4.3 Intragroup Analysis, the effects of manipulation with and without an audible cavitation needs to be further researched with larger sample sizes in order to get a more valid statistical analysis.

Race may have had significance with a p value of 0.079, but due to the unequal grouping and the small sample size it reflected no significant impact on the peak torque for internal rotation.

Figure 8 shows that for all groups there was an increase between pre and post manipulation in terms of the calculated mean for internal rotation peak torque.

<u>Possible hypothesis for the increase detected could include:</u>

1) The internal rotation movement was measured using a short lever maneuver (i.e. center of rotation is closer to the body) thus making it easier for the participant to exert a greater effort against the Cybex and allowing for smaller increases in the peak torque to be more effectively discriminated as a result.

2) Despite the level of innervation for the internal rotator muscles arising principally from C5, C6 and C7 (Moore, 1992, Gray *et al*. 1980), all 5 Groups as mentioned above improved significantly regardless of which levels were manipulated. Thus it is thought that biomechanical changes occurring following manipulation at one level could effect other levels without themselves having been manipulated, and thus restoring normalcy at those levels (Bergmann *et al.* 1993; Leach, 1994). This could explain why adjusting levels unrelated to the innervation of the internal rotators, still showed a significant increase in the mean peak torque values, post manipulation.

3) Lastly, of the 25 subjects sampled, 15 had multiple cavitations following manipulation. It is thus reasonable to argue that although when attempting a specific manipulation and more than one cavitation is heard, one could be manipulating other levels simultaneously. This could explain why the groups, which did not contain the main spinal cord segmental innervation of the internal rotator muscles (Group 1 and 2, if C6 was not manipulated, and Group 3), also showed improvement in mean peak torque over time.

4.4.2 External rotation

Table 4.4.2: Hypothesis Tests for Repeated Measures ANOVA for External Rotation

	Statistic	p value
Time	Wilk's lambda 0.693	***0.017***
Time *Group	Wilk's lambda 0.718	0.229
Group	F =0.650	0.635
Time* race	Wilk's lambda 0.983	0.609
Race	F=9.422	***0.007***
Time* cavitation	Wilk's lambda 0.993	0.750
Cavitation	F=0.918	0.352

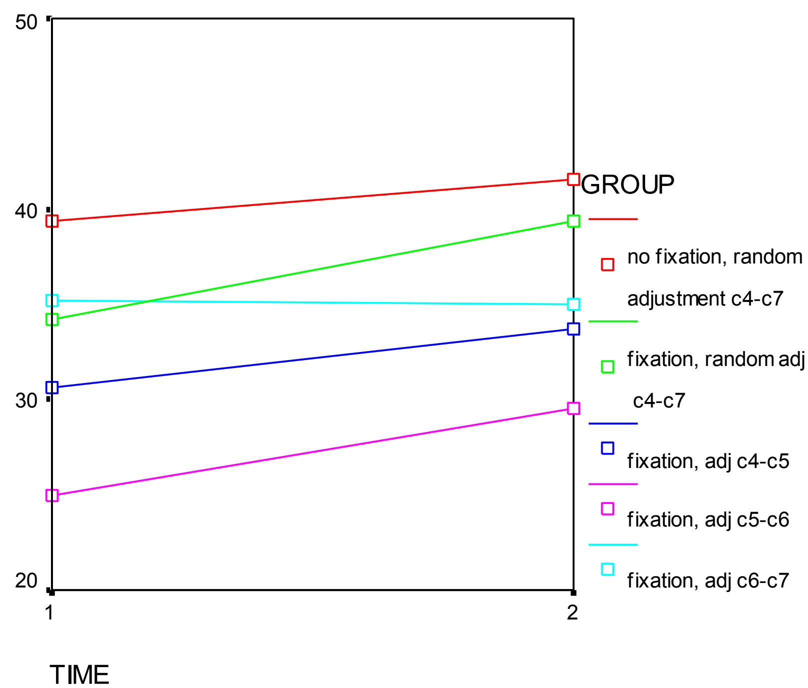


Figure 9: Mean External Rotation by Group over Time

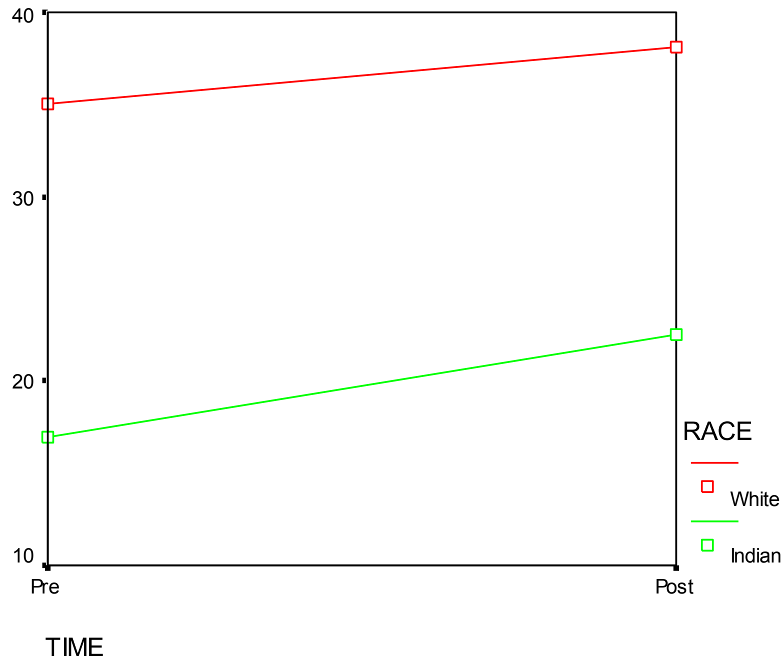


Figure 10: Mean External Rotation by Race over Time

There was a significant increase in mean external rotation in all groups between pre and post manipulation (p = 0.017) noted in Table 4.4.2. It can be seen in Figure 9 that most groups increased in mean external rotation between pre and post visits, except for Group 5, which showed no change over this time. There was also a significant difference overall between the race groups (p = 0.007) reflected in Table 4.4.2. 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. Again cavitations and fixations did not affect the mean external rotation over time.

The hypotheses discussed above in 4.4.1 for the significant increase in the internal rotation mean peak torque values will hold true for the increase in mean peak torque values for external rotation.

4.4.3 Abduction

Table 4.4.3: Hypothesis Tests for Repeated Measures ANOVA for Abduction

	Statistic	p value
Time	Wilk's lambda 0.952	0.383
Time *Group	Wilk's lambda 0.708	0.212
Group	F =0.743	0.577
Time* race	Wilk's lambda 0.915	0.240
Race	F=8.701	***0.009***
Time* cavitation	Wilk's lambda 0.942	0.334
Cavitation	F=2.544	0.130

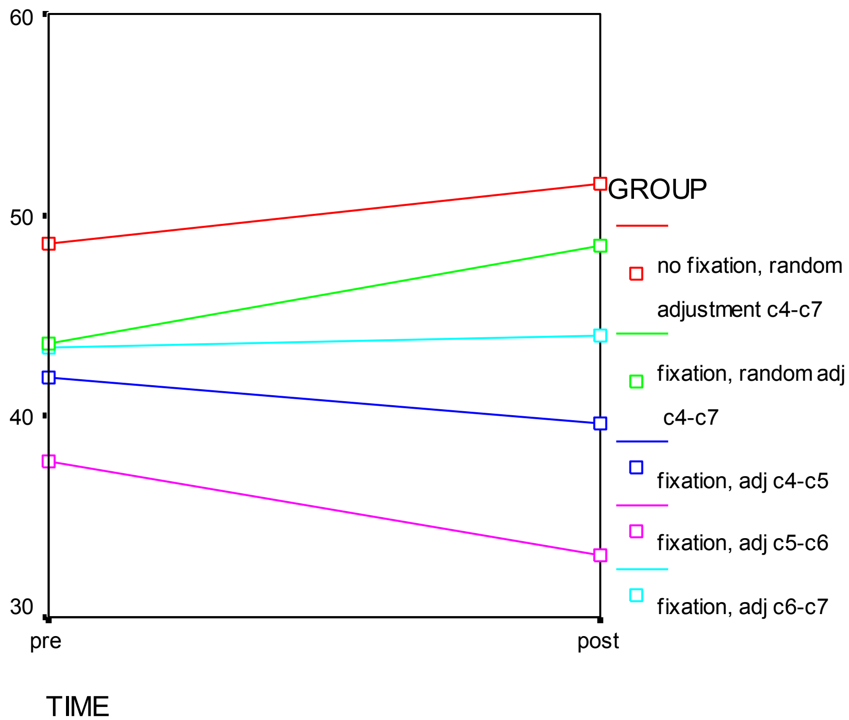


Figure 11: Mean Abduction by Group over Time

Table 4.4.3 highlights no significant time by group interaction or effect of time overall for abduction both pre and 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. Again caution should be undertaken when examining these results as although race appears to be statistically significant the results could be skewed due to unequal race representations.

Examination of Figure 11 shows that two of the groups decreased between pre and immediately post manipulation.

<u>Possible reasons for the downward trend noticed in Figure 11, are mentioned as follows:</u>

1) A long lever maneuver was utilized to measure abduction on the Cybex machine (i.e. the center of rotation was further away from the body) and thus it would be harder to produce the equivalent effort as compared with a short lever maneuver (internal and external rotation). This would have also decreased the ability of the measuring tool to detect small changes in the effort of the patient as the distance traveled over time would have had to have been greater to detect a small change as opposed to the shorted lever movements. This reason however does not hold true for Group 1 and Group 2, which did increase in peak torque over the time period.

2) Similar levels were manipulated in the Groups that increased, and those that decreased peak torque over time. This therefore poses a dilemma, as the only identified difference between these two Groups (i.e. Groups 1 and 2– versus Groups 3, 4 and 5) relates to the manipulation of non-fixated (Group 1 and Group 2 - *which although was a fixated group, the manipulation was random and not necessarily at the level of fixation* - versus fixated levels (Groups 3, 4 and 5). Where the non-fixated groups increased in peak torque over time and the fixated groups decreased in peak torque over time (having manipulations at the specific level of fixation).

   Furthermore, it is important to note that the patients were all asymptomatic, so there is no clinical reasoning why the non-fixated group would be faring any differently to the fixated group. Yet in contrast to this there is an obvious but insignificant improvement trend in the asymptomatic non-fixated group versus the asymptomatic fixated group as seen in Figure 11.

In attempting to explain this, the Adhesion Hypothesis outlined by Leach (1994) could be used as a model, due to the fact that it gives the reader a possible understanding as to how both groups (i.e. fixated and non-fixated) despite both being asymptomatic could fare differently in results, with the non-fixated groups obtaining greater torque values in comparison to the fixated groups.

<u>This theory is based on the following concept:</u>

Under normal (non-fixated) circumstances within a joint, the extensibility of connective tissue in and around the joint and therefore joint movement, is aided by the infusion of water between the layers of proteoglycan molecules, which provides lubrication and greater stretch under tension (Solomon *et al.* 1990)

The adhesion hypothesis model (Leach, 1994) states that a fixation (arising from whatever reason) causes a restriction in movement or immobilization. This immobilization is thought to cause dehydration within the connective tissue, which in turn will cause approximation of the proteoglycans within and between the connective tissues (“adhesion formation”). This limits the extensibility of the connective tissue and thus results in a further restriction of movement within the already fixated joint.

During the course of development of this adhesion, the patient may have had clinical signs and symptoms as related to an acute period of neck pain associated with the inciting trauma or cause. However after the resolution of the symptoms, the adhesion remains as long as the patient does not seek treatment at the time of the acute pain or at a later date (Leach 1994).

This therefore implies that the motion at the motion segment in question becomes restricted at a local level, without the presence of clinical signs or symptoms (Bergmann *et al.* 1993):

- As the patient's global range of motion remains the same due to compensations higher up or lower down the mechanical chain (Bergmann *et al.* 1993).
- The resolution of the inflammation has removed the pain stimuli (inflammatory mediators) (Leach 1994).

This restriction in motion has been explained previously utilizing the following diagram below (Figure 12) which illustrates the model proposed by Sandoz (1976), where he postulated that there is a paraphysiological space (beyond the passive range, but less than the anatomic limit). It is claimed that we as chiropractors adjust into this paraphysiological space in order to restore joint range of motion at or near the end of the joints' range of motion.

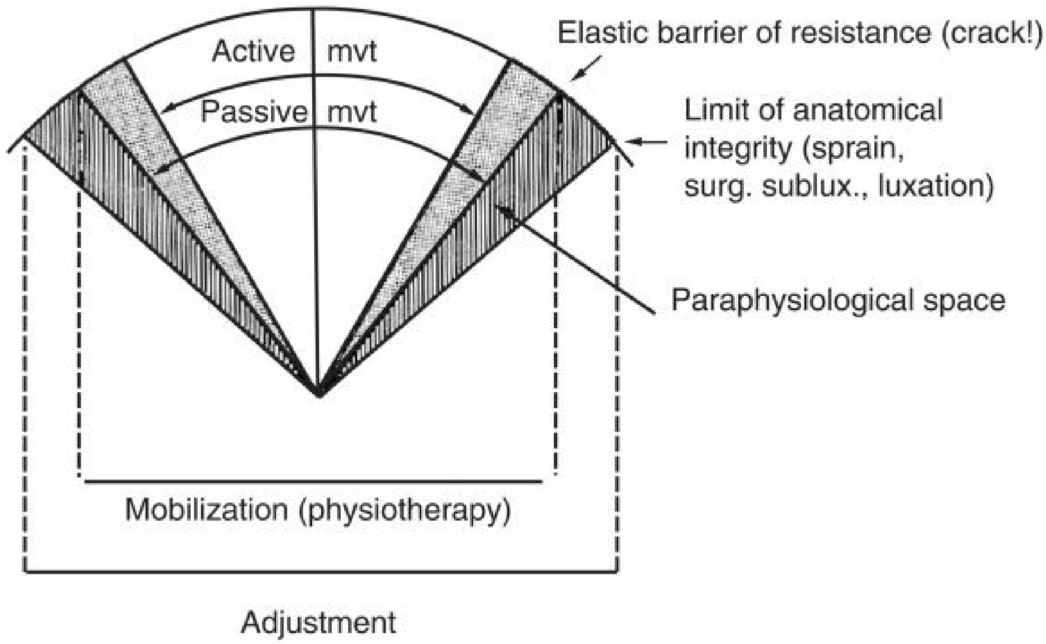


Figure 12: Joint Manipulation and Mobilization

[Vernon and Mrozek (2005) from Sandoz (1976)]

However if one critically analyses this assertion in the face of clinical experience, it would seem that all patients are adjusted at the end of the range of motion near the anatomical barrier, in order to attain the paraphysiological space and achieve a cavitation. This poses a question in relation to the type of joint under study in the research that supports (Roston and Wheeler-Haines (1947), Unsworth *et al.* 1971, and Miereau *et al*. 1988 as quoted from Vernon and Mrozek 2005) the hypothesis as proposed by Sandoz (1976). The answer to this question lies in the fact that, although these joints undergo a cavitation, these occur at the extremes of the NORMAL joint motion, within a NORMAL paraphysiological space.

Vernon and Mrozek (2005) challenge Sandoz's (1976) Hypothesis by stating that it is not normal joints that we as chiropractors are manipulating, but clinically compromised joints. Figure 13 below (from Vernon and Mrozek (2005)), describes the "clinical situation" where joint motion is reduced. The range of motion available in the clinical situation is called the “clinical physiological range” and manipulation is performed within the “clinical physiological range” and not in the paraphysiological space as previously thought by Sandoz (1976). In regards to Leach’s (1994) Adhesion Hypothesis proposed to describe the apparent decrease in peak torque of abduction in patients with a fixation, as compared to the increase in peak torque in patients without the fixation in this study, one could equate the ‘adhesion’ (although subclinical in this study) as the causative agent for the limitation in joint movement and thus maintaining it in the ‘clinical physiological range’ and allowing for the development of a restriction at that level.

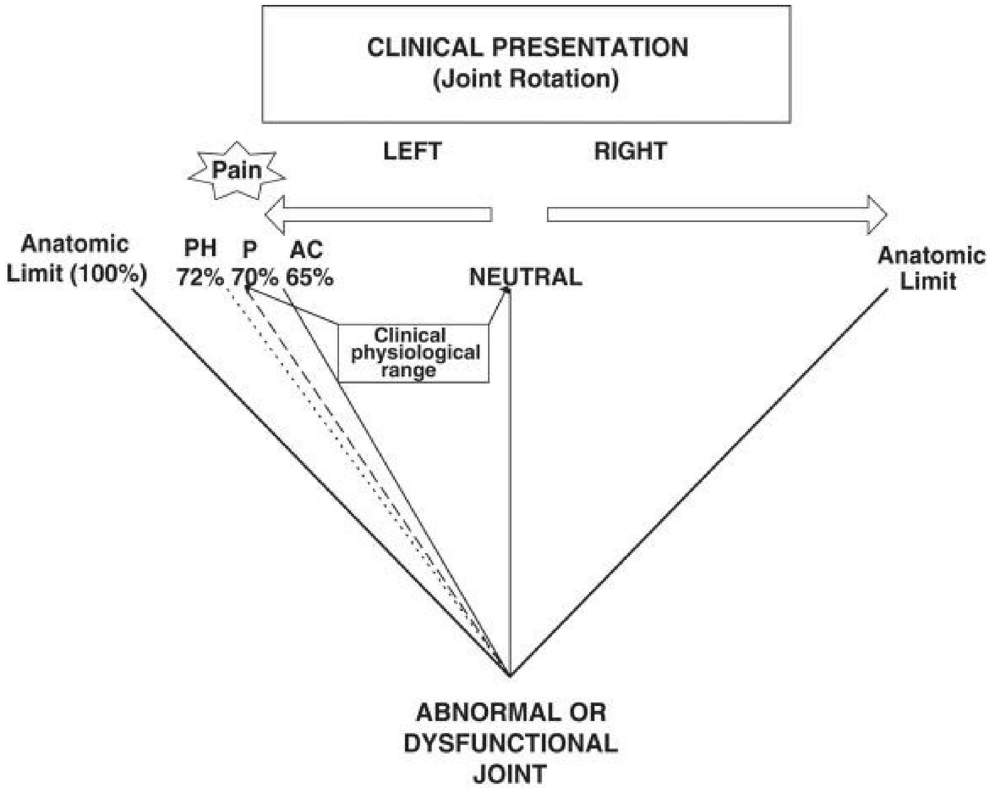


Figure 13: Clinical Presentation: Typical circumstances in which Manipulation is used. (Mrozek
AC = Active range, P = Passive, PH = paraphysiological space (small zone of joint or 'give').

Furthermore it must be noted that adjusting into the paraphysiological space, increased stimulation of the capsule, ligaments and musculature surrounding the joint will occur. This is as a result of the joint being moved beyond what has been termed the "neutral zone" (Panjabi *et al.* 1988), where there is little if no perceived stress on these tissues.

This is further supported by (Klein *et al.* 2002) who proposed the "elastic zone" beyond the neutral zone (Panjabi *et al.* 1988). In the "elastic zone" tissues undergo physiological levels of strain, but which is still less than the anatomical limit of integrity at which maximum tissue damage occurs (Vernon and Mrozek (2005) and Sandoz's (1976).

This therefore implies that by manipulating a non-fixated segment, a greater degree of improvement is expected in comparison to a fixated segment, if the basis for improvement in the Cybex readings is linked to neurological stimulation of the appropriate levels within the spine as:

> The fixated segment group requires the breaking of the adhesions and therefore there is a decreased chance of entering the paraphysiological space. From the above discussion it is more likely that the patient's joint is taken to a point that approximates the beginning of the paraphysiological space, but does not pass into it (Vernon and Mrozek (2005)). This would therefore imply that the degree of neurological stimulation of the surrounding tissues is less as the patient's joint is maintained within the "elastic zone".
>
> This is in contrast to the patients that presented with no fixations, where the adjustment would have been performed at the end of the normal range of motion. The patient's joint would have been taken past the elastic zone (Klein *et al*. 2002) and into the paraphysiological space (Sandoz, 1976). Here increased neurological stimulation would have been evident from the stressors applied to the soft tissues at this point in the range of motion (Sandoz, 1976), before reaching the point of anatomical integrity.

Thus the current literature supports the trend increase in the ***abduction*** range of motion tested on the Cybex in this study with respect to the patients presenting with no fixations as opposed to patients presenting with fixations. It should however be noted that further research needs to be conducted with larger sample sizes to see if the trends continue, which would allow for a more definitive analysis and interpretation of these trends and lend further support to or detract from the argument that is put forth above.

4.4.4 Adduction

Table 4.4.4: Hypothesis Tests for Repeated Measures ANOVA for Adduction

	Statistic	p value
Time	Wilk's lambda 0.681	***0.015***
Time *Group	Wilk's lambda 0.914	0.822
Group	F =0.278	0.888
Time* race	Wilk's lambda 0.999	0.898
Race	F=7.953	***0.012***
Time* cavitation	Wilk's lambda 0.957	0.411
Cavitation	F=0.225	0.642

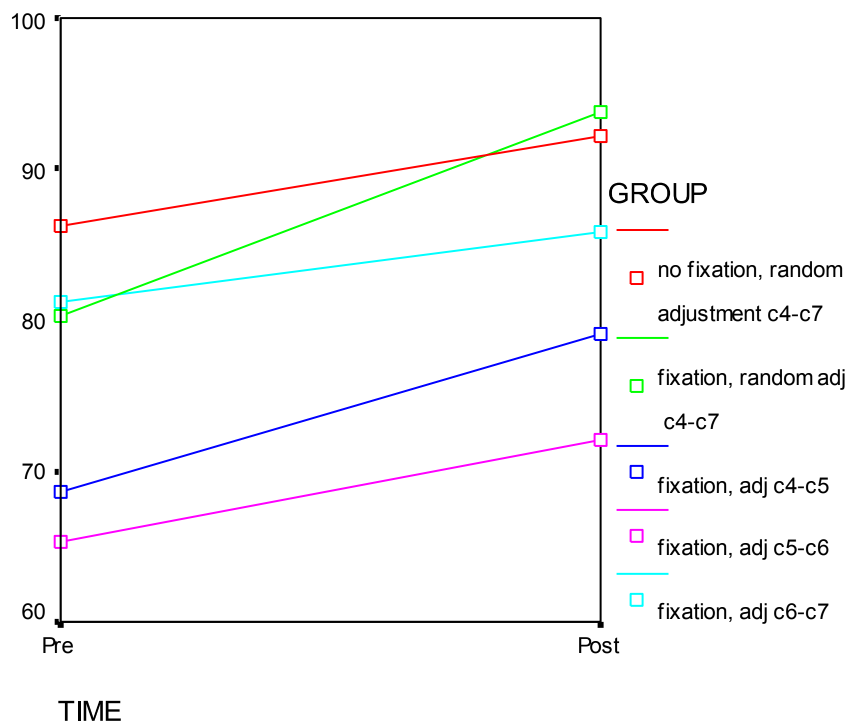


Figure 14: Mean Adduction by Group Over Time

All groups showed an increase in adduction over time between pre and post manipulation (p =0.015) see Table 4.4.4 and Figure 14. There were no differences between the groups or any statistical significant difference in the

Time*Group interaction which is reflected in the Table 4.4.4 above. Thus all groups behaved in the same manner over time. The only effect which was significant was the effect of race (p=0.012), which was constant across time (p = 0.898), however the same caution as mentioned above in the previous Intergroup analyses with regards to race, similarly holds true in this instance.

Similarly, the hypotheses explaining the increase in internal and external rotation will hold true for Adduction. The one difference being adduction measurements used the long lever maneuver, which stated above requires more effort as the axis of rotation is further away from the body and therefore negates the ability of the measurement tool to detect small changes. However this could be negated, as the number of muscles involved in adduction (Latissimus dorsi, Teres major, Pectoralis major and Subscapularis) in comparison to those involved in abduction (Deltoid and Supraspinatus) allows for a stronger more consistent response.

4.4.5 Summary of Intergroup Analysis

Internal Rotation: all groups increased between pre and post manipulation significantly. There was no difference in the rate of increase between the groups. It appeared that Group 1 increased more than the other groups.

External rotation: all groups increased significantly between the two time points. There was no difference in the rate of increase between the groups but it appeared that Groups 1 and 5 had the lowest increase. Groups 2 and 4 showed slightly higher increases than the other groups. Race was significant in that Indians had lower mean external rotation than Whites at both times.

Abduction: there was no significant increase over time because two groups showed a decrease in this time, two groups an increase, and one group no change. The increase in Group 2 appeared to be greater than that in Group 1. Race was also significant.

Adduction: there was a significant increase in time overall and Group 2 showed the steepest increase. Race was also significant.

4.5 Conclusion

In this study the age did not significantly influence the Cybex readings. Additionally the group to which the subject belonged did not seem to significantly affect the increase or change in Cybex measurements immediately after manipulation. Groups 2 and 3 showed increased peak torque values in all four movements measured. Groups 1 and 4 improved in all movements barring external rotation and abduction respectively. Group 5 only increased peak torque for internal rotation.

Cavitations, whether absent, present, one or many, did not statistically affect the change over time significantly. And the level of the manipulation did not appear to influence the results significantly.

Some trends however, which were observed but were not statistically significant, due to possible under powering of the study deserve further investigation:

- One such trend was the relatively steeper increase in all measurements between pre and post manipulation in Group 2 compared with the other groups.
- The second trend was that the average improvements in Groups 1 and 2 (non-fixated groups) (see italicized section pg.51) seemed to average above Groups 3, 4 and 5 (fixated groups) for all movements. However these trends were not significant and it is therefore proposed that larger sample sizes in future studies would need to be utilized in order to verify this trend.
- The third trend was the racial differences (lower values in Indians than whites) which also could have been due to chance and under representation of the Indian population.

In respect to the above 3 trends the role of chance cannot, unfortunately, be excluded due to the small sample size. A larger study should be done to fully explore the statistical significance of these trends.

Thus in the light of the preceding discussions the following becomes pertinent to the hypotheses developed at the outset of the study:

Hypothesis 1

Manipulation did have an effect on peak torque.

Accepted as a hypothesis. Reservations exist as to whether the effect is of a positive or negative nature, as the influence of various factors on the effect of the manipulation were not assessed as part of this study.

Hypothesis 2:

Manipulation of specific levels could raise the peak torque of the specific muscle innervated by those levels.

This hypothesis is rejected as the results of this study where inconclusive as to the relationship of the neurological level and its effect on the innervated structures at that level. This requires further study.

Hypothesis 3:

A fixation would not necessarily have to be present for manipulation to raise the peak torque.

This is accepted, however further research is required to collaborate this hypothesis.

CHAPTER FIVE

5.0 Recommendations and Conclusion

5.1 Recommendations

To attain more statistically significant results, future similar studies should utilize a statistically significant sample size. The small sample size in this study was due to the budget restrictions imposed upon the researcher. Financial resources are essential if significant research in this area is to be carried out in the future.

Although a study examining the short-term effects (within 24 hours) of manipulation on peak torque of the rotator cuff muscles, followed along side this research, a study investigating the long-term effects of manipulation on peak torque should be conducted.

One of the aims of this study was to develop a more efficient shoulder treatment protocol by examining the effects that manipulation had on the peak torque of the rotator cuff muscles. The results showed that there was in fact a significant increase in peak torque following manipulation (without the mechanism being named in this study). The subjects chosen where however asymptomatic and thus a study should be conducted where the subjects are symptomatic and present with a rotator cuff pathology. The effects of manipulation of the segmental levels on the peak torque of the rotator cuff could once again be observed in these patients in order to establish whether similar or different results are obtained.

The raising of the peak torque in asymptomatic subjects in this study also brings light to further avenues of research with regards to sports performance. A study could be conducted to see the effectiveness of raising the peak torque / distance through manipulation on performance of an athlete (for example javelin thrower).

Bearing in mind the controversy surrounding sport enhancing aids, manipulation could be a natural way to increase strength.

5.2 Conclusion

The purpose of this study was to evaluate the immediate effect of manipulation of selected cervical spinal segments on the peak torque of the rotator cuff muscles in asymptomatic patients with and without a mechanical cervical spine dysfunction. The results showed a significant rise in peak torque following manipulation and thus Hypothesis 1 stating that manipulation did have an effect on peak torque, is accepted.

Hypothesis 2 stated that manipulation of specific levels could raise the peak torque of the specific muscle innervated by those levels. This hypothesis is rejected as the results of this study where inconclusive as to the relationship of the neurological level and its effect on the innervated structures at that level.

The results also indicated that a fixation does not necessarily have to be present for manipulation to raise the peak torque. Hypothesis 3 is therefore also accepted.

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APPENDIX A:

LETTER OF INFORMATION

LETTER OF INFORMATION

Dear Patient

Welcome to this study!

Title of the study:
The immediate 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.

Supervisors: Dr C. Korporaal (031-2042205)
Mr D. Jackson (031-5662165)
Research student: Tamsyn Dixon (031-2042205)
Institution: Durban Institute of Technology (DIT)

Purpose of the study:
Twenty-five asymptomatic patients will receive manipulative treatment to the neck. The effects of the manipulation on the rotator cuff (shoulder muscles) muscle strength will be investigated to add to the knowledge on the effects of manipulation and the possible role manipulation may have in the rehabilitation of the shoulder.

Procedures:
Initial visit:
The first consultation will take place at the DIT Chiropractic Day Clinic. Here patients will be screened for suitability for this study, which will be determined by a case history, physical examination and a cervical spine regional examination. This appointment will take approximately 1 hour.

The second visit:
This consultation will take place at the Medigate Medical Centre in Umhlanga Rocks and is subject to the availability of the biokineticist, Mr Jackson. These premises have the relevant facilities for the isokinetic muscle testing. In the

Risks/discomfort:
The testing is relatively harmless, however some muscle stiffness after testing may be experienced.

Benefits:
- The manipulative treatment that will be given is a common treatment intervention in the treatment of cervical facet dysfunction.
- All treatments will be free of charge.
- On completion of your participation in this study you are eligible for two free treatments at the Durban Institute of Technology Chiropractic Day Clinic.

New findings:
You have the right to be made aware of any new findings that are made pertaining to this study.

Reasons why you can be withdrawn from the study without your consent:
- If you experience any discomfort during the isokinetic testing session.
- If you change any lifestyle habits during your participation in this study that may affect the outcome of this research. (eg. Change in medication, supplementation or treatment of any kind)

PLEASE NOTE: You are free to withdraw from the study at any time without giving a reason.

Remuneration:
You will not receive a travel allowance to get to the Medigate Medical Centre in Umhlanga.

Cost of the study:
All treatments will be free of charge and your participation is voluntary.

Confidentiality:
All patient information is confidential and the results will be used for research purposes only. Supervisors and senior clinic staff may however be required to inspect the records.

Persons to contact with problems or questions:
Should you have any further queries and you would like them answered by an independent source, you can contact my supervisors on the numbers above.

Thank you for your participation.

Tamsyn Dixon	**Dr. C. Korporaal**	**Mr. D. Jackson**
(Chiropractic Intern)	**(Supervisor)**	**(Supervisor)**

APPENDIX B:

INFORMED CONSENT FORM

INFORMED CONSENT FORM

(To be completed by patient / subject)

Date : **August 2004**

Title of research project :The immediate 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.

Name of supervisor : **Dr C. Korporaal**

Tel : **031-2042205**

Name of research student : **Tamsyn Dixon**

Tel : **031-2042205**

<u>Please circle the appropriate answer</u>		**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 at any time without having to give any a reason for withdrawing, and 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

<u>Please Print in block letters:</u>

Patient /Subject Name:___________________________Signature: ___

Parent/ Guardian:_________________________________Signature:__

Witness Name:___________________________________Signature:__

Research Student Name:___________________________Signature:__

APPENDIX C:

CASE HISTORY

APPENDIX D:

PHYSICAL EXAMINATION

APPENDIX E:

CERVICAL REGIONAL

APPENDIX F:

SHOULDER REGIONAL EXAMINATION

APPENDIX G:

CYBEX TESTING PROTOCOL

CYBEX TESTING PROTOCOL

Measurement procedure:

1. Strength Measurements

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 H:

MANIPULATION PROTOCOL

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) Loss of extension

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.

APPENDIX I:

LETTER OF PERMISSION FROM DENIS JACKSON

APPENDIX J:

QUOTE FROM DENIS JACKSON FOR THE USE OF THE CYBEX.

APPENDIX L

NORMATIVE REFERENCE RANGE FOR TORQUE RATIOS OF THE ROTATOR CUFF MUSCLES

APPENDIX K

CONTRAINDICATIONS TO ISOKINETIC MUSCLE TESTING:

Absolute

- Non United fractures to the limb
- Epilepsy
- Cardiac insufficiency
- Severe peripheral vascular disease
- Aneurysm
- Anticoagulants
- Recent (less than 3 months) of chemotherapy
- Long term steroid use (more than three months)
- Acute (less than 7 days) muscle/ligament tear (more than grade 1)
- Pregnancy
- Severe osteoporosis
- Malignancy in the area to be tested

Relative

- Pain
- Severe limited range of motion
- Effusions
- Soft tissue or bone healing