THE EFFECT OF A CHIROPRACTIC ADJUSTMENT WITH A RESISTANCE TRAINING PROTOCOL, COMPARED TO A CHIROPRACTIC ADJUSTMENT OR RESISTANCE TRAINING PROTOCOL ALONE, ON NECK STRENGTH IN CERVICAL FACET SYNDROME

A research dissertation presented to the Faculty of Health Sciences, University of Johannesburg, in partial fulfilment for the Masters Degree in Technology, Chiropractic by:

Kate Dawn Kelly

(Student number: 200507122)

Supervisor: ______________________ Date:___________________

Dr C. Yelverton

CANDIDATES DECLARATION

I, Kate Kelly, declare that this dissertation is my own, unaided work. It is being submitted as partial fulfilment for the Masters Degree in Technology, in the program of Chiropractic, at the University of Johannesburg. It has not been submitted for any or examination in any other Technicon or University.

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Kate Dawn Kelly

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ID number 8610170013088

Student number 200507122 enrolled student for the

Qualification Masters of Technology Chiropractic

Faculty of Health Sciences

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DEDICATION

To my parents, Martin and Jenni.

Pops, you have always inspired me with your passion and dedication to your work. You are an incredible role model. I hope that as I become the second Dr Kelly, I can do your name proud!

Mommy, thank you for your endless support, guidance, encouragement and love! You are always by my side and in my heart pushing me to achieve all that I can. You are my belt, I could not have done any of this without you.

I am where I am and who I am because of you both. You have always allowed me to and facilitated me in chasing my dreams. For this, words cannot express how grateful I am. I love you.

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To my friends and soon to be colleagues, we did it because we had each other. Good luck as we move forward!

To Dr Yelverton, my supervisor, thank you for your guidance and support.

To all those who participated in this study, thank you for giving of your time.

ABSTRACT

Aim: The aim of this study was to determine if a chiropractic adjustment had an effect on muscle strength. The study then aimed to compare the effects a resistance training protocol, to a chiropractic adjustment, to a combination of these two treatments on the neck strength of individuals with cervical facet syndrome.

Method: This study consisted of three groups of 10 participants each. The participants were grouped by stratified sampling to balance the groups in terms of age and gender. The participants ranged in age from 22 to 28 years. There were 18 male and 12 female participants. Participants were examined and accepted into the trail according to inclusion and exclusion criteria. Treatment was allocated according to groupings. Group 1 received a resistance training protocol, group 2 received chiropractic adjustment only and group 3 received a combination of both treatments.

Procedure: Treatment consisted of 6 treatment sessions and a 7th follow up session, over a three week period. Participants in group 1 and 3 were instructed to perform the demonstrated resistance training protocol 3 times a week for 3 weeks. Participants in group 2 and 3 received chiropractic adjustments to hypomobile cervical spine segments, twice a week for three weeks. Cervical range of motion (CROM) was mesured using a CROM device and strength readings were measured using a hand held isometric dynamometer. Measurements were recorded on the 1st, 4th and 7th visits. All participants were required to fill in a Vernon-Mior Neck Disability Index (NDI) on the 1st and 7th visits. The data collected was analysed by a statistician.

Results: Analysis of the Vernon-Mior NDI intra-group results showed that all three groups were effective in reducing cervical pain and disability. There was no statistical difference in improvement between the groups. CROM results indicated that all three groups successfully increased cervical range of motion. The combination group had the greatest improvement, followed by the adjustment group and lastly the resistance training group. The combination group showed statistical improvements in all ranges of motion at visit 4 while this was only achieved by the resistance training group at visit 7. In the adjustment group statistical changes in flexion, extension and lateral flexion were only noted at visit 7, however in rotation, statistical improvements were noted at visit 4. Isometric dynamometer analysis showed that all 3 groups did show a statistically significant increase in cervical muscle strength. The combination group provided the greatest gains, followed by the adjustment group. The smallest gains were seen in the resistance training group. Statistical changes in the resistance training group were only measured at visit 7, while in the combination and adjustment group, these changes were noted by visit 4.

Conclusion: Chiropractic adjustment was effective in increasing neck strength. Of the 3 groups, the combination treatment proved to be the most effective method of improving neck strength in individuals with cervical facet syndrome. Of the two individual treatments, chiropractic adjustment was more effective in terms of both strength gains and time taken to achieve these results, than the resistance training protocol.

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Chapter 1

1.1 Introduction

Neck pain is a commonly occurring problem within the adult population. There are many causes for neck pain and muscular weakness is known to be a major one of these (Goel, 1993).

When the body is functioning optimally, skeletal muscles have a stabilizing effect on the joints (Goel, 1993). Skeletal muscle is innervated by large, myelinated peripheral nerve fibres. These fibres originate in the spinal column and interact with the skeletal muscle fibres at the neuromuscular junction (Guyton and Hall, 1997).

The quality of the nervous innervations to the skeletal muscle is what determines the efficiency of the contraction of that muscle. If the nervous innervations to the muscle is disrupted or interrupted, contractile signals are not received by the skeletal muscle fibres. Contractile signals are necessary for the muscle to maintain normal function and strength. Without these signals, or with interrupted signals, the muscle may show signs of weakness or atrophy in as little as 2 weeks (Guyton and Hall, 1997). Pollard and Ward (1996) have shown that there is evidence that manual adjustment therapy does have a substantial effect on the functioning of the nervous system. There have also been linkes drawn between the vertebral subluxation complex and the hyper excitability of muscle fibres (Pickar and Budgell, 2001).

Manual adjustment therapy, performed by a chiropractor, is known to be an effective method of treating neck pain (Walker, Boyles, Young, Strunce, Garber, Whitman, Deyle, Wainner, 2008). Recently, researchers have started to investigate the neurophysiologic and biomechanical effects of manual adjustment therapy on muscle strength. Manual adjustment therapy stimulates the Golgi tendon organs and muscle spindle afferent nerves. This increases the inflow of sensory information to the central nervous system and thus causes the increase in biomechanical function

(Pickar, 2002). Inhibition of presynaptic nocioceptive afferents have also been noted, which lead to mediation of pain perceived by the central nervous system as well as inhibition of hypertonic muscles (Colloca, Keller, Grunsburg, Vandepute and Fuhr, 2000). Together these effects lead to improved functional ability of the muscle as a whole.

Mortani and De Vries (1979) noted that the initial strength gain that we notice in muscles in the first three weeks of resistance training is as a result of neural factors. Strength gained later in the training regime is bolstered by muscle hypertrophy. Muscle hypertrophy is only evident after a minimum of three weeks of resistance training. In this study, the participants perform the resistance training for three weeks only so as to eliminate muscle hypertrophy as a possible cause of an increase in muscle strength.

1.2 Aims of the Study

The aim of this study was to determine if a chiropractic adjustment had an effect on muscle strength. The study then aimed to compare the effects a resistance training protocol, to the chiropractic adjustment to a combination of these two treatments on the neck strength of individuals with cervical facet syndrome.

1.3 Benefits of the Study

The benefit of this study is that it may allow us to determine the most effective treatment protocol in increasing strength of the cervical muscles. It may also allow us to determine if a chiropractic adjustment delivered to a patient with cervical facet syndrome does in fact have an impact on the firing capacity of spinal nerves, there by offering greater insight into the full effect of the adjustment on the neurological innervation of related skeletal muscle.

The study may also allow us to determine the most time efficient treatment for muscle strength gain, which is vital in the rehabilitation of joint and muscle injuries.

Chapter 2

2.1 Introduction

This chapter discusses all the relevant existing literature around this trial. In this chapter the reader learns of the anatomy of the cervical region as a whole; including the skeletal, muscular and neurological components. An in depth analysis of the neurological system and its effects on the musculoskeletal system is also given. The researcher presents evidence of the effects of the chiropractic adjustment as well as the effects of isometric and isotonic resistances training on muscles strength. Evidence of the effects of a combination of these two treatment protocols on muscle strength is also provided.

2.2 Anatomy of the Cervical Spine

The cervical spine is made up of 7 cervical vertebrae and the intervertebral discs that connect them. It articulates with the skull at the cranial end and the thoracic spine at the caudal end. The vertebrae of this region are the smallest and thinnest of the spine as they bear less weight than those of the thoracic and lumbar regions. The cervical spine allows the greatest and most diverse range of motion in the spine, due to the thinner intervertebral discs and almost directly horizontal plane of the articulating facets (Moore and Dalley 2006).

2.2.1 Osseous Anatomy of the Cervical Spine

The cervical spine is composed of 7 cervical vertebrae, which are divided functionally into the upper and lower cervical regions. The upper cervical region is composed of C1 and C2 vertebrae and is known as the craniovertebral region. C3-C7 makes up the lower cervical region (Levangie and Norkin 2005).

A) Lower Cervical Region

The lower cervical region is composed of cervical vertebrae 3-7. C3-C6 are typical cervical vertebrae, while C7 is atypical in its structure as it has adaptations that specifically allow it to articulate with the first thoracic vertebrae inferiorly.

Typical cervical vertebrae (C3-C6), as seen in figure 3.1, have a vertebral body, that is wider laterally than it is anterior to posterior (Levangie and Norkin, 2005). Two thirds of the load transmitted through each vertebra is absorbed by the vertebral body. The superior surface of the body is concave with the superior lateral lips (uncus) of the body elevated to help form this concavity. The inferior surface is convexly curved. These lateral articulations of the vertebral body are known as the uncovertebral joints or joints of Luschka (Clark, Ducker, Dvorak, Garfin, Herkowitz, Levine, Pizzutillo, Sherk, Ullrich and Zeiderman, 1997).

Two pedicles project posterior laterally off each side of the vertebral body and then join with the lamina to form the posterior vertebral arch. This arch, together with the posterior aspect of the vertebral body, forms the spinal canal. The spinal canal is triangular in shape and houses the spinal cord. Each pedicle has a notch, both superiorly and inferiorly which when paired with vertebra above or below it, forms the intervertebral foramen, through which the spinal nerve exits the spinal canal. From the junction of the lamina, the bifid spinous process projects posteriorly (Clark et al, 1997).

At the junction of the pedicle and the laminae is the lateral mass. The lateral mass is formed by the union of the superior and inferior articular processes. The superior articular process (facing superiorly and posteriorly) articulates with the inferior articular process (facing inferiorly and medially) of the vertebra above to form the facet or zygapophyseal joint (Clark et al, 1997).

Off the junction of the pedicle and lamina is a lateral projection, the transverse process. The transverse process has an anterior and a posterior tubercle, which are joined laterally by the lamella. The transverse process joins with the pedicle to form a bony ring, the foramen transversarium. The foramen trasversarium is a distinguishing factor of all cervical vertebrae. These foramina align to create a canal through which the vertebral artery runs (Clark et al, 1997).

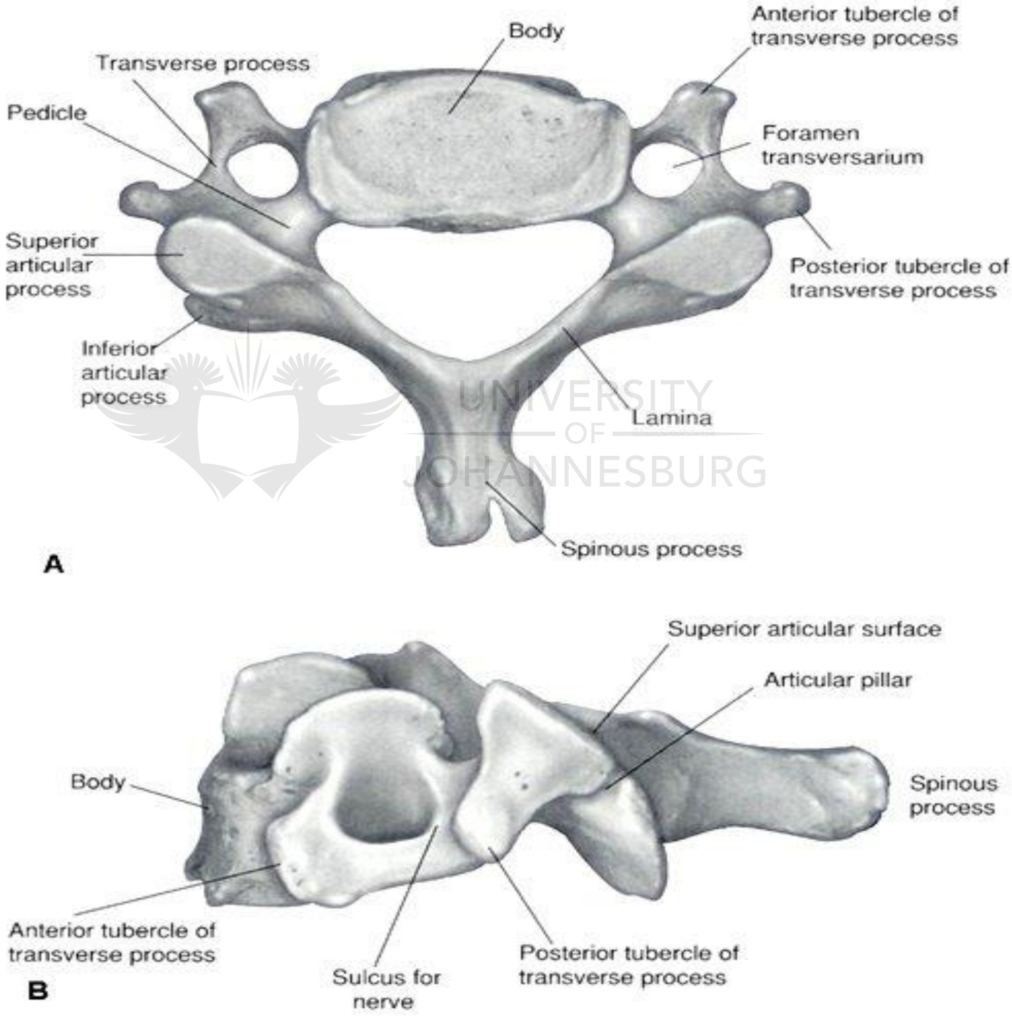


Figure 2.1 Typical Cervical Vertebra

Clarke, C.R. Ducker, T.B. Dvorak, J. Garfin, S.R. Herkowits, H.N. Levine, A.M. Pizzutillo, P.D. Sherk, H.H. Ullrich, C.G. and Zeiderman, S.M. (1998).

The 7th cervical vertebra is the only atypical vertebra in the lower cervical region. It is atypical as it has a longer spinous process, which is not bifid. Instead it has a notch at the posterior end that allows for the attachment of the ligamentum nuchae. C7 does not always have a foramen transversarium (Coetzee, 2004).

B) Upper Cervical Region

C1, the atlas, and C2, the axis, are both atypical cervical vertebra. They have specific structural differences to the typical cervical vertebrae (C3-C6) that allow them more specialized functions.

C1, the atlas, has specific anatomy that allows it to articulate not only with C2 inferiorly but also with the occipital condyles of the cranium superiorly. The atlas has no vertebral body and no spinous process, but is instead composed of an anterior and a posterior vertebral arch which form a bony ring around the spinal cord. At the junction of the anterior and posterior arches are the lateral masses. These lateral masses form large transverse processes to which cervical muscles attach. The lateral masses also form the articular processes of C1, which articulate superiorly with the occipital condyles and inferiorly with superior articulating facets of the C2 (axis). The superior articular facets are kidney shaped and deeply concave. The inferior articular facets are slightly convex in shape. The atlas also has a third articulating process. This is found on the internal margin or the anterior vertebral arch and articulates with the odontoid process of C2 (Levangie and Norkin 2005).

C2, the axis, is also an atypical cervical vertebra. The main function of the atlas is to provide rotation of the head on the neck. This specific function is reflected in the individual structural differences of the atlas. The atypical body of C2 extends inferiorly and not posteriorly. Off the superior border of this body is a vertical projection, the odontoid process. The odontoid process, or dens, articulates anteriorly with the posterior margin of the anterior vertebral arch of the atlas, and posteriorly it articulates with the transverse ligament. The axis has superior and inferior zygapophaseal facets. The superior zygapophyseal facet articulates superiorly with the inferior articulating facet of the atlas. The inferior zygapophyseal facet faces inferiorly and anteriorly and articulates with the superior articulating facet of C3. The axis also has the bifid spinous process and transverse foramen of a typical cervical vertebra (Levangie and Norkin 2005).

2.2.2 Neuro- Anatomy of the Cervical Region

A) The Spinal Cord

The spinal cord is the major neural component of the spine. It is a continuation of the medulla oblongata that exits the skull through the foramen magnum and enters the spinal canal. The spinal cord runs throughout the entire cervical and thoracic spine and terminates at approximately the level of L2 as the cauda equina (Moore and Dalley 2005).

The spinal canal is a bony ring formed by; the posterior border of the vertebral body anteriorly and the lateral and posterior borders are formed by the posterior vertebral arch, composed of the pedicles laterally and the lamina posteriorly. The posterior border is lined by the ligamentum flavum. The lateral borders are pierced by the exiting spinal nerves which leave the spinal canal via the successive intervertebral foramina (Clarke et al, 1997).

The spinal cord itself is composed of an inner, butterfly shaped layer of grey matter, an outer layer of white matter, two ventral nerve roots and two dorsal nerve roots. The two ventral nerve roots exit the spinal cord on the ventral lateral aspect of the cord. Between these two roots, on the anterior aspect of the cord is the anterior median fissure which houses the anterior spinal arteries and veins. On the posterior aspect of the cord is the posterior median sulcus and two posterior lateral sulci. The dorsal nerve roots enter the spinal cord along the posterior lateral sulci at the dorsal root entry zone. The posterior spinal medullary vessels also run along the posterior aspect of the spinal cord (Clark et al, 1997).

The white matter of the spinal cord is composed of nerve fibres and glia of both ascending and descending tracts. The white matter is divided into anterior, posterior and lateral columns. The anterior or ventral columns are composed of the ventral corticospinal, ventral spinothalamic, tectospinal, ventral reticulospinal and vestibulospinal tracts. These tracts play minor roles in pressure and touch sensation and distal limb movement as well as axial and proximal limb movement. The lateral column is composed mainly of the lateral spinothalamic and lateral corticospinal tracts. The lateral spinothalamic tract is responsible for pain and temperature sensations and the lateral corticospinal tract plays the major role in distal limb movement. The posterior column plays the major role in position and vibration sense as well as pressure sensation (Clarke et al, 1997).

The grey matter of the spinal cord is composed of the cell bodies of efferent and interneural neurons. The butterfly of grey matter is divided into anterior and posterior horns. The posterior horn contains the somatosensory neuron while the anterior horn contains the somatomotor neurons. These columns of neurons extend the entire length of the spinal cord (Clark et al, 1997).

B) Spinal Nerves

Before the dorsal root of the spinal cord leaves the spinal canal, it forms an oval shaped enlargement known as the spinal ganglion. After the ganglion, the dorsal root continues laterally and merges with the ventral root to form a spinal nerve. This spinal nerve then enters the intervertebral foramen and exits the spinal canal (Clarke et al, 1997).

The spinal nerve is now known as a mixed spinal nerve as it carries both afferent (from the dorsal root) and efferent (from the ventral root) fibres (Moore and Dalley, 2006). Afferent fibres carry sensory input from the receptors in joints, tendons and muscles as well as from the skin and internal organs. Efferent fibres effect change, in accordance with the sensory input, in their peripheral targets such a skeletal muscle (Clarke et al, 1997). Almost immediately after the spinal nerve is formed and has exited the intervertebral foramen, it splits once again to form the dorsal and ventral primary rami. These nerves too, like the spinal nerve, contain both motor (efferent) and sensory (afferent) fibres. The ventral rami of the cervical spine merge to form 2 plexuses. C1-C4 merge to form the cervical plexus. From this plexus the first 4 cervical nerves are formed. Ventral rami of C5- T1 form the brachial plexus, which gives rise to the remainder of the cervical nerves. Unlike the ventral rami, the posterior rami remain separate and innervate the synovial joints of the spine (corresponding segments) as well as the deep layer of the muscles of the back. The posterior rami also give sensory innervation to the skin (Moore and Dalley, 2006).

Motor and sensory innervation are given to specific regions corresponding to specific spinal levels. Specific areas of skin receiving innervations from a single spinal nerve are known as dermatomes. Specific muscle masses, innervated by single spinal nerves are known as myotomes (Moore and Dalley, 2006).

There are 8 cervical spinal nerves (C1- C8). Each spinal nerve emerges through the intervertebral foramen and, with the exception of C8, is numbered according to the vertebra that forms the inferior part of the intervertebral foramen. C8 emerges from the intervertebral foramen formed by C7 superiorly and T1 inferiorly (Moore and Dalley, 2006).

C) Cervical Plexus

The cervical plexus, shown in figure 3.2, is composed of the ventral rami of C1-C4. The rami of C2-C4 divide into an ascending and descending branch. These branches join with the corresponding branch of the adjacent vertebrae to form a series of loops that make up the cervical plexus. Off these loops come superficial and deep branches (Moore and Dalley, 2006).

The superficial branches of the plexus are cutaneous branches and innervate the skin of the neck, superolateral thoracic wall and a portion of the skin of the scalp. The deep braches are the motor branches of the plexus. These branches form the phrenic nerve, which innervates the diaphragm, as well as forming a secondary loop; the ansa cervicalis (Moore and Dalley, 2006).

The ansa cervicalis is formed by the union of the deep branches of the ventral rami of C2-C3 as well as the ventral ramus of C1. The nerves of the ansa cervicalis give motor innervation to the infrahyoid muscles (Moore and Dalley, 2006).

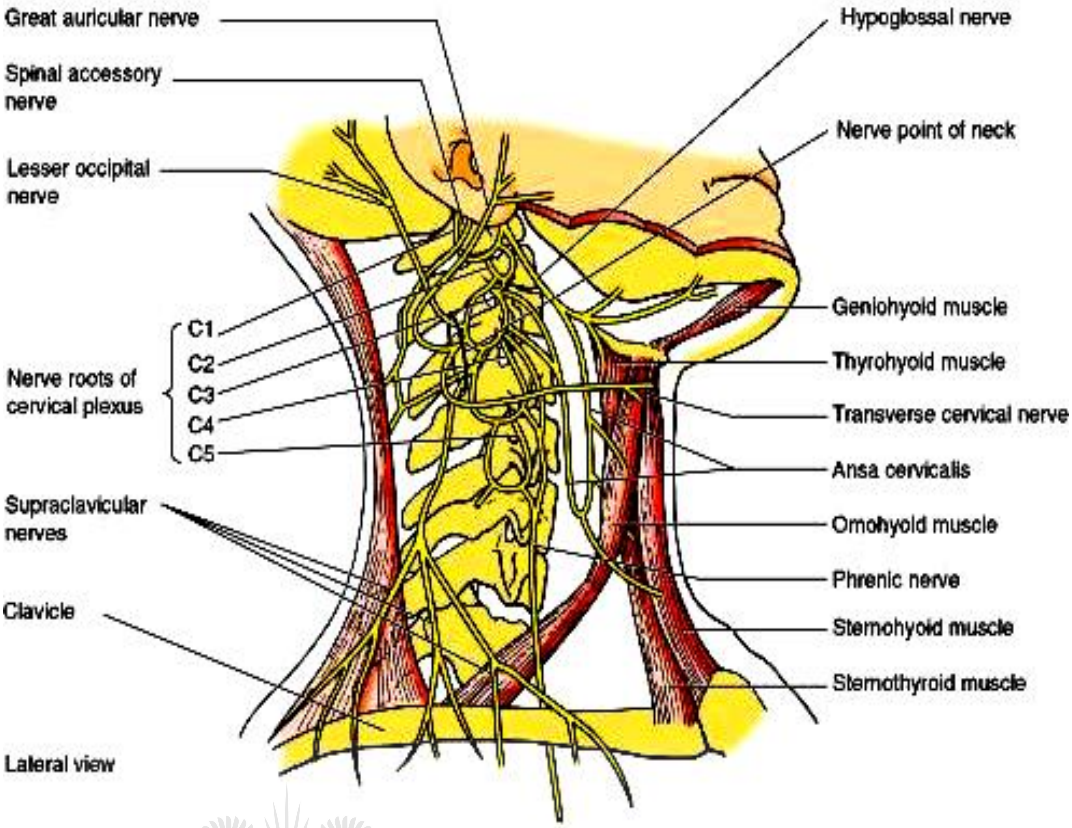


Figure 2.2 The Cervical Plexus of Nerves

Moore, K.L. and Dalley, A.F. (2006).

D) The Brachial Plexus

The brachial plexus is formed by the union of the ventral rami of C5-T1. From this plexus emerge the majority of the nerves of the cervical region. These nerves innervate the most of the muscles of the neck, axilla and upper limb, as well as the thorax (Moore and Dalley, 2006).

The rami of C5-T1 form the roots of the plexus. These roots merge to form three trunks, the superior, inferior and middle trunks. Each of these trunks then splits into an anterior and posterior division. The divisions then merge to form 3 cords. The anterior divisions of the superior and middle trunks merge to form the lateral cord. The anterior division of the inferior cord does not merge but simply continues as the medial cord. All three posterior divisions merge to form the posterior cord (Moore and Dalley, 2006).

The brachial plexus has five terminal branches which are formed by the splitting or merging of the cords. The medial and lateral cords give off a medial and lateral root respectfully, that join to form the median nerve. The median nerve is a terminal branch of the brachial plexus and innervates muscles of the anterior forearm and hand. The remainder of the lateral cord continues to form the musculocutaneous nerve. This is another terminal branch of the plexus and innervates the muscles of the anterior arm and the skin of the lateral forearm. The remaining fibres of the medial cord form the third terminal branch, the ulnar nerve. The ulnar nerve innervates the muscles of the anterior forearm not innervated by the median nerve, as well as the remaining hand muscles. The posterior cord splits to form the last 2 terminal branches, the radial and axillary nerves. The axillary nerve innervates the glenohumeral joint, the deltoid and teres minor muscles as well as the skin of superolateral arm. The radial nerve innervates the muscles of the posterior compartment of the arm and the skin over the posterior and inferolateral arm and forearm and the dorsum of the hand (Moore and Dalley, 2006).

The terminal branches are not the only nerves that branch off the brachial plexus. Many other nerves branch off various parts at various times, such as the long thoracic nerve, which innervates the serratus anterior muscle. These other nerves are; dorsal scapular, suprascapular, subclavian nerve, medial and lateral pectoral, medial cutaneous nerve of the arm and forearm, upper and lower subscapular and the thoracodorsal nerves (Moore and Dalley, 2006).

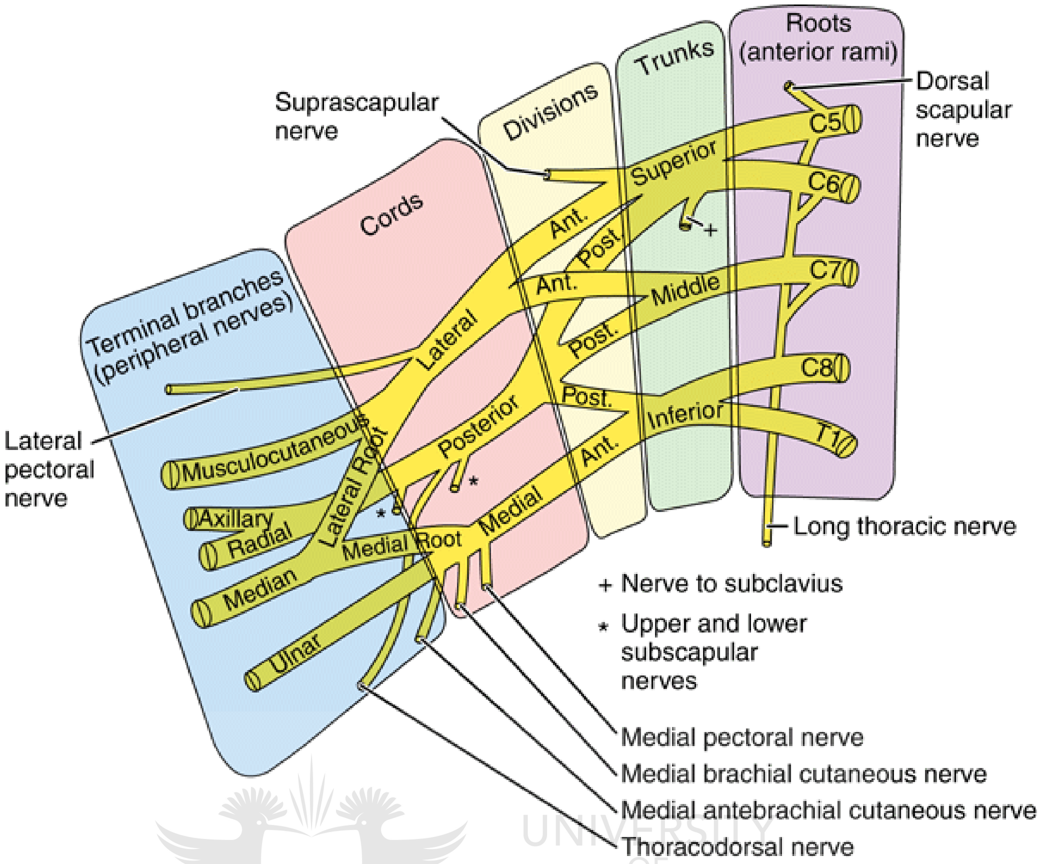


Figure 2.3 The Brachial Plexus

Moore, K.L. and Dalley, A.F. (2006).

2.2.3 Articular Anatomy of the Cervical Spine

The spinal motion segment is the functional motor unit of the cervical spine, and indeed the spine as a whole. Each motion segment is comprised of two adjacent vertebrae and their adjoining intervertebral disc. In the cervical spine we find both typical and the only 2 atypical spinal motion segments of the spine (Gatterman, 2005).

The typical spinal motion segments of the cervical spine extend from C2-C3, to C7-T1. The atypical nature of the atlanto-occipital (C0-C1) and atlanto-axial (C1-C2) joints largely allows for the great range of motion, particularly in rotation, found in the cervical spine. The typical spinal motion segment comprises three joints; the 2 posterior zygapophyseal or facet joints and the intervertebral disc. This is known as the three-joint-complex. The interaction between these three joints is pivotal to movement capabilities of the spine. A disturbance or degeneration in one, will affect the motion of the other 2 joints (Gatterman, 2005).

The rest of the spinal motion segment is formed by the supporting connective and muscular tissues as well as the neurovascular components (Gatterman, 2005).

A)The Intervertebral Disc

The intervertebral disc is a fibrocartilaginous ring composed of 2 parts, the outer annulus fibrosis and the inner nucleus pulposis and forms the articulation between adjacent vertebral bodies (Moore and Dalley, 2006). The disc serves a two-fold purpose as it both unites adjacent vertebral bodies but also, due to viscous tension, holds the vertebral bodies apart (Gatterman, 2005).

The outer portion of the disc, the annulus fibrosis, is composed of concentric rings of fibrocartilaginous lamellae. The annulus inserts onto the epiphyseal rims of the articular surfaces of the vertebrae above and below. The concentric rings of the annulus run obliquely and at right angles to each other to allow for the twisting motion during rotation (Moore and Dalley, 2006).

The viscous nucleus pulposis provides the hydrostatic pressure that allows for the shock absorber functions of the intervertebral disc (Gatterman, 2005). The fluid nature of the muscles also allows for the large range of motion seen in spinal motion segments.

B) Facet Joints

The two posterior joints, the facet or zygapophyseal joints are true synovial joints. These joints are lined by articular cartilage, have a synovial membrane and synovial fluid lining the joint and a joint capsule. The joint capsule is richly innervated by both mechanoreceptors and nociceptors, and as such are a common cause of pain (Gatterman, 2005).

There are three types of mechanoreceptors in joint capsules of synovial joints. These fibres are stimulated by an increase in the tension of the tissue in which they are embedded.

i) Type I Fibres

These mechanoreceptors lie in the outer most layer of the capsule. Type I fibres are static and dynamic mechanoreceptors and have a very low threshold. They respond to very small changes in the tension of the capsule and the frequency of their resting discharge rises proportionately according to the degree of change within the fibres of the capsule (Wyke, 1985).

ii) Type II Fibres

These fibres are embedded deeper in the capsule and have a thicker encapsulation than that of the type I fibres. Type II fibres have a low threshold and are rapidly adapting fibres and have an acceleration effect (Wyke, 1985).

iii) Type III Fibres

Type III fibres are not found in the facet joints. Unlike type I & II fibres, type III fibres are not found in the joint capsule itself but rather the surfaces of the ligaments of other synovial joints. These fibres respond to high tensions in the ligaments of the joints (Wyke, 1985).

The fourth type of receptors found in synovial joints are nociceptors (type IV fibres). They are embedded throughout the thickness of the joint capsule. In normal tissue these receptors will be dormant, however they become active when abnormally high tensions are registered in the joint capsule, or when exposed to noxious chemicals. Activation of these fibres causes pain, which is of particular importance to chiropractors (Wyke, 1985).

The facet joints and motion segments as a whole are supported by both muscles and ligaments which support and give motion to the joints. Limitation of the motion in these segments is due mainly to the orientation of the articulating surfaces of the superior and inferior facets (Gatterman, 2005).

2.3 Skeletal Muscle

2.3.1 Anatomy of Skeletal Muscle

Skeletal muscle is a unique type of muscle as it is under voluntary control. It is composed mainly of muscle cells but also contains blood vessels, nerve fibres and connective tissue. As the name suggests, skeletal muscle attaches to bones. It extends across one and sometimes two joints and is responsible for generating movement in the body (Marieb, 2001).

Skeletal muscle has alternating light and dark strands which give the muscle a striated appearance. These striations lie perpendicular to the long axis of the muscle and are clearly visible under a microscope. Muscle fibres are long and cylindrical in shape and are multinucleated. The nuclei are located on the periphery of the muscle fibre (Marieb, 2001).

Each muscle fibre contains hundreds to thousands of myofibrils that run parallel to each other. These myofibrils are densely packed together and surrounded by a plasma membrane known as the sarcolemma, as seen in figure 2.4. These myofibrils are the contractile elements of skeletal muscle (Marieb, 2001).

The myofibril is further made up of myofilaments. These are thin threadlike units that contain the contractile proteins of the muscle. Within skeletal muscle there are two such proteins; thick myosin filaments and thin actin filaments. Actin is composed of two further proteins; troponin and tropomyosin, which play an important role in muscle contraction (Powers and Howley, 1994).

Each myofilament can be further divided into a series of individual contractile units, or sarcomeres (Figure 2.4). A sarcomere is bounded on either side by a Z- line which anchors the myofilaments and joins adjacent sarcomeres. Each sarcomere has a dark A band (myosin filaments) and a light I band (Actin filament). The central myosin fibres extend only the length of the A band, giving it its dark appearance. The actin filaments run the entire length of the sarcomere, except for in the middle, the H-Zone. The H- zone is only present in relaxed muscles. When the muscle contracts, the actin filaments pull together and overlap which eliminates this H-zone (Marieb, 2001).

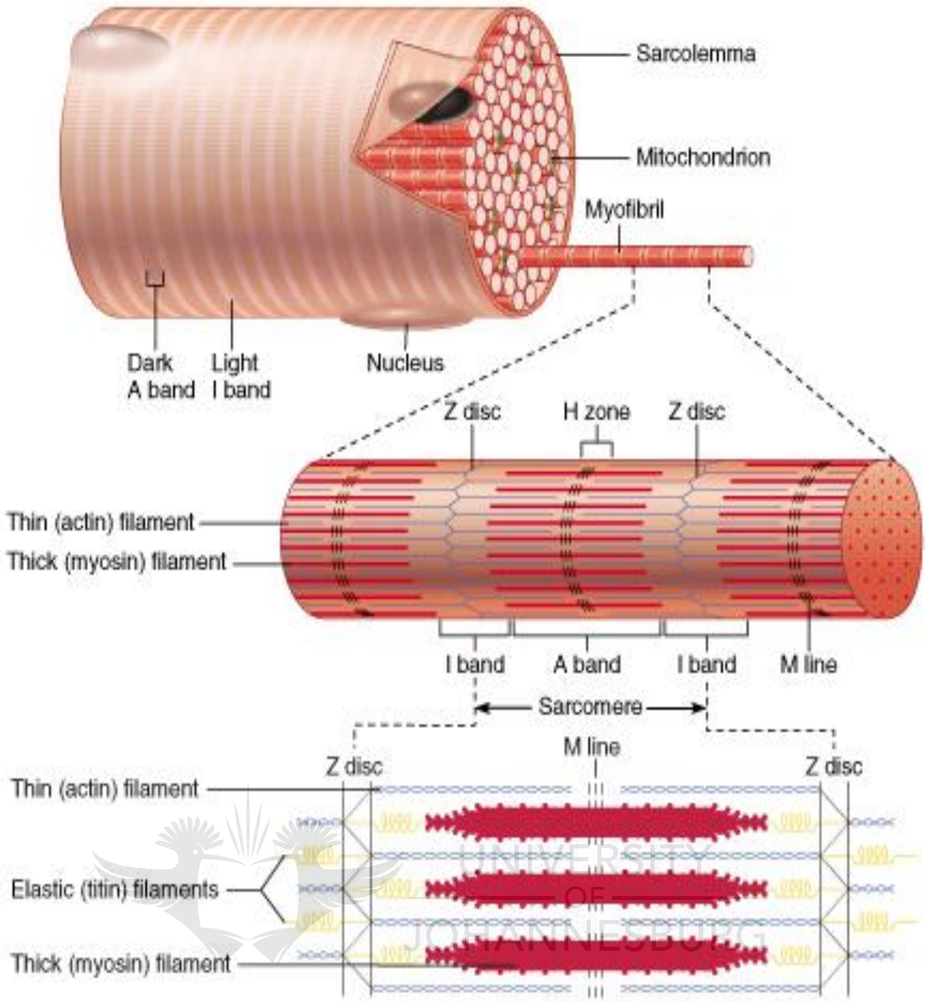


Figure 2.4 Microscopic Anatomy of a Skeletal Muscle Fibre

Marieb, E.N. (2001).

2.3.2 Neuromuscular Junction

Every muscle cell receives innervation from a nerve fibre branching off a motor neuron. The motor neuron causes excitation within the muscle cells and initiates contraction of that muscle. The motor neuron, all its branching nerve fibres and the muscle cells they innervate are known as a contractile unit (Powers and Howley, 1994).

Nervous stimulus is delivered to the muscle at the neuromuscular junction. The neuromuscular junction is the point at which the nerve fibre and muscle cell meet. Muscle spindles are sensory receptors found within the muscle belly that detect changes in muscle length and tension and supply proprioceptive information to the central nervous system. Muscle spindles are also a part of the contractile unit of muscle. Muscles respond to nervous stimulation delivered at the neuromuscular junction and a wave of excitation causes muscle contraction (Marieb, 2001).

Somatosensory information from skeletal muscle travels to the central nervous system (CNS) via four types of afferent nerve fibres. Type I and II afferents are large diameter, myelinated fibres. Type III and IV afferents have a smaller diameter. Type III fibres are myelinated, while type IV are the only unmyelinated afferent fibres. Type III and IV afferents are responsible for up to 60% of the sensory innervation to skeletal muscle and joints (Leach, 2004).

Skeletal muscle also receives efferent innervation, which is delivered to the muscle spindle via two types of efferent fibres, Alpha-motorneurons and Gamma-motorneurons. Alpha-motorneurons are myelinated fibres which innervate the large, force producing, extrafusal muscle fibres. Gamma-motorneurons are also myelinated however, their innervation is to the intrafusal fibres of the muscle spindle. The gamma-motorneurons control the sensitivity of the muscle spindle to stretch (Leach, 2004).

A)Type I and II Afferent Fibres

Type I fibres are further divided into group Ia, primary muscle spindle afferents, and Ib, Golgi tendon organ afferents. Group Ia afferents respond to muscle stretch. Depending on the rate and magnitude of change recorded in the muscle spindle, these fibres signal either a phasic or tonic response respectively. Ia afferents are inhibited by muscle contraction when gamma-motoneuron discharge is absent. Group Ib afferents respond to muscle tension. These fibres are found at the musculotendinous junction and are activated by low levels of force during muscle contraction. Both the muscle spindles (Ia) and Golgi tendon organs (Ib) act together to monitor the mechanical state of skeletal muscle. When working in unison, muscle spindles and Golgi tendon organs regulate the ratio of muscle tension change to muscle length change, thereby regulating muscle stiffness (Leach, 2004).

Type II fibres are composed mainly of secondary muscle spindles and behave very similarly to type Ia fibres. Both fibres respond to muscle stretch and are inhibited by muscle contraction in the absence of gamma-motorneuron efferent impulses. However, type II fibres only have tonic effects; they respond only to changes in muscle length and not to the rate of this change. Nonmuscle spindle type II fibres also innervate skeletal muscle, joints and skin and are mediated by Ruffini-like end organs and Pacinian corpuscles (Leach, 2004).

B)Type III and IV Afferent Fibres

Type III and IV afferents respond very similarly to both chemical and mechanical stimulus and produce similar responses. As a result of this, these fibres will be discussed together. However, it is important to note that these fibres can and do act independently of each other. Some groups of these fibres respond only to mechanical or chemical stimulation, whereas others respond to both. The exact functioning of these fibres independently is not well documented in the human vertebral column, and as a result varied responses to electrical and chemical stimulation tests have been recorded (Leach, 2004).

It is known that sensory input to the CNS from type III and IV afferents can activate a reflex loop involving alpha-motorneurons. Chemical stimulation of type III and IV afferents in the triceps surae muscle, by inflammatory and muscle fatigue agents, resulted in an increased discharge of gamma-motorneuron efferents. This increase in gamma-motorneuron discharge leads to an increased sensitivity to stretch within the muscle spindles, which in turn results in joint protection as well as altered movement and posture (Leach, 2004).

2.4 Muscles of the Cervical Spine

The cervical region is divided anatomically into 4 regions; the anterior, posterior, lateral and sternocleidomastiod regions. These regions are separated by the trapezius and sternocleidomastoid muscles which are usually large and easily visible (Moore and Dalley, 2006).

2.4.1 Anterior Cervical Region

The anterior cervical region is bordered superiorly by the inferior border of the mandible, inferiorly by the sternal notch of the manubrium and posteriorly by the anterior border of the sternocleidomastoid (SCM). There are many small muscles that lie in this region and are concerned mainly with the stabilization and movement of the hyoid bone. There are no muscles in this region that are concerned with the movement of the cervical spine (Moore and Dalley, 2006).

2.4.2 Sternocleidomastoid Region

The sternocleidomastoid (SCM) is an important anatomical landmark in the cervical region as a whole. It is usually easily visible and demarcates the line between the anterior and lateral regions of the neck. The SCM region is the region that overlies the bulk of the muscle. The SCM is the only muscle that falls in this region. It is a broad strap-like muscle that has two heads, the sternal head and the clavicular head (Moore and Dalley, 2006).

Both heads have a common attachment superiorly, to the mastoid process and superior nuchal line. From this common point the two heads separate and have separate distal attachments. The sternal head attaches to the anterior surface of the manubrium of the sternum. The clavicular head attaches to the superior surface of the middle third of the clavicle. The innervation of the SCM comes both from spinal and cranial nerves. The spinal accessory nerve (Cranial Nerve XI) gives motor innervation where as the sensory innervations (pain and proprioception) is given by C2 and C3 (Moore and Dalley, 2006).

The movement generated by the SCM is dependent on whether it contracts unilaterally or bilaterally. If it contracts unilaterally it will bring about lateral flexion and rotation to the side of contraction. When the SCM contracts bilaterally it brings about flexion of the cervical spine and can also cause extension at the atlanto-occipital joints (Moore and Dalley, 2006).

2.4.3 Lateral Cervical Region

The lateral cervical region lies between the posterior border of the SCM and the anterior border of the trapezius muscle. Although four muscles contribute to the floor of this region, none of the muscles in this region are responsible for or contribute to gross cervical spine movement (Moore and Dalley, 2006).

2.4.4 Posterior Cervical Region

The posterior cervical region is that which is posterior to the anterior border of the trapezius. The trapezius muscle is a large muscle that covers the neck and posterior thorax. As it covers such a large area and has differently orientated fibres in different parts of the muscle, the trapezius is involved not only in the cervical region and its movement, but also in the pectoral girdle (Moore and Dalley, 2006).

The trapezius attaches superiorly at the superior nuchal line and ligament as well as the posterior occipital protuberance. It extends attachments to the spinous processes of C7- T12 and even lower in some people. The distal attachment of the trapezius is to the clavicle, spine of scapula and acromion. As with the SCM, the trapezius has dual innervation with motor coming from CN XI and the pain and proprioception from C2- C3 (Moore and Dalley, 2006).

There are many actions of the trapezius depending on where and how it contracts. Bilateral contraction, with fixed shoulders (not when lifting shoulders) produces cervical spine extension. When unilateral contraction occurs, the movement produces lateral flexion to the side of contraction (Moore and Dalley, 2006).

The splenius muscle is part of the superficial layer of intrinsic back muscles. This muscle is divided into two parts, the splenius capitus and splenius cervicis. The splenius muscle originates from the nuchal ligament and spinous processes of C7-T4. The insertion of this muscle is different for the two portions of the muscle. The splenius capitus runs superolaterally from its origin, to attach to the mastoid process and lateral third of the nuchal line. The splenius cervicis attaches to the tubercles and transverse processes of C1-C4. Innervation to these muscles is from the posterior rami C1-T4. Unilateral contraction of the splenius muscles results in lateral flexion and rotation of the head to the side of contraction. Bilateral contraction leads to extension of the cervical spine (Moore and Dalley, 2006).

The deep layer of intrinsic back muscles comprises the semispinalis, multifidus and rotatores muscles. These muscles are all innervated by the posterior rami of the spinal nerves of the spinal segments that they correlate to (Moore and Dalley, 2006).

This semispinalis, like the splenius is divided into different portions, semispinalis capitus, cervicis and thoracis. This muscle originates on the transverse processes of C4-T12. The muscle fibres run superomedially, spanning 4-6 spinal segments, and attach to the above spinous processes and the occiput. The action of the semispinalis is to extend the cervical and thoracic regions when contracting bilaterally and to rotate when contracting unilaterally (Moore and Dalley, 2006).

The multifidus originates on the posterior sacrum, posterior superior iliac spine, aponeurosis of the erector spinae, sacroiliac ligaments, mammillary processes of the lumbar vertebrae, transverse processes of the thoracic vertebrae and articular processes of C4-C7. The fibres then run supermedially, spanning 2-4 spinal segments and attach to the above spinous processes. The main action of the multifidus muscles is to stabilize the spine during movement (Moore and Dalley, 2006).

The rotatores muscles arise from the transverse processes of the lumbar, thoracic and cervical vertebrae. They attach to the junction of the lamina with the spinous or transverse process of the vertebrae 1 or 2 levels superior to its origin. The rotatores act to stabilize the spine during movement, extend the spine when contracting bilaterally and rotate the spine when acting unilaterally. Rotatores also has a proprioceptive roll (Moore and Dalley, 2006).

2.5 The Vertebral Subluxation Complex

The vertebral subluxation complex (VSC) has long been regarded as the science of chiropractic. Chiropractic subluxation differs vastly from a medical subluxation. Lantz (1995) defined a chiropractic subluxation as a motion segment in which the alignment, movement integrity, and or indeed the physiologic function are altered, although contact between the joint surfaces remains intact.

Initially, chiropractors postulated that subluxation caused an osseous impingement on the spinal nerve root as it exited the intervertebral foramen. This impingement was believed to interfere with the normal functioning capacity of the spinal nerve. Other theories suggested that the interference was caused by muscles impinging blood vessels which then also resulted in pain and dysfunction. Today chiropractors work off the VSC. The VSC is a model that incorporates all aspects into the dysfunction. When a joint complex is dysfunctional, all tissues are involved to such an extent that it is often impossible to determine where the effect of one tissue ends and the next begins. It is from this complex framework that the basis of chiropractic care is built (Lantz, 1995).

Subluxation of a spinal motion segment will result in a restricted range of motion in one or more movements of the spine. The movements are; flexion, extension, right and left lateral flexion, right and left rotation and long-axis distraction. Although there are many aspects to the VSC, at the apex of the model is kinesiological dysfunction. Hypomobility, or joint restriction, is the primary form of kinesiopathpology. The aim of a chiropractic adjustment is to restore a dysfunctional spinal motion segment to normal motion (Lantz, 1995).

The four tissue components of the VSC fall directly below kinesiopathology. These four components are; myopathology, neuropathology, vascular pathology and connective tissue pathology, as shown in figure 2.5. This organization suggests that normal motion is brought on by the muscles, controlled by nervous stimulation and guided and limited by ligaments and other connective tissue structures. It also highlights the importance of the vascular system in nutrition of the joint and also the role it plays in the inflammatory process. It is important to note that interference in the normal functioning of any one of these four factors will lead to kinesiopathology (Lantz, 1995).

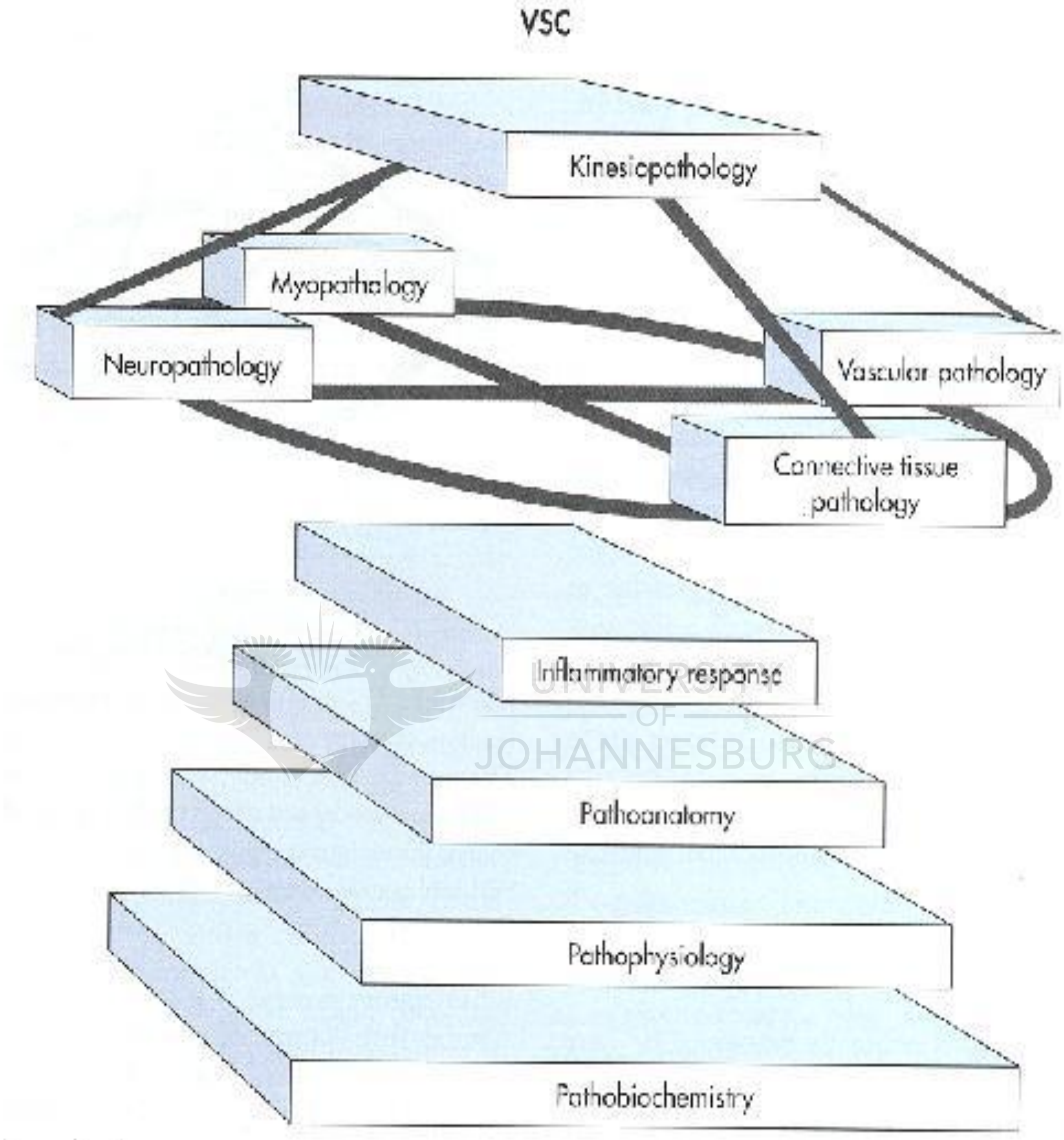


Figure 2.5 The Vertebral Subluxation Complex

Lantz, C.A. (1995).

2.5.1 Kinesiopathology

According to chiropractic principles, the primary form of kinesiopathology is hypomobility. The term immobilization degeneration is used to describe a pattern of degeneration that occurs in all joint tissues as a result of immobilization or restriction. Therefore restricted or fixated spinal motion segments will lead to degeneration. By restoring normal joint motion, using a chiropractic adjustment, normal joint function and physiology may be restored to the motion segment. The degenerative effects of the restriction can potentially be completely reversed, this is however dependant on the duration and extent of the restriction (Lantz, 1995).

2.5.2 Myopathology

When a joint is immobilized the surrounding muscles undergo disuse atrophy. This leads to functional imbalances within the muscles, such as tightening and shortening. As with joint degeneration, the muscle imbalances can be reversed by restoring motion (Seaman, 1997).

Morphological, biomechanical and physiological changes are seen in muscle spindles as a result of immobilization. These changes include degeneration of the muscle spindle endings, shortening and thickening of the spindles, inflammation of the capsules and even the loss of striations in the muscle. The physiological effects of these alterations are; an increased rate of resting discharge and an increased sensitivity to stretch in the muscle spindles. This increase in activity of the spindles gives excessive neurological feedback to the central nervous system and as a result the muscle becomes over stimulated (Lantz, 1995). Over stimulation may lead to muscle spasms and the development of trigger points as well as the reflex inhibition of the muscle. Reflex inhibition of the muscles leaves the joint vulnerable to damage as the muscles do not respond adequately to challenge and as such the stability of the joint is compromised (Lantz, 1995).

2.5.3 Neuropathology

The neurologic component of the VSC is of great importance in this study. The chiropractic adjustment not only restores motion to the motion segment, but also stimulates the nervous tissue in and around that joint. This has an effect not only on the joint neurology but also any other tissues or organs that receive innervation from that spinal nerve root (Lantz, 1995).

Immobility due to subluxation of a spinal motion segment may lead to compression of the spinal nerve roots and segmental nerves. Compression of the nervous tissues leads to decreased functionality and firing capacity of these structures. Decreased muscle strength, diminished reflexes, loss of sensation and pain sensitivity are the primary indicators of decreased neurological function (Lantz, 1995).

2.5.4 Connective Tissue Component

Immobilization leads to the formation of adhesions between adjacent connective tissue structures (Thaxter, Mann and Anderson, 1965). By restoring motion to a joint these adhesions are disrupted. Different connective tissues undergo specific changes as a result of immobilization. Synovial membranes undergo fibrous fatty consolidation which produces a more adherent connective tissue. Cartilage begins to shrink when immobilized. This causes the cartilage to become softer and as such is more prone to injury (Lantz, 1995).

2.5.5 Vascular Component

Each spinal nerve root has a segmental artery and vein that runs along side it and as such, these vascular components are subject to the same compression as the nerves. Immobilization leads to venous stasis. This stasis creates a negative pressure in this region of immobilization and leads to retrograde venous flow. Stasis diminishes the ability of the venous system to remove metabolic toxins from the area of immobilization, which in turn leads to inflammation (Lantz, 1995).

2.6 Cervical Facet Syndrome

Cervical facet syndrome is characterized by head, neck and even shoulder pain. The pain usually does not follow a dermatomal pattern and is dull or aching in nature (Freedman, Overton, Saulina and Holding, 2008). A study has estimated that 39% of non-surgical neck pain patients are suffering from facet joint related symptoms (Manchikanti, Manchikanti, Pampati, Brandon and Giordano, 2008).

2.6.1 Definition of Cervical Facet Syndrome

Facet syndrome is described as being pain or dysfunction that arises from the zygapophyseal or facet joints, as well as from the surrounding soft tissues (Gatterman, 2004). The characteristic features of cervical facet syndrome are neck pain and a decreased range of cervical motion (Bovim, Schrader and Sand, 1994).

2.6.2 Aetiology of Cervical Facet Syndrome

Gatterman (2004) suggests that there are three main causes of facet syndrome; direct trauma, overuse and mechanical defects. Hypomobility of the cervical spine will lead to adaptive changes in all joint structures; the facet joint, intervertebral discs, muscles and ligaments.

A)Direct Trauma

Direct trauma to the facet joints will result in inflammation within the joint, causing acute pain. Inflammation and pain lead to immobilization of the joint. As discussed before, immobilization causes adhesions between adjacent connective tissue structures. The inflammatory process brings about repair. Once the repair process is complete, these fibrous adhesions within the joint become scar tissue (Gatterman, 2005).

B)Overuse

The cervical spine is a highly mobile region of the body. It is involved not only in every motion that involves head movement and positioning, but also plays a major role in maintaining posture. It has been suggested that the average person moves their neck 600 times per hour (Boden, Wiesels and Borenstein, 1996).

Overuse related cervical facet syndrome is usually of insidious and gradual onset. It is often related to incorrect posture that leads to cumulative microtrauma to all structures of the spinal motion segment (Fuhr, Colloca, Green and Keller, 1997). Movements that occur within the normal range of motion may become harmful or damaging when performed in the incorrect posture (Dreyer and Boden, 1998).

C)Mechanical Factors

There are two facet joints in any normal spinal motion segment. If a situation arises where there is asymmetry between these 2 joints, the mechanical functionality of the motion segment will be compromised. Intra-articular jamming of the facets may be caused by the entrapment of the synovial membrane or a meniscoid. Both these structures have nociceptive fibres and when entrapped produce noxious stimuli which are delivered to the central nervous system resulting in pain. The entrapment of these structures between the facets interferes with the normal motion and function of the joint (Gatterman, 2005).

2.6.3 Signs and Symptoms of Cervical Facet Syndrome

Cervical facet syndrome is characterized by head, neck and even shoulder pain. The pain usually does not follow a dermatomal pattern and is dull or aching in nature (Freedman et al, 2008). This pain is usually exacerbated by flexion, extension or lateral flexion of the cervical spine (Waldman, 2009)

The clinical features of cervical facet syndrome, as described by Gatterman (2005) are:

- Local and referred pain (referral depends on vertebral level of involvement)
- Abnormal end feel on motion palpation
- Abnormal soft tissue resistance
- Pain on palpation over affected segments, both static and motion palpation

Many patients suffer from associated muscle spasms and trigger points in the associated musculature.

2.7 Chiropractic Adjustment

As previously discussed, any form of immobilization will result in degeneration of the involved joint (Lantz, 1995). The chiropractic adjustment is aimed at hypomobile joints, with the aim of restoring normal joint motion and function (Gatterman, 1990).

2.7.1 Definition of a Chiropractic Adjustment

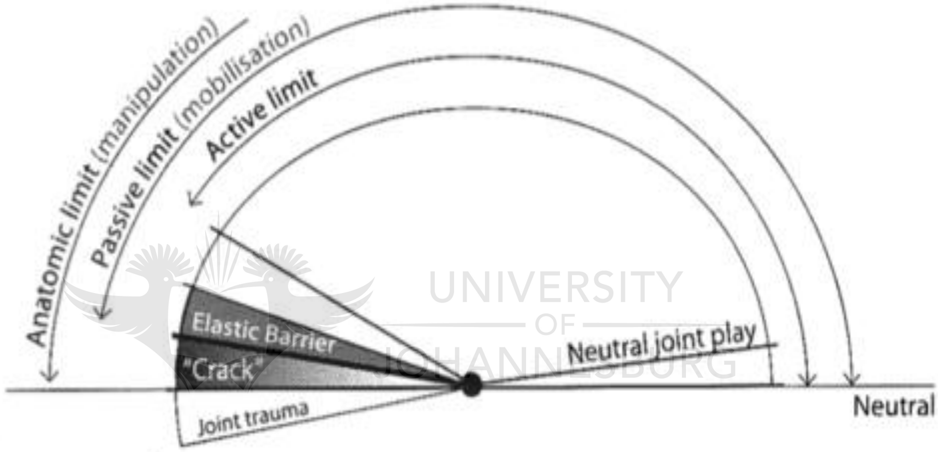
A chiropractic adjustment uses specific short levers combined with a high velocity thrust of controlled amplitude, with the aim of restoring normal mobility to individual articulations. The adjustment or manipulation is a manual procedure that involves thrusting into a joint such that it moves past the physiologic range of motion but does not exceed the anatomic limit of motion (Gatterman, 1990).

According to Sandoz (1976) there are four zones of movement and two barriers (Figure 2.6). These zones are:

- Zone one: Active range of motion. This is controlled by active muscles.
- Zone two: Passive range of motion. This is controlled by an external force. When examining a patient, a chiropractor should be able to move the joint slightly beyond the active range of motion. This extents the joint into the first of the two barriers, which is the elastic

barrier of resistance. In doing this the chiropractor is able to assess joint play.

- Zone three: Paraphysiological space. This zone lies between the two limits, the elastic barrier of resistance and the anatomic limit of integrity. It is when a joint is moved into this space that a joint cavitation occurs.
- Zone four: Joint trauma. If movement extends into this region, it has moved beyond the limit of anatomical integrity of that joint and damage will occur (Esposito and Philipson, 2005).



Neutral joint play	Can occur through whole of active range.
Active limit	End of active range.
Passive limit	End of passive range
Elastic Barrier	Variable range at end of passive range. Joint play occurs here.
Paraphysiological Space	Joint cavitation occurs here ("Crack").
Anatomic limit	Limit of anatomical integrity.
Joint trauma	Ligamentous damage occurs.

Figure 2.6 Joint Ranges of Motion

Esposito, S. Philipson, S. (2005).

The chiropractic adjustment moves the joint beyond the elastic barrier of resistance and into the paraphysiological joint space. Here there are three events that occur that constitute the adjustment.

1. A sudden separation of joint surfaces
2. An audible cracking or popping sound
3. Appearance of a radiolucent space in the joint, evident on radiograph

(Esposito and Philipson, 2005).

2.7.2 Reflexogenic Effects of the Chiropractic Adjustment

Spinal structures, including muscle, ligaments, facet joints, discs and peripheral skin, are highly innervated by multiple sensory receptors. The theory of chiropractic is that the chiropractic subluxation is considered an aberrant relation between spinal structures. This aberrant relation is believed to stimulate the sensory receptors in the paraspinal tissues. This results in impulses to the neural reflex centers of the spinal cord which lead to somato-visceral as well as somato-motor responses, which may lead to muscle spasm (Haldeman, 2000). This response may be stimulated by the application of a chiropractic adjustment (Smith and Cox, 2000).

Post adjustment, skeletal muscle exhibits a change in both its tone and the properties of its stretch reflexes. This can be attributed to articular mechanoreceptors exerting co-ordinated reflexogenic responses, involving both the inhibition and facilitation of motor unit activity (Wyke, 1985).

2.7.3 Neurologic Effects of the Chiropractic Adjustment

A chiropractic adjustment is proposed to activate both proprioceptors and mechanoreceptors in the related spinal structures. As a result of this stimulation, afferent impulses are altered resulting in increased motorneuron excitability (Suter, McMorland, Hertzog and Bray, 1999).

Gamma motorneuron activity will be increased in muscles of restricted vertebral segments. Impaired joint mobility allows the myostatic stretch reflex to detect minor changes in muscle length. The impulses generated in the muscle spindle in response to the chiropractic adjustment, reduce the increased activity of the gamma motorneuron loop. Colloca, Keller, Gunsburg, Vandeputte and Fuhr (2000), proposed that the adjustment increases joint mobility by producing a barrage of impulses to the muscle spindle efferents, thereby decreasing the activity of facilitated gamma motorneurons (Colloca et al, 2000).

Electromyography (EMG) was used to examine 20 segmentally related muscles of upper cervical joints with restricted motion. He noted spontaneous myoelectric activity in these muscles while normally muscle does have spontaneous activity at rest. Immediately following chiropractic adjustment, this spontaneous activity ceased. From this, it was concluded that correction of the vertebral subluxation complex, by chiropractic adjustment, has a normalizing affect on the central nervous system by modifying the afferent input from joint receptors (Gatterman, 2005).

Dvorak (1985), proposed a model whereby the vertebral subluxation complex creates both mechanical and chemical stimulation which activate nociceptors and the spinothalamic tract. According to this model the VSC results in both articular pain and reflex muscular changes. In the case of muscles of the cervical spine, the muscles contract in response to the VSC. Resultant increased muscle spindle activity leads to increased firing of Ia fibres (gamma-motorneurons), leading to further muscle contraction (Leach, 2004).

2.8 Effects of Chiropractic Adjustment on Muscle Strength

According to Smith and Cox (2000), correction of a restricted spinal motion segment will promote normal joint and muscle function by enhancing neurological integrity. Chiropractic adjustment reduces neurological interference at the involved spinal level. By reducing interference within the nervous system, it allows muscles associated to that spinal level to fully express their functional ability and as such display an improvement in strength. Table 2.1 shows some of the clinical and experimental effects regarding vertebral subluxation (Smith and Cox, 2000).

Table 2.1: Clinical and Experimental Effects of the Vertebral Subluxation Complex (Smith, D.L. and Cox, R.H. 2000).

Clinical Effects	**Experimental Effects**
Disturbance in blood flow Tissue inflammation Neurological dysfunction (<-100 mmHg pressure)	Change of impulse propagation Interneural oedema with subsequent intra-neural fibrosis Increased microvascular permeability of endoneurial capillaries
Loss of nerve function (sensory deficit and/ or muscle weakness) (100- 200 mmHg pressure)	Deformation of nerve fibres Displacement of Nodes of Ranvier Invagination of paranodal myelin sheaths Blockage of axonal transport

The compression subluxation theory was originally thought to be caused by compression of the spinal nerves as they pass through the intervertebral foramen (IVF). However, the IVF is not the only site at which this compression may occur. Factors such as facet joint degeneration, posterior vertebral body, disc protrusions and pressure produced by inflammation of the superior pedicle of the IVF are now also considered as causes for compression subluxation. It has also been noted that the dorsal root of the spinal nerve seems to be more sensitive to pressure than the ventral root or spinal nerve (Smith and Cox, 2000).

According to Patterson (1993), neurological interference of a spinal level and the resultant inflammation in the related region can lead to and maintain hyper-excitability in the spinal cord. This hyper- excitability can cause interference in normal muscle function. This has been referred to as a facilitated segment. A facilitated segment produces a positive feedback gamma-motor loop, which can lead to muscle spasm and pain (Mootz, 1995).

Wilmore and Costill (1999) define strength as "the maximal force that a muscle or muscle group can generate". Williams and Bannister (1995) state that "strength is usually measured on intact subjects in tasks that require the participation of several muscles; it is then as much an expression of the skilful activation and co-ordination of these muscles as it is a measure of the forces that they contribute individually. Thus it is possible to increase without a concomitant increase in the true force generating capacities of the muscles involved, especially during early stages of training".

Research by Pickar (2002) has shown a significant link between the muscle spindle and vertebral subluxation complex (VSC). It has been demonstrated that the chiropractic adjustment has the ability to influence the discharge of the muscle spindle, in both type 1 and type 2 afferent fibres. Increases of up to 200 percent have been noted. A change in stimulus this large will have a significant effect on the functionality of a muscle (Pickar, 2002).

Keller and Colloca et al (2000), used surface electromyography (sEMG) to measure the effects of chiropractic adjustment on trunk muscle strength. Their research showed a significant increase in sEMG output, of 21% in 19 of the 20 subjects who received chiropractic adjustment, while no significant improvement was found in the control groups. These results indicate that increased muscle strength is an effect of chiropractic adjustment (Smith and Cox, 2000).

Pollard and Ward (1996), showed an increase in quadriceps muscle strength following chiropractic adjustment. Asymptomatic students received chiropractic adjustments to their lumbar spine while the control group received “sham” adjustments. The control group showed a decrease in strength as a result of fatigue (Smith and Cox, 2000).

Suter, McMorland, Hertzog and Bray (1999), measured muscle activation and inhibition, during isometric contraction, of knee extensor muscles, pre and post adjustment of the sacro-iliac (SI) joint, in patients with knee pain. After the adjustment there was a significant decrease in muscle inhibition of the knee extensors in the painful leg. Increased EMG readings were also noted post-adjustment (Smith and Cox, 2000). This implies that the chiropractic adjustment has a significant effect on the neurological control of muscle activation.

2.9 The Effects of Isotonic and Isometric Neck Exercises on Neck Strength

Research has shown that by strengthening the cervical musculature it is possible to decrease the incidence of cervical pain and disability, as well as improve the functioning of the cervical spine as a whole (Fiebert et al, 2004). Isometric and isotonic exercises are primarily involved in rehabilitation as it involves muscle contraction without movement occurring at the joint (isometric) or without changing muscle tension (isotonic). By doing this we are able to isolate the muscle contraction and activate the neural impulse to this muscle with little strain on the joints or joint surfaces. As a result of this, isometric and isotonic resistance training exercises have been recommended as part of the rehabilitation of athletes with neck injuries (Fiebert et al, 2004).

Research conducted by Fiebert et al (2004) showed that a control group who did not receive these resistance training exercises exhibited minimal, if any changes to their neck strength over the course of the 4-week clinical trial. The changes ranged from an increase in cervical muscle strength of 6,6%, to a decrease of 6%. In comparison, the experimental group, who used the same resistance training protocol as is used in the trial, reported increases in cervical muscle strength of 20-29%.

The resistance training program used in this clinical trial used only gravity and the weight of the patient's head as resistance. The cervical musculature contracts isotonically during the lifting of the head from its resting position, against gravity. This is followed by isometric contraction to hold the head in this lifted position (Fiebert et al, 2004).

During these exercises, the muscle is overloaded in order to promote a catabolic response. This catabolic response results in the slight disruption of muscle fibres. The muscle adapts to this by synthesizing new myofibrillar proteins. The increased myofibril size and numbers leads to an increased cross-sectional area, a phenomenon known as muscle hypertrophy. Hypertrophy allows the muscle to withstand higher loads and therefore increases strength. Muscle hypertrophy is specific to the type of resistance training used (Kilmer, 1998).

Muscle hypertrophy is known as the primary reason for muscle strength gains in long- term training. However, according to Mortani and De Vries (1979), a minimum of three to six weeks of resistance training is necessary before muscle hypertrophy occurs. Strength gains prior to this occur without structural changes to the muscle and can therefore be attributed to neural adaptations, such as more efficient motor unit recruitment (Kilmer, 1998).

2.10 Conclusion

It is known that resistance training can improve muscle strength. According to chiropractic literature, some of the many benefits of chiropractic adjustment are restoring normal motion and reducing spinal cord hyperexcitability. It is postulated that the muscle hyperexcitability leads to abnormal physiologic responses, including diminished muscle functional capability and strength. If chiropractic adjustment can reduce or remove this hyper-excitable state, it would allow for optimal functioning of that muscle (Pollard and Ward, 1996).

As explored in this chapter, it is evident that muscle strength is complex. It does not depend solely on the muscle fibres themselves, but also on the ability of the nervous system, both central and peripheral, to activate the involved muscle. By training these muscles, greater and more efficient muscle activation may be achieved (Poole, 1991).

Chapter 3

3.1 Introduction

This chapter describes the methods by which this research was conducted. It explains not only how the data was collected but also the equipment used to do so. This chapter will cover all research methodology; from how and why patients were selected, to group selection, to the process of data collection.

3.2 Study Design

This study was a comparative experimental design.

3.3 Participant Recruitment

Participants were selected from patients at the University of Johannesburg Chiropractic Clinic. Potential participants were those who were over the age of 18 and were suffering from neck pain at the time. These potential participants were approached by the researcher who briefly described the research to them and asked if they would be interested in participating. The researcher explained in detail the purpose and process of the research as well as what would be expected of the participant for the duration of the trial. Any questions or concerns from the participant were then addressed. The participant was then asked to sign an information and consent form (Appendix A). Once this was signed, the researcher began her assessment process, which included a case history (Appendix B), full physical (Appendix C) and cervical spine regional examination (Appendix D).

3.3.1 Inclusion Criteria

In order to be accepted into this clinical trial, the participant was required to meet certain inclusion criteria. These were:

- Must be over the age of 18, the average age of skeletal maturity

- Must have cervical facet syndrome at the time of trail. Diagnostic criteria include:
    - A positive local Kemps sign (Fuhr , Colloca, Green and Keller 1997)
    - Decreased range of motion, particularly in lateral flexion and rotation to the side of inflammation (Fuhr, Colloca, Green and Keller 1997)

3.3.2 Exclusion Criteria

If any of the following were present in the potential participant, they were excluded from the trial:

- Must not display any of the contra-indications to spinal manipulative therapy (Appendix E)

- Neurological or radicular symptoms

- Any pre-existing contraindications to resistance training. These include:
    - Neck injuries such as whiplash
    - Cervical muscle strains
    - Cervical ligament sprains

- Undergoing any supplementary treatment to the cervical region during the course of the clinical trial. This includes:
    - Anti-inflammatory drugs
    - Analgesics
    - Any other manual therapies.

3.3.3 Group Allocation

Once deemed to meet the inclusion and exclusion criteria the 30 participants were divided into 3 groups of 10 participants. This was done by using stratified sampling according to age and gender, in order to balance the groups.

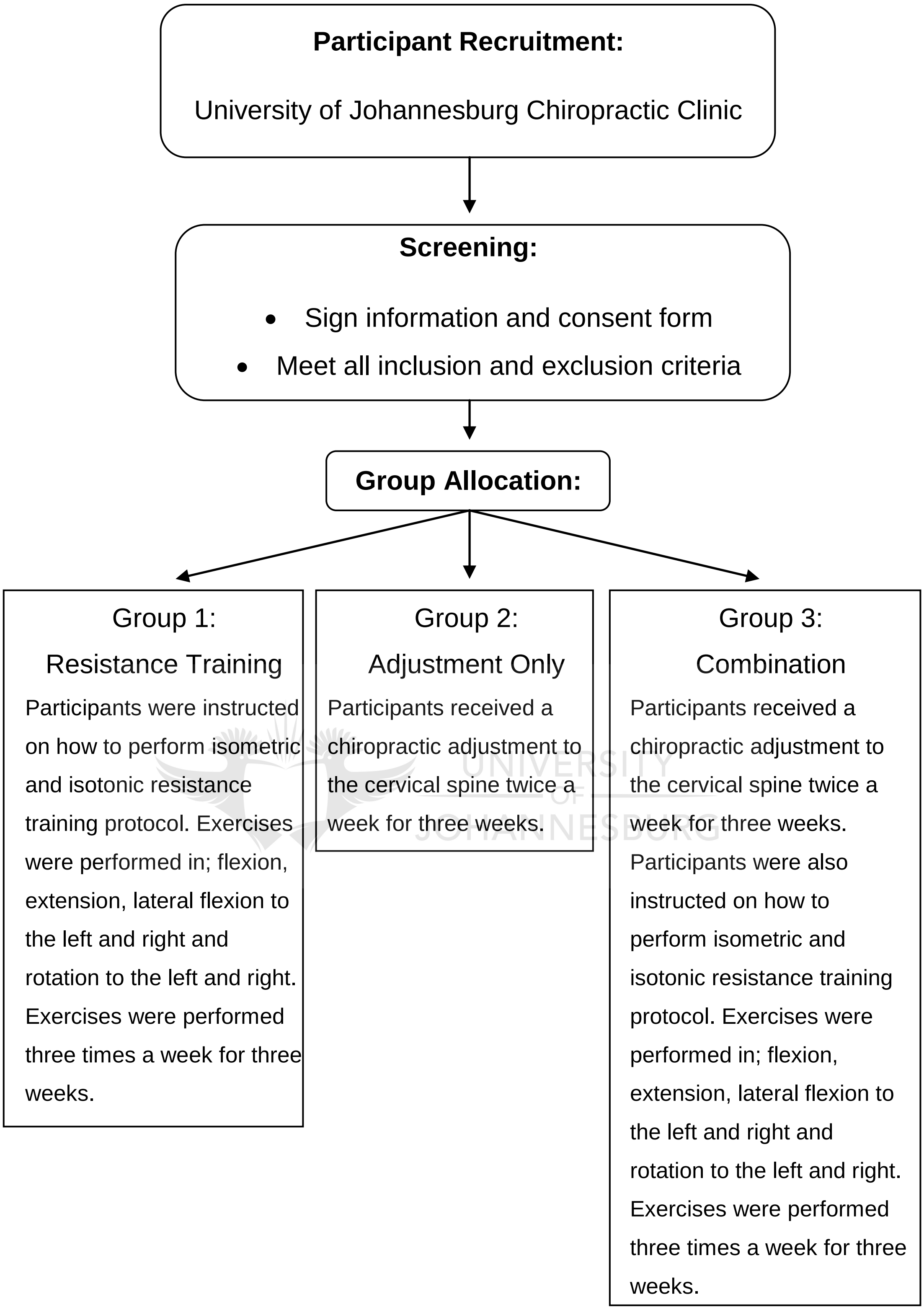


Figure 3.1 Schematic Representation of Methodology

3.4 Methodology

The participants were placed into three groups of ten participants in each. The groups were; group 1 – received the resistance training protocol alone, group 2 – received a cervical spine adjustment alone and group 3 – received a combination of the resistance protocol and a cervical spine adjustment (figure 3.1).

On the first visit, after the case history, full physical and cervical regional examination were completed, the participants were measured in terms of their cervical range of motion (using a CROM Devise), and in terms of their neck strength (using a hand held Isometric Dynamometer). Both the CROM and dynamometer readings were taken in all six ranges of motion; flexion, extension, right and left lateral flexion and right and left rotation. Participants were then asked to complete a Vernon-Mior Neck Disability Index (Appendix F).

3.4.1 Group 1

After having CROM and dynamometer readings taken, participants in group 1 were motion palpated for restrictions of the cervical spine. Any restrictions were noted. The researcher then demonstrated the resistance training protocol (Figure 3.1) to the participant and then asked the participant to perform the exercises themselves in order to ensure the exercises were being performed correctly.

Resistance Training Protocol

Participants were instructed to perform the isometric and isotonic exercises 10 times in each range of motion, three times per week. The exercises consisted of the participant lying down moving the head in each range of motion, against gravity (isotonic). At the end of the range of movement the participant was instructed to hold the contraction (isometric) for three seconds before repeating (Fiebert et al, 2004).

Flexion

Participants were positioned supine with their head resting on a pillow, arms resting at their sides, legs straight and uncrossed. They would then lift their head off the bed as far as possible and then hold that position for three seconds (Figure 3.2). Participants were given strict instructions to use only their neck muscles to lift the head and not to engage their core muscles in the process. This isolates the contraction to the neck flexors.

Extension

Participants were positioned prone, with a pillow placed under their abdomen for support and their forehead resting on their hands. They were then instructed to lift their head off their hands as far as possible and then hold that position for three seconds (figure 3.2).

Participants were instructed not to arch their backs while doing this, so as to isolate the contraction to the neck extensors.

Lateral Flexion

Participants were positioned on their side, legs bent slightly for stability and their head resting on a pillow. They were then instructed to lift their head off the pillow, as far as possible and then hold this position for three seconds (figure 3.2). This was done both on the left and right sides. Participants were instructed not to use their abdominal obliques while doing this, so as to isolate the contraction to the lateral flexors of the neck.

Rotation

Participants were positioned supine, heads resting on a pillow and arms resting at their sides, legs straight and uncrossed. They were instructed to turn their head to one side, while the head was resting on the pillow. From this position they were instructed to lift their head off the pillow as far as possible and hold this position for three seconds (figure 3.2). This was done with the head rotated both to the left and right. Participants were instructed not to engage their core muscles while doing this, so as to isolate the contraction to the muscles of neck rotation.

Flexion

Extension

Lateral flexion

Rotation

Figure 3.2 Isotonic and Isometric Resistance Training Protocol

Fiebert et al (2004).

Participants in group 1 were seen once a week for three weeks (total of three visits). On each visit they were motion palpated and had their CROM and dynamometer readings taken. All readings were recorded on the data collection form (Appendix G). Participants were also asked to complete a Vernon-Mior Neck Disability Index (Appendix F) on the initial and final visits.

3.4.2 Group 2

Participants placed in group 2 received chiropractic adjustments to their cervical spine. After having their CROM and dynamometer readings taken, the participants were motion palpated for restrictions of the cervical spine. The restrictions were noted and a chiropractic adjustment was delivered to the restricted segments.

Chiropractic Adjustment

Participants were adjusted using a supine, index contact on the restricted segment.

Participant position: Lying supine with their head resting on a pillow.

Doctor position: Standing at the head of the bed, facing inferiorly.

Contact: Index finger contact on the articular process of the listed vertebra and induces lateral flexion over this point.

Indifferent hand: Cups the occiput and rotates the head slightly.

Line of drive: Chiropractor thrusts in the line of the facets.

(Esposito and Philipson, 2005).

Participants in group 2 were seen twice a week for three weeks (total of 7 visits). They were adjusted in every session, bar visit 7, as visit 7 was only for the final readings to be taken. CROM and dynamometer readings were taken on visits 1, 4 & 7. All readings were recorded on the data collection form (Appendix G). Participants were also asked to complete a Vernon-Mior Neck Disability Index (Appendix F) on the initial and final visits.

3.4.3 Group 3

Participants in group 3 received a combination of chiropractic adjustment and a resistance training protocol. After having their CROM and dynamometer readings taken, the participants were motion palpated for any restrictions of the cervical spine. The restrictions were noted and a chiropractic adjustment was delivered to the restricted segments.

Chiropractic Adjustment

Participants were adjusted using a supine, index contact delivered to the restricted segment.

Participant position: Lying supine with their head resting on a pillow.

Doctor position: Standing at the head of the bed, facing inferiorly.

Contact: Index finger contact on the articular process of the listed vertebra and induces lateral flexion over this point.

Indifferent hand: Cups the occiput and rotates the head slightly.

Line of drive: Chiropractor thrusts in the line of the facets.

(Esposito and Philipson, 2005).

After the adjustment was delivered the researcher then demonstrated the resistance training protocol (Figure 3.2) to the participant and then asked the participant to perform the exercises themselves in order to ensure the exercises were being performed correctly. Participants were instructed to perform the isometric and isotonic exercises 10 times in each range of motion, three times per week.

Resistance Training Protocol

Flexion

Participants were positioned supine with their head resting on a pillow, arms resting at their sides, legs straight and uncrossed. They would then lift their head off the bed as far as possible and then hold that position for three seconds (Figure 3.2). Participants were given strict instructions to use only their neck muscles to lift the head and not to engage their core muscles in the process so as to isolate the contraction to the neck flexors.

Extension

Participants were positioned prone, with a pillow placed under their abdomen for support and their forehead resting on their hands. They were then instructed to lift their head off their hands as far as possible and then hold that position for three seconds (figure 3.2). Participants were instructed not to arch their backs while doing this, so as to isolate the contraction to the neck extensors.

Lateral Flexion

Participants were positioned on their side, legs bent slightly for stability and their head resting on a pillow. They were then instructed to lift their head off the pillow, as far as possible and then hold this position for three seconds (figure 3.2). This was done both on the left and right sides. Participants were instructed not to use their abdominal obliques while doing this, so as to isolate the contraction to the lateral flexors of the neck.

Rotation

Participants were positioned supine, heads resting on a pillow and arms resting at their sides, legs straight and uncrossed. They were instructed to turn their head to one side, while the head was resting on the pillow. From this position they were instructed to lift their head off the pillow as far as possible and hold this position for three seconds (figure 3.2). This was done with the head rotated both to the left and right. Participants were instructed not to engage their core muscles while doing this, so as to isolate the contraction to the muscles of neck rotation.

Participants in group 3 were seen twice a week for three weeks (total of 7 visits). They were adjusted and performed the resistance training protocol in every session, bar visit 7, as visit 7 was only for the final readings to be taken. CROM and dynamometer readings were taken on visits 1, 4 & 7. All readings were recorded on the data collection form (Appendix G).

Participants were also asked to complete a Vernon-Mior Neck Disability Index (Appendix F) on the initial and final visits.

3.5 Objective Data

Objective measurements of the participant's cervical range of motion were obtained using a Cervical Range of Motion Device (CROM). Objective measurements for the participant's neck strength in flexion, extension, right and left lateral flexion and right and left rotation were measured using a hand held isometric dynamometer.

3.5.1 CROM Devise

The CROM device is an instrument used to accurately measure cervical movement by combining inclinometers and magnets. This pairing eliminates positioning and tracking errors. The inclinometers are attached to the frame which is fastened onto the head using Velcro straps. There are two fixed inclinometers; one in the sagittal plane to measure flexion and extension and one in the frontal plane to measure lateral flexion. A third, detachable inclinometer is found in the horizontal plane, to measure rotation. It is the third inclinometer that makes use of the magnets (Tousignant, de Bellefeuille, O' Donoghue and Grahovac, 2000).

Participants were seated and the CROM was place on their nose as with a pair of glasses and fastened in position using the Velcro straps. A magnetic brace was then fastened around the participant's neck. Participants then moved their heads through flexion, extension, right and left lateral flexion ranges of motion (sagittal and frontal planes). In these planes of motion, the inclinometer needle is gravity dependant (Tousignant et al, 2000). Readings were recorded after each movement on the data collection form (Appendix G).

The third inclinometer was then added to the CROM device in order to obtain rotation readings (horizontal plane). The needle on this inclinometer is magnetic. The inclinometer was zeroed, using the magnets, for accurate measurement (Tousignant et al, 2000). The participant then moved their head through left and right rotation ranges of motion. Readings were recorded after each movement on the data collection form (Appendix G).

The CROM devise has been shown to be both valid and reliable in measuring cervical range of motion (Audette et al, 2010).

3.5.2 Isometric Dynamometer

Participants were seated on a chiropractic bed, comfortably and with their arms resting on their lap. Participants were instructed to use only their necks when pressing into the devise and not to use their arms or legs for greater force. The researcher then explained the process of how the data would be collected.

The participants were instructed to move their head slightly into the direction that was being measured (eg: forward flexion). Using the break test technique, the dynamometer was set to zero and gently placed against the participant's forehead. The participant was instructed to push their head into the device with their full force and hold this contraction for three seconds. No movement was allowed in this motion so as to insure isometric contraction. The researcher applied force against the participant's contraction to prevent movement (Fabrication Enterprises Inc.).

The position of contact between the dynamometer and the participants head varied according to which motion was being tested. For forward flexion, the dynamometer was placed on the participant's forehead. For extension, it was place on the participant's occipital region. For lateral flexion it was placed on the temple and for rotation it was place slightly above and in front of the ear (Baseline, 2012).

A study by Sullivan et al (1998) has shown this instrument to be an accurate and reliable measure of muscle strength.

3.6 Subjective Data

The Vernon-Mior neck disability index was used to measure the participant subjective data. This was a measure of how the participant perceived their neck pain before and after treatment. The questionnaire asks a series of questions pertaining to how the participant's neck pain affects their daily living. The participants filled in this questionnaire on the first and final visits (Appendix F).

There were ten questions in the questionnaire, each with 5 possible answers. Each question was scored out of 5 and the total score of all questions was then tallied. This final score was used to determine the degree of disability the participant perceives him/ herself to have. A score of 0-4 indicated no disability, 4-14 indicated mild disability, 15-24 indicated moderate disability, 25- 34 indicated severe disability and above 34 indicated complete disability. A maximum score of 50 could be obtained and this score was then doubled to obtain the percentage disability of the participant (Vernon and Mior, 1992).

The Vernon-Mior neck disability index has been found to be valid and reliable (Vernon and Mior, 1992).

3.7 Ethical Considerations

All participants that wished to partake in this study were requested to read and sign the information and consent form specific to this study (Appendix A). The information and consent form outlined the name of the researcher, purpose of the study and benefits of partaking in the study, as well as the participant assessment and treatment procedure. Any risks, benefits and discomforts pertaining to the treatments involved were also explained and that the participant's safety was ensured (prevention of harm).

The information and consent form explained that the participant's privacy would be protected as only the doctor, participant and clinician would be in the treatment room and that anonymity would be ensured as the participant information would be converted into data and therefore could not be traced back to the individual. The form also stated that standard doctor/patient confidentiality would be adhered to at all times when compiling the research dissertation.

The participants were informed that their participation was on a voluntary basis and that they were free to withdraw from the study at any stage. If the participant had any further questions, they were answered by the researcher; whose contact details were available.

The participants were then required to sign the information and consent form, signifying that they understood all that was required of them for this particular study. Results of the study were made available on request.

Participants were referred if and when necessary.

3.8 Data Analysis

All the data collected from this trial was analysed by a statistician. The results of both the subjective and objective data were tested for normality using the Shapiro-Wilk test as the groups contained less than 50 people per group. Inter-group analysis was analysed using the Kruskal-Wallis test and intra-group analysis was by means of the Friedman test.

Post-Hoc tests for both inter and intra-group analysis was done by the Mann-Whittney test.

Chapter 4

4.1 Introduction

All the results of this study were statistically analyzed by a statistician. The results used were dynamometer and CROM readings (objective readings), as well as the Vernon-Mior neck disability index (subjective readings). The results of both the subjective and objective data were tested for normality using the Shapiro- Wilk test as the groups contained less than 50 people per group. Intergroup analysis was analysed using the Kruskal- Wallis test and intra-group analysis was by means of the Friedman test. Post-Hoc tests for both inter and intra-group analysis was done by the Mann-Whittney test.

Throughout all tests used by the statistician, a statistical significance value for all data was calculated. A statistically significant result was that which had a p value of less than 0.05 ($P < 0.05$). The closer the p value is to 0.00, the less the probability of the result occurring by chance.

This study comprised of three groups. Statistical analysis was done on inter-group as well as intra-group results. The demographical make up of the groups was also analysed.

4.2 Demographic Analysis

This section deals with the statistical make up of the three groups with regards to age and gender.

4.2.1 Age

The table below indicates the age range of the participants across the three groups.

Table 4.1: Age Range of Participants

	Resistance Training	Adjustment Only	Combination	Total
Minimum Age	22	22	22	22
Maximum Age	27	26	28	28
Mean Age	24.5	23.8	24.6	24.3
Std Deviation	1.780	1.476	2.119	1.784
Asymp Sig				0.628

Table 4.1 indicates that the mean age of the participants in all three groups was 24.3 years, with the minimum age being 22 years and the maximum age 28 years. The standard deviation across all three groups was 1.784 years. Asymp. sig = 0.628, indicating that there was no statistical difference in the mean ages of the three groups (Asymp. sig > 0.05).

4.2.2 Gender

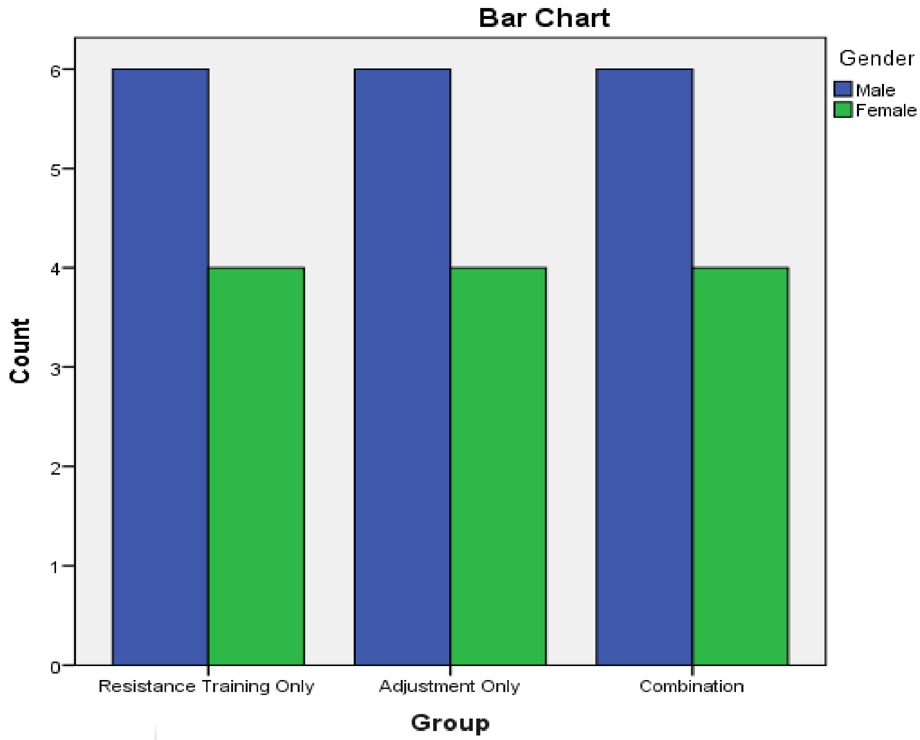


Figure 4.1: A Bar Graph Indicating the Ratio of Males to Females in Each Group

Figure 4.1 illustrates the ratio of males to females in each of the three groups. From this chart it is evident that the three groups had the same ratio of males to females. In each group, resistance training, adjustment only and combination, there were 6 male and 4 female participants.

4.3 Intra-Group Analysis

Non-parametric testing on intra-group results was done using the Friedman test. This test indicated the changes over time within each group.

4.3.1 Intra-Group CROM Results

Table 4.2: Intra-Group Results of CROM Flexion

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	62.20°	64.90°	69.40°	7.20°	0.001
Adjustment Only	68.30°	69.90°	74.60°	6.30°	0.000
Combination	63.60°	69.20°	73.00°	9.40°	0.000

The above table (table 4.2) indicates the intra-group analysis of the CROM readings (degrees) in forward flexion. The resistance training group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 7.20 degrees. This was a statistically significant change as asymp sig = 0.001 ($P < 0.05$).

The adjustment only group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 6.30 degrees. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 9.40 degrees. This was a significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.3: Post-Hoc Testing on CROM Flexion

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.507	0.121	0.007
Visit 1 – 7	0.008	0.004	0.005

Table 4.3 represents the results of post-hoc testing of the CROM flexion intra-group testing. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as asymp sig = 0.008 ($P < 0.05$). From this we deduced that the increase in range of motion in flexion was gained between visits 4 and 7.

In the adjustment only group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as asymp sig = 0.004 ($P < 0.05$). From this we deduced that the increase in range of motion in flexion was gained between visits 4 and 7.

In the combination group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.007 ($P < 0.05$) and visits 1 and 7 as asymp sig = 0.005 ($P < 0.05$). In the combination group, a statistically significant increase in range of motion of flexion was measured throughout the course of treatment.

Table 4.4: Intra-Group Results of CROM Extension

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	56.10°	57.20°	61.40°	5.30°	0.010
Adjustment Only	57.70°	63.00°	66.20°	8.50°	0.002
Combination	63.70°	70.20°	73.40°	9.70°	0.000

The above table (table 4.4) indicates the intra-group analysis of the CROM readings (degrees) in extension. The resistance training group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 5.30 degrees. This was a statistically significant change as asymp sig = 0.010 ($P < 0.05$).

The adjustment only group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 5.50 degrees. This was a statistically significant change as asymp sig = 0.002 ($P < 0.05$).

The combination group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 9.70 degrees. This was a significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.5: Post-Hoc Testing on CROM Extension

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.570	0.102	0.011
Visit 1 – 7	0.027	0.012	0.008

Table 4.5 represents the results of post-hoc testing of the CROM extension intra-group testing. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as asymp sig = 0.027 ($P < 0.05$). From this we deduced that the increase in range of motion in extension was gained between visits 4 and 7.

In the adjustment only group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as asymp sig = 0.004 ($P < 0.05$). From this we deduced that the increase in range of motion in extension was gained between visits 4 and 7.

In the combination group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.011 ($P < 0.05$) and visits 1 and 7 as asymp sig = 0.008 ($P > 0.05$). In the combination group, a statistically significant increase in range of motion of extension was measured throughout the course of treatment.

Table 4.6: Intra-Group Results of CROM Lateral Flexion to the Right

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	47.40°	48.20°	49.60°	2.20°	0.131
Adjustment Only	44.20°	47.70°	52.60°	8.40°	0.000
Combination	45.60°	50.60°	54.80°	9.20°	0.000

The above table (table 4.6) indicates the intra-group analysis of the CROM readings (degrees) in lateral flexion to the right. The resistance training group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 2.20 degrees. This was not a statistically significant change as asymp sig = 0.131 ($P > 0.05$).

The adjustment only group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 8.40 degrees. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 9.20 degrees. This was a significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

<u>Table 4.7: Post-Hoc Testing on CROM Lateral Flexion to the Right</u>

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	-	0.049	0.005
Visit 1 – 7	-	0.005	0.005

Table 4.7 represents the results of post-hoc testing of the CROM lateral flexion to the right intra-group testing. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured in the original testing therefore no post hoc testing was necessary.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.049 ($P < 0.05$). Between visits 1 and 7, the change was also statistically significant as asymp sig = 0.005 ($P < 0.05$). In the adjustment only group, a statistically significant increase in range of motion of lateral flexion to the right was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.005 ($P < 0.05$) and visits 1 and 7 as asymp sig = 0.005 ($P > 0.05$). In the combination group, a statistically significant increase in range of motion of lateral flexion to the right was measured throughout the course of treatment.

<u>Table 4.8: Intra-Group Results of CROM Lateral Flexion to the Left</u>

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	48.00°	45.60°	48.40°	0.40°	0.018
Adjustment Only	46.70°	48.10°	51.80°	5.10°	0.003
Combination	47.80°	52.00°	56.40°	8.60°	0.000

The above table (table 4.8) indicates the intra-group analysis of the CROM readings (degrees) in lateral flexion to the left. The resistance training group showed a decrease in range of motion on visit 4 but an increase in range of motion on visit 7, with a mean increase of 0.40 degrees. This was a statistically significant change as asymp sig = 0.018 ($P < 0.05$).

The adjustment only group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 5.10 degrees. This was a statistically significant change as asymp sig = 0.003 ($P < 0.05$).

The combination group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 8.60 degrees. This was a significant change as asymp sig = 0.000 (P < 0.05).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.9: Post-Hoc Testing on CROM Lateral Flexion to the Left

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.085	0.343	0.007
Visit 1 – 7	0.339	0.058	0.005

Table 4.9 represents the results of post-hoc testing of the CROM lateral flexion to the left intra-group testing. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4 as asymp sig = 0.085 (P > 0.05). Between visits 1 and 7, the change was also not statistically significant as asymp sig = 0.339 (P < 0.05). From this we deduced that there was in fact no statistically significant change in this group.

In the adjustment only group, no statistically significant change was measured between visits 1 and 4 as asymp sig = 0.343 (P >0.05) or visits 1 and 7 as asymp sig = 0.058 (P > 0.05). From this we deduced that there was in fact no statistical change in this group.

In the combination group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.007 (P < 0.05) and visits 1 and 7 as asymp sig = 0.005 (P > 0.05). In the combination group, a statistically significant increase in range of motion of lateral flexion to the left was measured throughout the course of treatment.

Table 4.10: Intra-Group Results of CROM Rotation to the Right

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	65.20°	67.00°	70.90°	5.70°	0.009
Adjustment Only	62.20°	68.40°	73.00°	7.80°	0.000
Combination	58.80°	64.60°	70.80°	12.00°	0.000

The above table (table 4.10) indicates the intra-group analysis of the CROM readings (degrees) in right rotation. The resistance training group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 5.70 degrees. This was a statistically significant change as asymp sig = 0.009 ($P < 0.05$).

The adjustment only group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 7.80 degrees. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 12.00 degrees. This was a significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.11: Post-Hoc Testing on CROM in Rotation to the Right

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.319	0.007	0.005
Visit 1 – 7	0.022	0.005	0.005

Table 4.11 represents the results of post-hoc testing of the CROM right rotation intra-group testing. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as asymp sig = 0.022 ($P < 0.05$). From this we deduce that the increase in range of motion in right rotation was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.007 ($P < 0.05$) and visits 1 and 7 as asymp sig = 0.004 ($P < 0.05$). In the adjustment only group, a statistically significant increase in range of motion of right rotation was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.005 ($P < 0.05$) and visits 1 and 7 as asymp sig = 0.005 ($P > 0.05$). In the combination group, a statistically significant increase in range of motion of right rotation was measured throughout the course of treatment.

Table 4.12: Intra-Group Results of CROM Rotation to the Left

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	65.30°	67.40°	70.80°	5.50°	0.001
Adjustment Only	67.10°	72.40°	73.50°	6.40°	0.002
Combination	63.30°	71.10°	76.00°	12.70°	0.000

The above table (table 4.12) indicates the intra-group analysis of the CROM readings (degrees) in left rotation. The resistance training group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 5.50 degrees. This was a statistically significant change as asymp sig = 0.001 ($P < 0.05$).

The adjustment only group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 6.40 degrees. This was a statistically significant change as asymp sig = 0.002 ($P < 0.05$).

The combination group showed an increase in range of motion on both visits 4 and 7, with a mean increase of 12.70 degrees. This was a significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.13: Post-Hoc Testing on CROM in Rotation to the Left

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.142	0.007	0.005
Visit 1 – 7	0.005	0.025	0.005

Table 4.13 represents the results of post-hoc testing of the CROM left rotation intra-group testing. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as asymp sig = 0.005 (P < 0.05). From this we deduced that the increase in range of motion in left rotation was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.007 (P < 0.05) and visits 1 and 7 as asymp sig = 0.025 (P < 0.05). In the adjustment only group, a statistically significant increase in range of motion of left rotation was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as asymp sig = 0.005 (P < 0.05) and visits 1 and 7 as asymp sig = 0.005 (P > 0.05). In the combination group, a statistically significant increase in range of motion of left rotation was measured throughout the course of treatment.

4.3.2 Intra-Group Isometric Dynamometer Results

Table 4.14 Intra-Group Testing of the Isometric Dynamometer Readings in Flexion

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	6.80kg	7.00kg	8.50kg	1.70kg	0.003
Adjustment Only	8.20kg	9.40kg	10.80kg	2.60kg	0.000
Combination	7.00kg	8.90kg	10.30kg	3.30kg	0.000

The above table (table 4.14) indicates the intra-group analysis of the isometric dynamometer readings (kg) in forward flexion. The resistance training group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 1.70kg. This was a statistically significant change as asymp sig = 0.03 ($P < 0.05$).

The adjustment only group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 2.60kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.30kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

<u>Table 4.15: Post-Hoc Testing on Isometric Dynamometer Results in Flexion</u>

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.589	0.016	0.004
Visit 1 – 7	0.01	0.005	0.005

Table 4.15 represents the results of post-hoc testing of the isometric dynamometer flexion intra-group results. Post-hoc testing was necessary to determine where over time the statistically significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as Asymp sig = 0.010 ($P > 0.05$). From this we deduced that the increase in neck strength in flexion was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.016 (P > 0.05) and visits 1 and 7 as Asymp sig = 0.005 (P > 0.05). In the adjustment only group, a statistically significant increase in neck strength in flexion was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.004 (P > 0.05) and visits 1 and 7 as Asymp sig = 0.005 (P > 0.05). In the combination group, a statistically significant increase in neck strength in flexion was measured throughout the course of treatment.

Table 4.16 Intra-Group Testing of the Isometric Dynamometer Readings in Extension

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	8.80kg	8.40kg	10.30kg	1.50kg	0.001
Adjustment Only	8.60kg	9.90kg	11.90kg	3.30kg	0.000
Combination	7.50kg	9.40kg	11.40kg	3.90kg	0.000

The above table (table 4.16) indicates the intra-group analysis of the isometric dynamometer readings (kg) in extension. The resistance training group showed a decrease in neck strength between visits 1 and 4 and an increase in neck strength between visits 4 and 7, with a mean increase of 1.50kg. This was a statistically significant change as asymp sig = 0.001 (P < 0.05).

The adjustment only group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.30kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.90kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

<u>Table 4.17: Post-Hoc Testing on Isometric Dynamometer Results in Extension</u>

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	1.000	0.010	0.004
Visit 1 – 7	0.004	0.007	0.004

Table 4.17 represents the results of post-hoc testing of the isometric dynamometer extension intra-group results. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as Asymp sig = 0.004 ($P < 0.05$). From this we deduced that the increase in neck strength in extension was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.010 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.007 ($P < 0.05$). In the adjustment only group, a statistically significant increase in neck strength in extension was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.004 (P < 0.05) and visits 1 and 7 as Asymp sig = 0.004 (P < 0.05). In the combination group, a statistically significant increase in neck strength in extension was measured throughout the course of treatment.

Table 4.18 Intra-Group Testing of the Isometric Dynamometer Readings in Right Lateral Flexion

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	6.80kg	7.40kg	7.80kg	1.00kg	0.013
Adjustment Only	7.40kg	8.50kg	10.20kg	2.80kg	0.000
Combination	6.70kg	8.10kg	10.20kg	3.50kg	0.000

The above table (table 4.18) indicates the intra-group analysis of the isometric dynamometer readings (kg) in right lateral flexion. The resistance training group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 1.00kg. This was a statistically significant change as asymp sig = 0.013 (P < 0.05).

The adjustment only group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 2.80kg. This was a statistically significant change as asymp sig = 0.000 (P < 0.05).

The combination group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.50kg. This was a statistically significant change as asymp sig = 0.000 (P < 0.05).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.19: Post-Hoc Testing on Isometric Dynamometer Results in Right Lateral Flexion

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	1.000	0.010	0.004
Visit 1 – 7	0.004	0.007	0.004

Table 4.19 represents the results of post-hoc testing of the isometric dynamometer right lateral flexion intra-group results. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as Asymp sig = 0.004 ($P < 0.05$). From this we deduced that the increase in neck strength in right lateral flexion was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.010 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.007 ($P < 0.05$). In the adjustment only group, a statistically significant increase in neck strength in right lateral flexion was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.004 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.004 ($P < 0.05$). In the combination group, a statistically significant increase in neck strength in right lateral flexion was measured throughout the course of treatment.

Table 4.20 Intra-Group Testing of the Isometric Dynamometer Readings in Left Lateral Flexion

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	6.70kg	7.20kg	7.80kg	1.10kg	0.018
Adjustment Only	7.30kg	8.90kg	10.30kg	3.00kg	0.000
Combination	6.50kg	8.40kg	10.40kg	3.90kg	0.000

The above table (table 4.20) indicates the intra-group analysis of the isometric dynamometer readings (kg) in left lateral flexion. The resistance training group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 1.10kg. This was a statistically significant change as asymp sig = 0.018 ($P < 0.05$).

The adjustment only group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.00kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.90kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.21: Post-Hoc Testing on Isometric Dynamometer Results in Left Lateral Flexion

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.084	0.015	0.016
Visit 1 – 7	0.020	0.007	0.005

Table 4.21 represents the results of post-hoc testing of the isometric dynamometer left lateral flexion intra-group results. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as Asymp sig = 0.020 ($P < 0.05$). From this we deduced that the increase in neck strength in left lateral flexion was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.015 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.007 ($P < 0.05$). In the adjustment only group, a statistically significant increase in neck strength in left lateral flexion was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.016 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.005 ($P < 0.05$). In the combination group, a statistically significant increase in neck strength in left lateral flexion was measured throughout the course of treatment.

Table 4.22 Intra-Group Testing of the Isometric Dynamometer Readings in Right Rotation

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	7.10kg	7.50kg	8.40kg	1.40kg	0.017
Adjustment Only	7.00kg	8.40kg	10.20kg	3.20kg	0.000
Combination	6.60kg	8.50kg	10.20kg	3.60kg	0.000

The above table (table 4.22) indicates the intra-group analysis of the isometric dynamometer readings (kg) in right rotation. The resistance training group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 1.40kg. This was a statistically significant change as asymp sig = 0.017 ($P < 0.05$).

The adjustment only group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.20kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.60kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.23: Post-Hoc Testing on Isometric Dynamometer Results in Right Rotation

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.340	0.010	0.007
Visit 1 – 7	0.016	0.005	0.005

Table 4.23 represents the results of post-hoc testing of the isometric dynamometer right rotation intra-group results. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as Asymp sig = 0.016 ($P < 0.05$). From this we deduced that the increase in neck strength in right rotation was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.010 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.005 ($P < 0.05$). In the adjustment only group, a statistically significant increase in neck strength in right rotation was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.007 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.005 ($P < 0.05$). In the combination group, a statistically significant increase in neck strength in right rotation was measured throughout the course of treatment.

Table 4.24 Intra-Group Testing of the Isometric Dynamometer Readings in Left Rotation

Group	Mean			Mean Change	Asymp. Sig
	Visit 1	Visit 4	Visit 7		
Resistance Training	7.10kg	7.20kg	8.20kg	1.10kg	0.006
Adjustment Only	6.90kg	8.90kg	10.30kg	3.40kg	0.000
Combination	6.50kg	8.40kg	10.60kg	4.10kg	0.000

The above table (table 4.24) indicates the intra-group analysis of the isometric dynamometer readings (kg) in left rotation. The resistance training group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 1.10kg. This was a statistically significant change as asymp sig = 0.006 ($P < 0.05$).

The adjustment only group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 3.40kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

The combination group showed an increase in neck strength on both visits 4 and 7, with a mean increase of 4.10kg. This was a statistically significant change as asymp sig = 0.000 ($P < 0.05$).

Further testing was necessary to determine where in the treatment regimen the change occurred.

Table 4.25: Post-Hoc Testing on Isometric Dynamometer Results in Left Rotation

Pair	Asymp sig		
	Resistance Training	Adjustment Only	Combination
Visit 1 – 4	0.705	0.004	0.004
Visit 1 – 7	0.041	0.005	0.005

Table 4.25 represents the results of post-hoc testing of the isometric dynamometer left rotation intra-group results. Post-hoc testing was necessary to determine where over time the significant change in range of motion was gained.

In the resistance training group, no statistically significant change was measured between visits 1 and 4. However, between visits 1 and 7, the change was statistically significant as Asymp sig = 0.041 ($P < 0.05$). From this we deduced that the increase in neck strength in left rotation was gained between visits 4 and 7.

In the adjustment only group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.004 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.005 ($P < 0.05$). In the adjustment only group, a statistically significant increase in neck strength in left rotation was measured throughout the course of treatment.

In the combination group, a statistically significant change was measured between visits 1 and 4 as Asymp sig = 0.004 ($P < 0.05$) and visits 1 and 7 as Asymp sig = 0.005 ($P < 0.05$). In the combination group, a statistically significant increase in neck strength in left rotation was measured throughout the course of treatment.

4.3.3 Intra-Group Vernon-Mior Neck Disability Index Results

Table 4.26: Intra-Group Results of the Vernon-Mior Neck Disability Index

Visit	Group								
	Resistance Training			Adjustment Only			Combination		
	Mean	Mean Change	Asymp Sig	Mean	Mean Change	Asymp Sig	Mean	Mean Change	Asymp Sig
1	10.40			9.40			10.60		
7	1.50	8.90	0.005	2.40	7.00	0.005	2.10	8.50	0.005

Table 4.26 indicates the results of the intra-group testing on the scores from the Vernon-Mior Neck Disability Index. From this table it is evident that changes occurred within all three groups, between the first and 7th visits. In the resistance training group, a mean change of 8.90 was measured. This change was statistically significant as Asymp sig = 0.005 ($P > 0.05$).

In the adjustment only group, a mean change of 7.00 was measured. This was statistically significant as Asymp sig = 0.005 ($P > 0.05$).

In the combination group, a mean change of 8.50 was measured. This was statistically significant as Asymp sig = 0.005 ($P > 0.05$).

4.4 Inter-Group Analysis

The following tables show the results of the tests for normality between the three groups. Non- parametric testing was done using the Kruskal- Wallis test as there were three groups. These results compare the results of the three groups to each other to determine whether there was a significant change between the groups.

4.4.1 Inter-Group CROM Results

<u>Table 4.27: Inter-Group Analysis of CROM Devise in Flexion</u>

	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	62.20°	68.30°	63.60°	64.70°	0.349
Visit 4	64.90°	69.90°	69.20°	68.00°	0.407
Visit 7	69.40°	74.60°	73.00°	72.33°	0.376
Mean Change	7.20°	6.30°	9.40°		

Table 4.27 indicates the results of the inter-group analysis of CROM flexion readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean CROM readings (degrees) in flexion, between the three groups as asymp sig = 0.349 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean CROM readings (degrees) in flexion, between the three groups as asymp sig = 0.407 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean CROM readings (degrees) in flexion, between the three groups as asymp sig = 0.376 ($P > 0.05$).

No further testing was necessary as no statistically significant change was measured across the three groups.

Table 4.28: Inter-Group Analysis of CROM Devise in Extension

	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	56.10°	57.70°	63.70°	59.17°	0.729
Visit 4	52.70°	63.00°	70.20°	63.47°	0.297
Visit 7	61.40°	66.20°	73.40°	67.00°	0.423
Mean Change	5.30°	8.50°	9.70°		

Table 4.28 indicates the results of the inter-group analysis of CROM extension readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean CROM readings (degrees) in extension, between the three groups as asymp sig = 0.729 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean CROM readings (degrees) in extension, between the three groups as asymp sig = 0.297 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean CROM readings (degrees) in extension, between the three groups as asymp sig = 0.423 (P > 0.05).

No further testing was necessary as no statistically significant change was measured across the three groups.

Table 4.29: Inter-Group Analysis of CROM Devise in Right Lateral Flexion

	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	47.40°	44.20°	45.60°	45.73°	0.726
Visit 4	48.20°	47.70°	50.60°	48.83°	0.909
Visit 7	49.60°	52.60°	54.80°	52.33°	0.565
Mean Change	2.20°	8.40°	9.20°		

Table 4.29 indicates the results of the inter-group analysis of CROM right lateral flexion readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean CROM readings (degrees) in right lateral flexion, between the three groups as asymp sig = 0.726 (P > 0.05).

On visit 4, there was not a statistically significant difference in the mean CROM readings (degrees) in right lateral flexion, between the three groups as asymp sig = 0.909 (P > 0.05).

On visit 7, there was not a statistically significant difference in the mean CROM readings (degrees) in right lateral flexion, between the three groups as asymp sig = 0.565 (P > 0.05).

No further testing was necessary as no statistically significant change was measured across the three groups.

Table 4.30: Inter-Group Analysis of CROM Devise in Left Lateral Flexion

	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	48.00°	46.70°	47.80°	47.50°	0.874
Visit 4	45.60°	48.10°	52.00°	48.57°	0.423
Visit 7	48.40°	51.80°	56.40°	52.20°	0.261
Mean Change	0.40°	5.10°	8.60°		

Table 4.30 indicates the results of the inter-group analysis of CROM left lateral flexion readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean CROM readings (degrees) in left lateral flexion, between the three groups as asymp sig = 0.874 (P > 0.05).

On visit 4, there was not a statistically significant difference in the mean CROM readings (degrees) in left lateral flexion, between the three groups as asymp sig = 0.423 (P > 0.05).

On visit 7, there was not a statistically significant difference in the mean CROM readings (degrees) in left lateral flexion, between the three groups as asymp sig = 0.261 (P > 0.05).

No further testing was necessary as no statistically significant change was measured across the three groups.

Table 4.31: Inter-Group Analysis of CROM Devise in Right Rotation

	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	65.20°	62.20°	58.80°	62.07°	0.389
Visit 4	67.00°	68.40°	64.60°	66.67°	0.446
Visit 7	70.90°	73.00°	70.80°	71.57°	0.868
Mean Change	5.70°	10.80°	12.00°		

Table 4.31 indicates the results of the inter-group analysis of CROM right rotation readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and

combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean CROM readings (degrees) in right rotation, between the three groups as asymp sig = 0.389 (P > 0.05).

On visit 4, there was not a statistically significant difference in the mean CROM readings (degrees) in right rotation, between the three groups as asymp sig = 0.446 (P > 0.05).

On visit 7, there was not a statistically significant difference in the mean CROM readings (degrees) in right rotation, between the three groups as asymp sig = 0.868 (P > 0.05).

No further testing was necessary as no statistically significant change was measured across the three groups.

Table 4.32: Inter-Group Analysis of CROM Devise in Left Rotation

	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	65.30°	67.10°	63.30°	65.23°	0.669
Visit 4	67.40°	72.40°	71.10°	70.30°	0.448
Visit 7	70.80°	73.50°	76.00°	73.43°	0.392
Mean Change	5.50°	6.40°	12.70°		

Table 4.32 indicates the results of the inter-group analysis of CROM left rotation readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If significant difference was found, further testing was done to determine where the difference was found, between the resistance training

and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean CROM readings (degrees) in left rotation, between the three groups as asymp sig = 0.669 (P > 0.05).

On visit 4, there was not a statistically significant difference in the mean CROM readings (degrees) in left rotation, between the three groups as asymp sig = 0.448 (P > 0.05).

On visit 7, there was not a statistically significant difference in the mean CROM readings (degrees) in left rotation, between the three groups as asymp sig = 0.392 (P > 0.05).

No further testing was necessary as no statistically significant change was measured across the three groups.

4.4.2 Inter-Group Analysis of Isometric Dynamometer Results

<u>Table 4.33 Inter-Group Results of the Isometric Dynamometer in Flexion</u>

Visit	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	6.80kg	8.20kg	7.00kg	7.33kg	0.603
Visit 4	7.00kg	9.40kg	8.90kg	8.43kg	0.103
Visit 7	8.50kg	10.80kg	10.30kg	9.87kg	0.179

Table 4.33 indicates the results of the inter-group analysis of Isometric Dynamometer flexion readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the

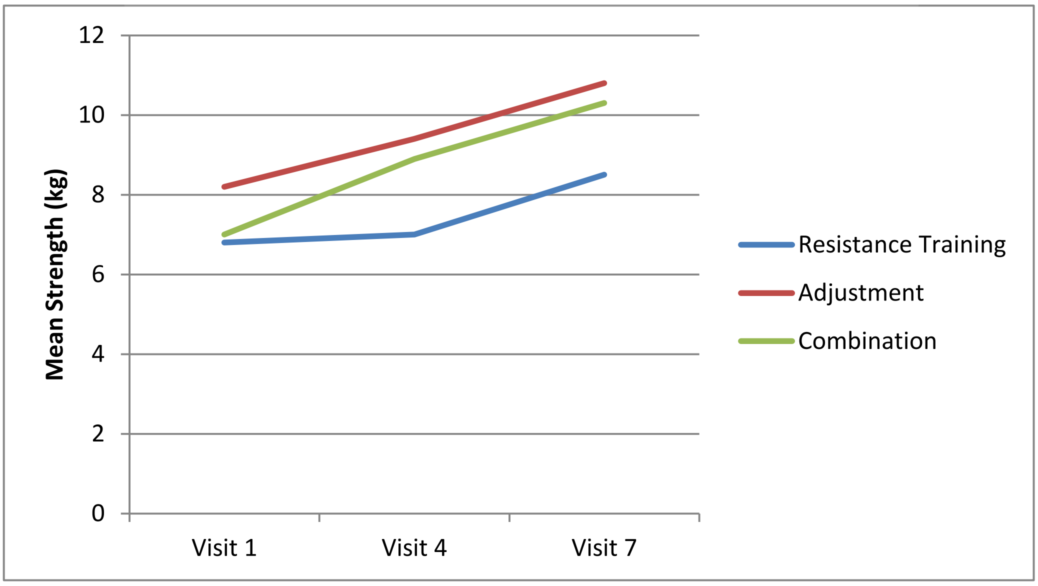
means of each group on each visit. If a statistically significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in flexion, between the three groups as asymp sig = 0.603 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in flexion, between the three groups as asymp sig = 0.103 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in flexion, between the three groups as asymp sig = 0.179 ($P > 0.05$).

No further testing was necessary as no statistically significant change was measured across the groups.



<u>Figure 4.2: Line Graph Illustrating the Change in Mean Strength of Flexion From Visit 1 to Visit 7, in Each of the Three Groups</u>

Figure 4.2 illustrates the mean change in strength (kg) in flexion between the three groups. Although not statistically significant, it is clear that all three groups did show an increase in strength. Resistance training showed a mean change of 1.70kg. The adjustment only group showed a mean change of 2.60kg and the combination group showed a mean change of 3.30kg.

Table 4.34 Inter-Group Results of the Isometric Dynamometer in Extension

Visit	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	8.80kg	8.60kg	7.50kg	8.30kg	0.540
Visit 4	8.40kg	9.90kg	9.40kg	9.23kg	0.544
Visit 7	10.30kg	11.90kg	11.40kg	11.20kg	0.370

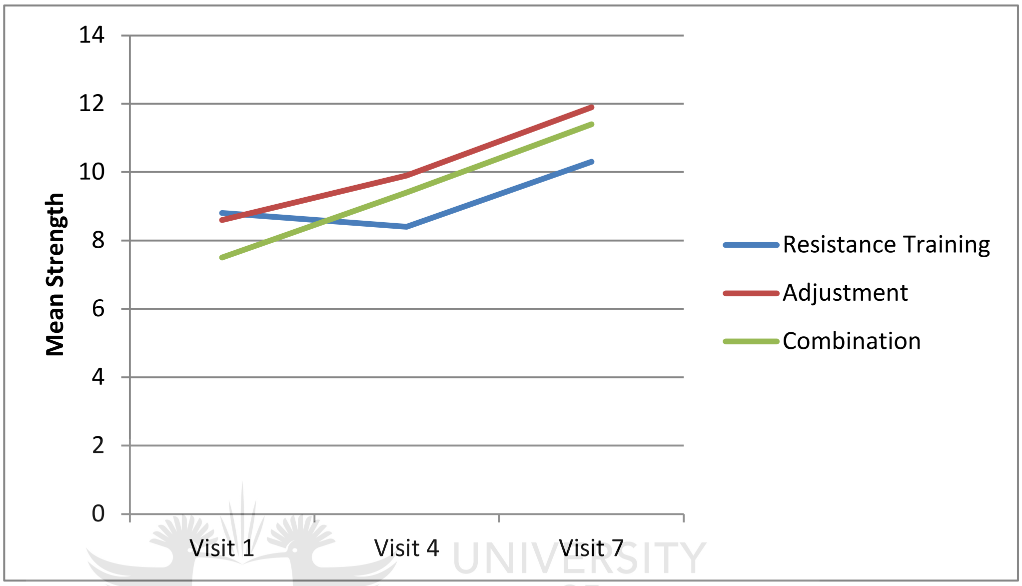
Table 4.34 indicates the results of the inter-group analysis of Isometric Dynamometer extension readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If a statistically significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in extension, between the three groups as asymp sig = 0.540 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in extension, between the three groups as asymp sig = 0.544 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in extension, between the three groups as asymp sig = 0.370 (P > 0.05).

No further testing was necessary as no statistically significant change was measured across the groups.



<u>Figure 4.3: Line Graph Illustrating the Change in Mean Strength of Extension From Visit 1 to Visit 7, in Each of the Three Groups</u>

Figure 4.3 illustrates the mean change in strength (kg) in extension between the three groups. Although not statistically significant, it is clear that all three groups did show an increase in strength. Resistance training showed a mean change of 1.50kg. The adjustment only group showed a mean change of 3.20kg and the combination group showed a mean change of 3.90kg.

<u>Table 4.35 Inter-Group Results of the Isometric Dynamometer in Right Lateral Flexion</u>

Visit	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	6.80kg	7.40kg	6.70kg	6.97kg	0.941
Visit 4	7.40kg	8.50kg	8.10kg	8.00kg	0.952
Visit 7	7.80kg	10.20kg	10.20kg	9.40kg	0.196

Table 4.35 indicates the results of the inter-group analysis of Isometric Dynamometer right lateral flexion readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If a statistically significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in right lateral flexion, between the three groups as asymp sig = 0.941 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in right lateral flexion, between the three groups as asymp sig = 0.952 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in right lateral flexion, between the three groups as asymp sig = 0.196 ($P > 0.05$).

No further testing was necessary as no statistically significant change was measured across the groups.

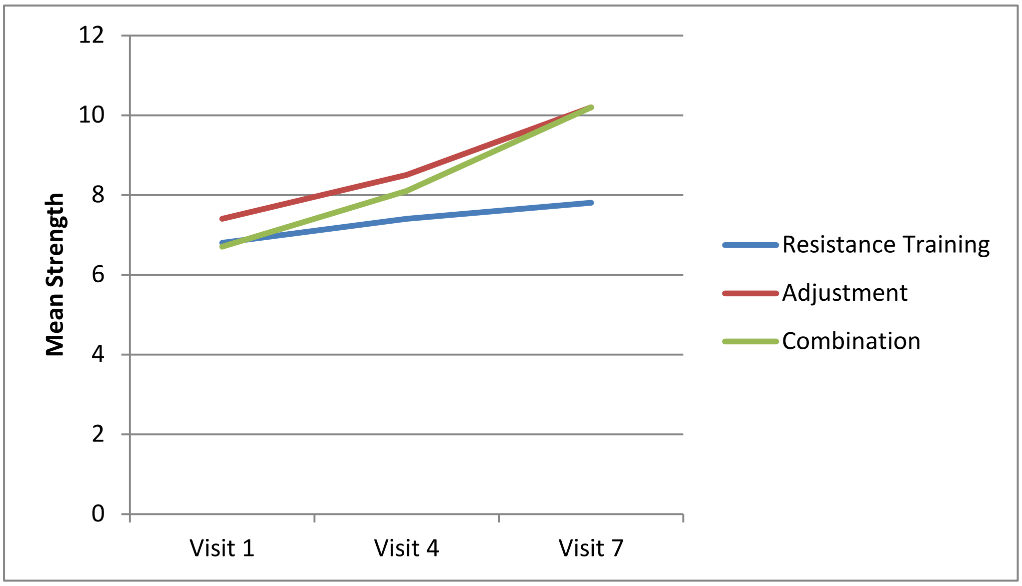


Figure 4.4: Line Graph Illustrating the Change in Mean Strength of Right Lateral Flexion from Visit 1 to Visit 7, in Each of the Three Groups

Figure 4.4 illustrates the mean change in strength (kg) in right lateral flexion between the three groups. Although not statistically significant, it is clear that all three groups did show an increase in strength. Resistance training showed a mean change of 1.00kg. The adjustment only group showed a mean change of 2.80kg and the combination group showed a mean change of 3.50kg.

Table 4.36 Inter-Group Results of the Isometric Dynamometer in Left Lateral Flexion

Visit	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	6.70kg	7.30kg	6.50kg	6.83kg	0.864
Visit 4	7.20kg	8.90kg	8.40kg	8.17kg	0.673
Visit 7	7.80kg	10.30kg	10.40kg	9.50kg	0.142

Table 4.36 indicates the results of the inter-group analysis of Isometric Dynamometer left lateral flexion readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If a statistically significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in left lateral flexion, between the three groups as asymp sig = 0.864 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in left lateral flexion, between the three groups as asymp sig = 0.673 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in left lateral flexion, between the three groups as asymp sig = 0.142 ($P > 0.05$).

No further testing was necessary as no statistically significant change was measured across the groups.

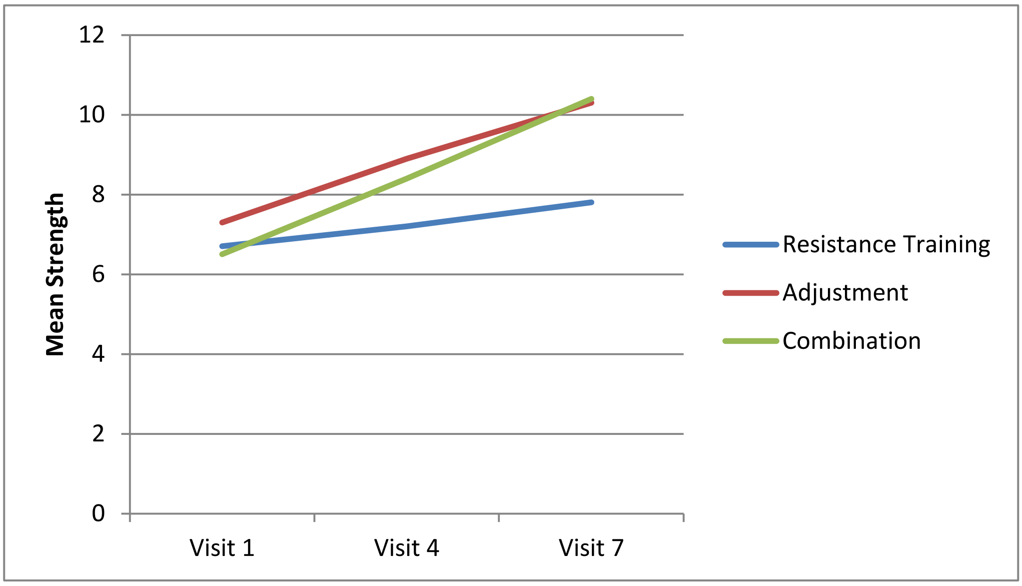


Figure 4.5: Line Graph Illustrating the Change in Mean Strength of Left Lateral Flexion from Visit 1 to Visit 7, in Each of the Three Groups

Figure 4.5 illustrates the mean change in strength (kg) in left lateral flexion between the three groups. Although not statistically significant, it is clear that all three groups did show an increase in strength. Resistance training showed a mean change of 1.10kg. The adjustment only group showed a mean change of 3.00kg and the combination group showed a mean change of 3.90kg.

Table 4.37 Inter-Group Results of the Isometric Dynamometer in Right Rotation

Visit	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	7.10kg	7.00kg	6.60kg	6.90kg	0.855
Visit 4	7.50kg	8.40kg	8.50kg	8.13kg	0.811
Visit 7	8.40kg	10.20kg	10.20kg	9.60kg	0.225

Table 4.37 indicates the results of the inter-group analysis of Isometric Dynamometer right rotation readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If a statistically significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in right rotation, between the three groups as asymp sig = 0.855 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in right rotation, between the three groups as asymp sig = 0.811 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in right rotation, between the three groups as asymp sig = 0.225 ($P > 0.05$).

No further testing was necessary as no statistically significant change was measured across the groups.

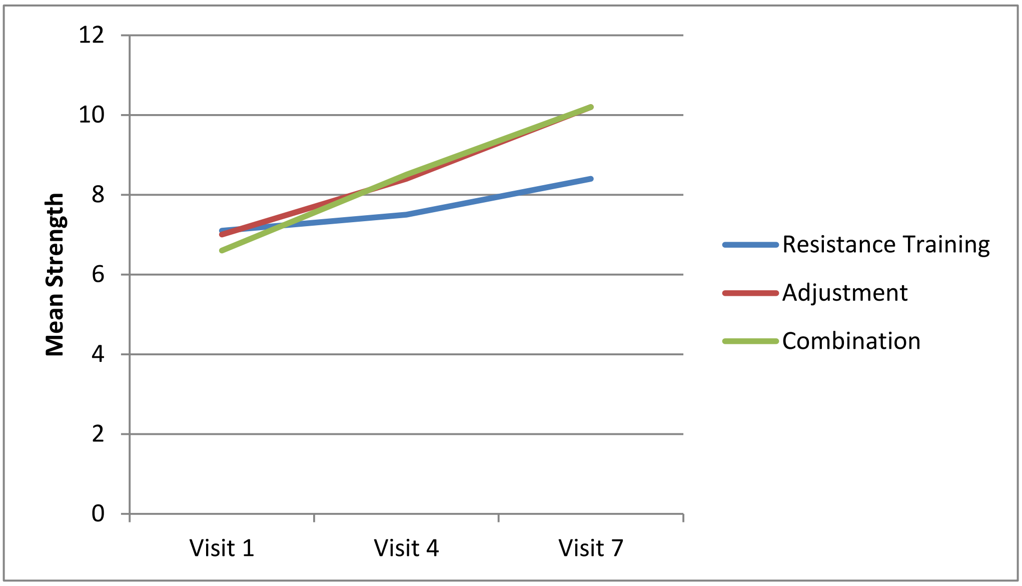


Figure 4.6: Line Graph Illustrating the Change in Mean Strength of Right Rotation From Visit 1 to Visit 7, in Each of the Three Groups

Figure 4.6 illustrates the mean change in strength (kg) in right rotation between the three groups. Although not statistically significant, it is clear that all three groups did show an increase in strength. Resistance training showed a mean change of 1.30kg. The adjustment only group showed a mean change of 3.20kg and the combination group showed a mean change of 3.60kg.

Table 4.38 Inter-Group Results of the Isometric Dynamometer in Left Rotation

Visit	Mean			Mean Across all Three Groups	Asymp Sig
	Resistance Training	Adjustment Only	Combination		
Visit 1	7.10kg	6.90kg	6.50kg	6.83kg	0.726
Visit 4	7.20kg	8.90kg	8.40kg	8.17kg	0.408
Visit 7	8.20kg	10.30kg	10.60kg	9.70kg	0.048

Table 4.38 indicates the results of the inter-group analysis of Isometric Dynamometer left rotation readings. A Kruskal-Wallis test was used to determine if there was a statistically significant difference between the means of each group on each visit. If a statistically significant difference was found, further testing was done to determine where the difference was found, between the resistance training and adjustment only groups, between the adjustment only and combination groups or between the resistance training and combination groups.

On visit 1, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in left right rotation, between the three groups as asymp sig = 0.726 ($P > 0.05$).

On visit 4, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in left rotation, between the three groups as asymp sig = 0.408 ($P > 0.05$).

On visit 7, there was not a statistically significant difference in the mean isometric dynamometer readings (kg) in left rotation, between the three groups as asymp sig = 0.048 ($P > 0.05$).

Visits 1 and 4 showed no statistically significant change however, visit 7 did show a statistically significant change as asymp sig = 0.048 ($P < 0,05$). Further testing was carried out on the results for visit 7 to determine between which groups the change occurred.

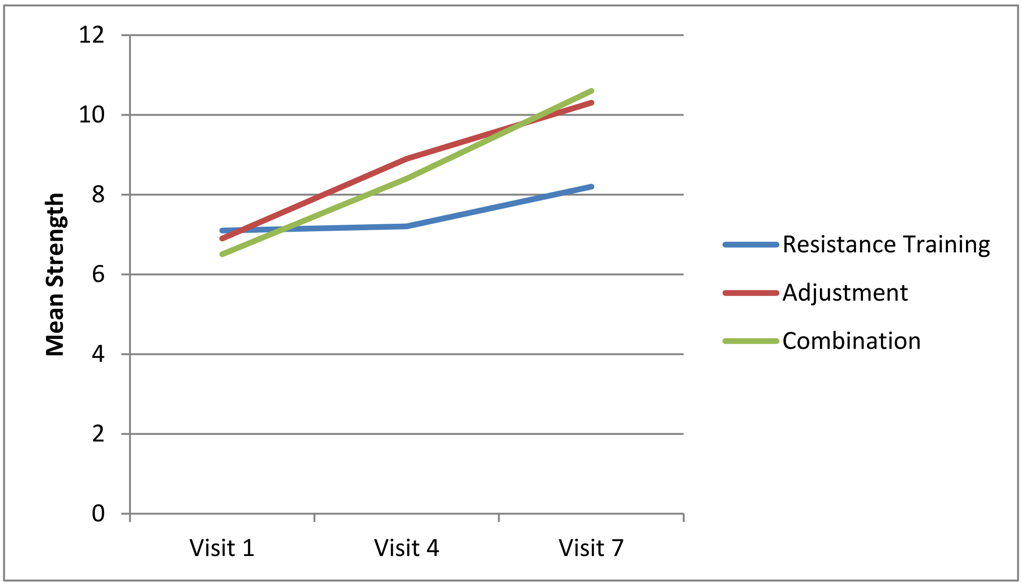


Figure 4.7: Line Graph Illustrating the Change in Mean Strength of Left Rotation From Visit 1 to Visit 7, in Each of the Three Groups

Figure 4.7 illustrates the mean change in strength (kg) in left rotation between the three groups. Although not statistically significant, it is clear that all three groups did show an increase in strength. Resistance training showed a mean change of 1.10kg. The adjustment only group showed a mean change of 3.40kg and the combination group showed a mean change of 4.10kg.

Post-Hoc Testing of Inter-Group Results of Isometric Dynamometer Readings in Left Rotation, on Visit 7

Bonferroni Adjustments

Test smallest p-value against a significance level of 0.05 / 3 = 0.0167

Test 2nd smallest p-value against a significance level of 0.05 / 2 = 0.025

Test largest p-value against a significance level of 0.05 / 1 = 0.05

The Mann-Whitney test was used to analyse this data as it was only necessary to compare two groups at a time, therefore the P value was 2-tailed. Pair 1 was resistance training against adjustment only, pair 2 was resistance training against combination and pair three was adjustment only against combination.

Table 4.39: Post-Hoc Testing of Isometric Dynamometer Results For Left Rotation, Pair 1

Group	Mean	Asymp sig
Resistance Training	8.20kg	
Adjustment Only	10.30kg	
		0.121

Table 4.39 indicates that there was no statistically significant change between pair 1 as asymp sig = 0.121 ($P > 0.025$).

Table 4.40: Post-Hoc Testing of Isometric Dynamometer Results For Left Rotation, Pair 2

Group	Mean	Asymp sig
Resistance Training	8.20kg	
Combination	10.60kg	
		0.0097

Table 4.40 indicated that there was a statistically significant change between pair 2 as asymp sig = 0.0097 ($P < 0.0167$).

Table 4.41: Post-Hoc Testing of Isometric Dynamometer Results For Left Rotation, Pair 3

Group	Mean	Asymp sig
Adjustment Only	10.30kg	
Combination	10.60kg	
		0.588

Table 4.41 indicates that there was not a statistically significant difference between pair 3 as asymp sig = 0.588 ($P > 0.05$).

Post-Hoc analysis of the Isometric dynamometer results for left rotation on visit 7 shows that the statistically significant change was found between the resistance training and combination groups. No statistically significant changes were noted when comparing the resistance training group to the adjustment only group, or when comparing the adjustment only group to the combination group.

4.4.3 Inter-Group Vernon-Mior Neck Disability Index Results

Table 4.42: Inter-Group Vernon-Mior Neck Disability Index Results

	Visit 1	Visit 7
Resistance Training	10.40	1.50
Adjustment Only	9.40	2.40
Combination	10.60	2.10
Asymp Sig	0.405	0.525

Table 4.42 represents the results of the Kruskal-Wallis testing on the scores from the Vernon-Mior Neck Disability Index. From this table it is evident that there was not a statistically significant difference on the 1st visit as Asymp sig = 0.405 ($P > 0.05$), or the 7th visit as Asymp sig = 0.525 ($P > 0.05$).

Chapter 5

5.1 Introduction

The following chapter will discuss the results of this trial, with reference to the previous chapter as well as relevant literature.

An increase in muscle strength is most often attributed to muscle hypertrophy. According to Mortani and De Vries (1979) a minimum of three weeks of resistance training is necessary for muscle hypertrophy to occur. Gabriel, Kamen and Frost (2006) noted that strength gains in the early phase of a resistance training regimen were associated with an increase in surface electromyography (sEMG) results. They interpreted these findings as an increase in the magnitude of efferent neural output from the central nervous system (CNS) to the active muscle fibres.

According to Pollard and Ward (1996), neural integrity is vital to the proper functioning of skeletal muscle. Smith and Cox (2000) showed that a clinically weak muscle may be as a result of decreased neural input. This decreased neural output may originate at the spinal nerves or from central control centres. They proposed two mechanisms by which neural interference may impair muscle function. The first mechanism is aligned with the vertebral subluxation complex, whereby spinal nerve root compression results in impaired efferent neural firing. The second mechanism, known as segmental facilitation, is that of hyper functioning of the efferent neural receptors leading to spasticity.

5.2 Demographic Analysis

The demographic make-up of the three trial groups was analysed. This was done to ensure that the groups were evenly matched and no bias could be implied as a result of age or gender differences.

5.2.1 Age

The minimum age of participants across the trial was 22 years, the maximum age was 28 years (Table 4.1). The mean age of each of the trial groups varied by less than 1 year and no statistically significant difference was noted here. The three groups are therefore comparable in terms of age.

A study was performed by Croft, Jayson, Lewis, Macfarlane, Papageorgiou, Silman and Thomas (2001) to determine the incidence of episodic cervical spine pain over the period of one year. The results of this study showed that there was minimal fluctuation in cervical spine incidence between the age groups studied. Therefore, the age group represented in this study is an adequate representation of the population with regards to incidence of cervical spine pain.

5.2.2 Gender

For the purpose of this trial, thirty participants were recruited and were then distributed into the three treatment groups. There were a total of 18 male and 12 female participants who participated in this trial. Stratified sampling was used to equally distribute male and female participants between the three treatment groups.

Each of the three groups contained 6 male and 4 female participants. The groups were exactly balanced in terms of gender and therefore comparable (figure 4.1). There was no statistical difference between the three groups.

5.3 Intra-Group Analysis

The intra-group analysis compared the test values within each group over time. This testing was done by means of the Friedman test. From these results it was possible to analyse whether each of the treatment protocols, resistance training, adjustment and the combination treatment, did in fact have an effect on the cervical range of motion and strength of the participants.

If the results of the Friedman test were statistically significant, further post-hoc testing was conducted using the Mann-Whitney test. This was done to determine where in the treatment regimen the change occurred; between the 1st and 4th visits or between the 4th and 7th visits.

5.3.1 Cervical Range of Motion Intra-Group Analysis

Cervical range of motion was measured in 6 ranges of motion; flexion, extension, right and left lateral flexion and right and left rotation. Overall there was a statistically significant increase in all 6 range of motion across all three groups except, right lateral flexion in the resistance training group.

The mechanism by which the increases were achieved was consistent across all 6 ranges of motion. The results of each range shall be discussed individually and the mechanism shall be discussed with reference to all 6 ranges of motion.

A)CROM Flexion

A statistically significant increase in flexion range of motion was measured in all three treatment groups. The largest overall increase was noted in the combination group, where a mean increase of 14.7% was found. The resistance training group showed an overall increase of 11.6% and the adjustment only group 9.2%.

Further analysis revealed that the resistance training and adjustment only groups did not show a significant increase between visits 1 and 4, but did show a significant change between visits 1 and 7. From this, we can deduce that the statistically significant change occurred between visits 4 and 7. In the combination group, a statistically significant increase was measured at both treatment intervals.

From these results we see that although all three treatment protocols do significantly increase cervical flexion, the combination treatment is not only most effective in terms of range of motion gains, but also shows the most immediate effect.

B)CROM Extension

An overall increase in all three treatment groups was measured in the extension range of motion. The combination group registered the largest gains, with an increase of 15.2%. Gains of 9.4% and 14.7% were registered in the resistance training and adjustment only groups respectively.

Further testing showed that the resistance training and adjustment only groups only showed a statistically significant increase between the 4th and 7th visits only, while the combination group showed statistically significant increases between both the 1st and 4th and 4th and 7th visits.

From these results it is clear that the combination treatment is most effective in terms of range of motion gains in extension, as well as having a more immediate effect that that of resistance training or adjustment alone.

C)CROM Lateral Flexion to the Right

The results of the range of motion testing for right lateral flexion are unique, as there was not an overall statistically significant increase in right lateral flexion range of motion in the resistance training group. As the treatment groups were so small (10 participants), results such as this can be skewed by a single participant. Although not statistically significant, an increase of 4.6% was still noted in this group. Both the adjustment only and combination groups showed significant changes of 19.0% and 20.1% respectively. In right lateral flexion, a statistically significant increase was found to occur both between visits 1 and 4 and visits 1 and 7 in both the adjustment only and combination groups.

In right lateral flexion it is evident that resistance training group was not as effective as the other two treatment protocols. Both the adjustment only and combination groups showed significant increases in range of motion at both the 4th and 7th visits, while the combination group showed a marginally larger increase in range of motion.

D)CROM Lateral Flexion to the Left

Although overall this group did show an increase in this range of motion, there was an initial decrease in range of motion between visits 1 and 4. The increase between visits 4 and 7 was however large enough to result in an overall gain in range of motion of 6.1%. The adjustment only group showed an increase of 10.9% and the combination group showed an increase of 17.9%.

Further testing showed that the resistance training group did not show a statistically significant change at any point during the treatment regimen. The adjustment only group showed a statistically significant increase only between visits 4 and 7, while the combination group showed statistically significant gains at between visits 1 and 4 and visits 4 and 7.

The combination group proved more effective in both range of motion gain and time taken for effect.

E)CROM Rotation to the Right

In right rotation, statistically significant range gains were noted in all three groups. The largest gain was noted in the combination group, 20.4%, while the adjustment only group gained 12.5% and the resistance training group 8.7%.

The resistance training group only showed statistically significant changes between visits 4 and 7, while both the adjustment only and combination groups showed changes between visits 1 and 4 and visits 1 and 7.

These results show the combination group to be most effective in terms of range of motion gain, but it was equally as effective as the adjustment only group in terms of time taken for effect.

F)CROM Rotation to the Left

All three groups showed statistically significant range of motion gains in left rotation. The resistance training group showed an increase of 8.4%, the adjustment only group 9.6% and the combination group 20.0%. The resistance training group only showed a statistically significant increase between visits 1 and 4, while both the adjustment only group and combination group showed the increase between visits 1 and 4 and visits 4 and 7.

These results show the combination group to be most effective in terms of range of motion gain, but it is equally effective as the adjustment only group in terms of time taken for effect.

5.3.2 Discussion of Intra-Group CROM Analysis

The results of the intra-group analysis of the CROM readings clearly show that all three treatment protocols did significantly increase cervical range of motion as a whole. Resistance training alone was not effective in increasing lateral flexion.

In the resistance training group this increase in range of motion could be attributed to the conditioning of neural input. In most ranges of motion, statistically significant changes were only noted at the 7th visit. This may be attributed to the motor learning effect being active throughout the treatment regimen, however these effects were only expressed once the learned response has been programmed (Gabriel et al, 2006). The initial phase of the resistance training programme involved neural conditioning, during which time the efferent impulses were conditioned to improve neural output, resulting in more effective and coordinated movement. Between visits 4 and 7, the effects of this conditioning became evident.

In the case of lateral flexion, resistance training alone did not cause a significant increase. This may be as a result of the presence of cervical facet syndrome. Cervical facet syndrome causes hypomobility, inflammation and pain within a motion segment (Gatterman, 2005). According to Fuhr, Colloca, Green and Keller (1997), hypomobility as a result of cervical facet syndrome is most pronounced in lateral flexion and rotation. As a result of this restricted motion, adequate motion cannot be achieved in order to trigger neural conditioning. Nociceptive input from the motion segment may activate inhibition of motion from the motor cortex (Pollard and Ward, 2001).

In the adjustment only group, much larger range of motion gains were noted in most directions than those of the resistance training groups. In accordance with the vertebral subluxation complex, this increase may be attributed to the correction of hypomobility within the cervical spine by means of a chiropractic adjustment. According to Lantz (1995), subluxation of a spinal motion segment will result in a restricted range of motion (hypomobility) in one or more movements of the spine. Hypomobility, or joint restriction, is the primary form of kinesiopathpology. The chiropractic adjustment aims to correct these restrictions, thereby restoring normal joint range of motion.

In rotation, the results indicated that adjustment alone was as effective as the combination treatment in terms of the time taken for a statistically significant change to occur. According to Fuhr, Colloca, Green and Keller (1997), hypomobility as a result of cervical facet syndrome is most evident in lateral flexion and rotation. Correction of the hypomobility in rotation, caused by cervical facet syndrome, by means of a chiropractic adjustment, appears to have a more immediate effect than other ranges of motion.

The vertebral subluxation complex also states the movement is brought about by muscle and controlled by the nervous system. Apart from correcting hypomobility, the chiropractic adjustment may also restore the neural integrity of the surrounding musculature and in so doing, enhance muscle function (Lantz, 1995).

The combination treatment group showed the greatest gains in all ranges of motion, and statistically significant gains were always noted at the 4th visit. These results indicated that the greatest gains were achieved when the treatments were combined.

Resistance training and adjustment are both effective in increasing cervical range of motion, yet achieve these gains using different pathways. Resistance training causes a learned response as a result of neural conditioning which results in conditioned, more effective movement control from the motor cortex (Gabriel et al, 2006). Adjustment corrects mechanical obstruction to movement (hypomobility) as well as restores neural integrity to surrounding musculature (Lantz, 1995). When these methods are combined, the effects are synergistic, resulting in greater range of motion gains, in a shorter time frame.

5.3.3 Isometric Dynamometer Intra-Group Analysis

The isometric dynamometer was used to measure maximal isometric cervical strength in all 6 directions; flexion, extension, right and left lateral flexion and right and left rotation. The intra-group analysis was performed by means of the Friedman test. If a statistically significant change was noted after this test, post-hoc testing was performed, using the Mann-Whitney test, to determine where in the treatment regimen this change occurred. Measurements were taken after the 1st, 4th and 7th visits.

The Friedman test revealed that all three groups showed statistically significant increases in cervical strength, in all 6 directions, by the end of the 7th visit.

The mechanism by which the strength increases were achieved was consistent across all 6 ranges of motion. The results of each range shall be discussed individually; however the mechanism shall be discussed with reference to all 6 ranges of motion.

A)Isometric Dynamometer Analysis in Flexion

Statistically significant strength gains were measured in all three treatment groups in flexion. The largest gain was measured in the combination group, where there was a gain of 47%. A smaller gain of 31% was measured in the adjustment only group, while the resistance training group increased by 25%.

The adjustment only group and combination group recorded a more immediate effect. Both groups registered statistically significant increases between the 1st and 4th and 4th and 7th visits, while the resistance training group only showed a statistically significant change between the 4th and 7th visits.

B)Isometric Dynamometer Analysis in Extension

Statistically significant strength increases were measured in all three treatment groups in extension. However, much larger gains were noted in the adjustment only and combination groups than in the resistance training group. In the resistance training group a 17% gain was measured between the 1st and 7th visits, compared to the 38% and 52% gains measured in the adjustment only and combination group respectively.

The results of the resistance training group in extension differed from all other results as the there was a decrease of strength of 5% between visits 1 and 4. Therefore, although there was an overall increase in this group of 17%, there was in fact an increase in strength of 22% between visits 4 and 7. This result does not correlate with any other results and seems to be an anomaly, most likely as a result of the small sample size of the groups.

In extension, the largest strength gains were achieved by the combination group. In the resistance training group the result was anomalous. After an initial decrease in strength, there was an overall statistically significant increase in strength. In the adjustment only group there were large gains at both intervals, but the majority of the strength gain was achieved between 4^{th} and 7^{th} visits. The combination group showed a consistent gain throughout the course of treatment. Overall, the results for extension show that all three methods of treatment are effective in increasing neck strength however, the largest and most consistent gain occurred in the combination group. Statistically significant strength gains were more immediate in the combination and adjustment only group than the resistance training group.

C)Isometric Dynamometer Analysis in Right Lateral Flexion

In right lateral flexion, the results indicate that the greatest strength gains were measured in the combination group where an overall increase of 52% was measured. The resistance training and adjustment only groups also showed significant increases of 15% and 38% respectively.

All three groups achieved statistically significant strength gains. The resistance training group only achieved this by the 7^{th} visit. The adjustment only group and combination group showed statistically significant changes by the 4^{th} visit. Therefore, the resistance training group not only showed smaller gains, but also took longer to express these gains. The adjustment only group showed consistent gains throughout treatment, although there was a slightly larger gain between visits 1 and 4. The gains achieved in the combination group remained relatively constant at both intervals.

D)Isometric Dynamometer Analysis in Left Lateral Flexion

All three groups achieved statistically significant strength gains over the full course of treatment. The largest gains were measured in the combination group, where an increase of 60% was seen. The adjustment only group increased by 41% and the resistance training group increased by 16%.

It is evident that the greatest effect in terms of strength gains was seen in the combination group. In terms of the time needed for a statistically significant change to occur, the combination and adjustment groups were equally effective, while the resistance training group lagged behind. All three groups showed relatively constant strength gains at both intervals.

E)Isometric Dynamometer Analysis in Right Rotation

All three groups recorded statistically significant strength increases over the full course of treatment. The greatest increase in strength was seen in the combination group, 55%. Increases of 46% and 18% were seen in the adjustment only and resistance training groups respectively.

The adjustment only and combination group were equally as effective in the time taken for a statistically significant change to occur as both groups recorded these changes by visit 4. The resistance training group only measured such a change at visit 7.

F)Isometric Dynamometer Analysis in Left Rotation

All three groups recorded statistically significant strength increases over the full course of treatment in left rotation. The greatest increase in strength was seen in the combination group, 63%. Increases of 49% and 16% were seen in the adjustment only and resistance training groups respectively.

The adjustment only group and combination group were equally as effective in terms of the time taken for a statistically significant change to be expressed, while the resistance training took longer for this to be evident.

5.3.4 Discussion of Intra-Group Isometric Dynamometer Analysis

In all three groups, statistically significant strength increases were measured, in all 6 ranges of motion, over the course of the three week clinical trial. According to Mortani and De Vries (1979), a minimum of three to six weeks of strength training is necessary before muscle hypertrophy occurs. Therefore, all three methods of treatment are effective in increasing cervical strength, in the absence of muscle hypertrophy.

In the resistance training group, relatively smaller, yet statistically significant strength increases were noted. Given the time frame of the trail, these changes cannot be attributed to muscle hypertrophy and therefore it is assumed that strength is not solely dependent on the size of the muscle. Williams and Bannister (1995) state that "strength is usually measured on intact subjects in tasks that require the participation of several muscles; it is then as much an expression of the skilful activation and co-ordination of these muscles as it is a measure of the forces that they contribute individually. Thus it is possible to increase without a concomitant increase in the true force generating capacities of the muscles involved, especially during early stages of training". This increase is therefore attributed to neural factors, both centrally and peripherally.

There is evidence of central control of strength related adaption to resistance training. According to Gabriel et al (2006), unilateral resistance training in one limb results not only in an increase in strength in the trained limb but also in the opposite, untrained limb. This suggests resistance training not only activates receptors within the muscles and the involved peripheral nerves but also results in enhanced neural expression at a central level, from the motor cortex. This is in accordance with the motor learning theory, where in the associative stage skills become more refined and less error occurs as a result of the enhancement of neural patterns (Poole, 1991).

At a peripheral level, Golgi tendon organs within the muscle spindles have a proprioceptive function that prevents harmful forces being generated in the muscles. It is possible that repeated resistance training may result in these receptors desensitizing, leading to the disinhibition of the muscle thereby allowing the muscle to express increased muscular contractions (Gabriel et al, 2006).

In the resistance training group, none of the 6 directions of movement displayed a statistically significant increase in strength between the 1st and 4th visits. This indicated that there is an initial learning period where by the muscle and its innervations are programmed or disinhibited before the increased expression is noted.

Strength gains for lateral flexion and rotation in both directions were smaller than those of flexion and extension. Lateral flexion and rotation are the movements which are particularly inhibited by cervical facet syndrome (Fuhr, Colloca, Green and Keller 1997). From these results it is clear that resistance training is hindered by the presence of the facet syndrome and resulting hypomobility. The smaller strength gains may be as a result of peripheral neural interference caused by the facet syndrome and resulting inflammation and pain. It may also be as a result of the hypomobility within the effected motion segments diminishing the effectiveness of the resistance training.

In the adjustment group, much larger strength gains were noted than those of the resistance training group. These results were also achieved in a shorter time frame. According to Smith and Cox (2000), correction of a hypomobile spinal motion segment will promote normal joint and muscle function by enhancing neurological integrity. This enhanced neural integrity is as a result of reduced interference at a spinal level.

Neural interference, whatever the cause, leads to inflammation in that motion segment. Inflammation may lead to, or maintain pre-existing hyperexcitability in the related muscle. This hyper excited state of the motion segment is known as a facilitated segment. A facilitated segment cannot function optimally and as a result, muscle spasm and pain ensue (Patterson, 1993).

By correcting the hypomobile segment by means of a chiropractic adjustment, the neural interference is removed and as such the spinal segment is allowed to return to normal function. The effects of the adjustment are immediate (Gatterman, 2005). This is proven as the results show that in all 6 ranges of motion, statistically significant changes were recorded at visit 4.

Although the direct interference has been removed, the effect of the interference; such as the inflammation, do not dissipate immediately. By continued adjustment, the segment is continuously stimulated, activating proprioceptors within the joint and surrounding muscles and promoting normal function. With time, the inflammation, spasm and pain are reduced as the inciting agent has been removed and optimal function may resume (Patterson, 1993). This is evident by the continued strength increases beyond the 4th treatment. In fact in most directions there was a greater increase in strength between the 4th and 7th visits indicating that not only does the adjustment remove interference but also enhances neural performance.

The greatest and most significant strength gains were noted in the combination group. This is to be expected as both individual treatment protocols were shown to be successful, and would appear to achieve the strength gains by utilizing different mechanisms. By combining the two mechanisms, compound effects are achieved. This resulted in early strength gains that exceeded that of both the individual treatment approaches between both the 1st and 4th and the 4th and 7th visits. This indicates that there is a synergistic relationship between chiropractic adjustment and resistance training, the results of which exceed those of either individual treatment.

5.3.5 Intra-Group Analysis of the Vernon-Mior Neck Disability Index

The Vernon-Mior neck disability index is a subjective test, used to determine the patient's perception of their own pain and disability. In all three groups there was a statistically significant decrease in pain and disability. The greatest result was seen in the resistance training group where there was a decrease in pain and disability of 86%. In the adjustment only group there was a decrease of 75% and in the combination group a decrease of 80%.

5.3.6 Discussion of Vernon-Mior Neck Disability Index Intra-Group Analysis

Neck pain is a common musculoskeletal disorder, affecting a large portion of society. Up to 67% of people will suffer from neck pain in their lifetime (Walker et al, 2008) and up to 15% are suffering from it at any given time (Vernon & Humphreys, 2008). According to the World Health Organization's Global Burden of Disease Study (2010), neck pain is the 4th most common cause of disability, world-wide. A study has revealed that not only is manual therapy an effective way of treating neck pain but also one of the most cost effective methods, as determined by Korthals- de Bos, Holbing, van Tulder, Rutten- van Molken, Ader, de Wet, Koes, Vondeling and Bouter (2003).

The results of the Vernon-Mior Neck Disability Index indicate that while all three treatment groups are effective in reducing pain and disability, the resistance training group showed the greatest effect. The chiropractic only group produced the least improvement. This is consistent with the findings of Bronfort, Evans, Nelson, Aker, Goldsmith and Vernon (2001), who found that in patients with chronic neck pain, the use of spinal exercises, either alone or in combination with chiropractic adjustment, was more effective in reducing neck pain than chiropractic adjustment alone.

The participants decreased disability perception may be attributed to the stabilizing effect of the increased muscle strength on the cervical spine (Goel, 1993). The larger improvements found in the resistance training and combination groups may be as a result of the motor learning effect. Repetitive resistance training conditions the neural input from the motor cortex to produce more coordinated muscle contraction, resulting in greater muscle fibre activation and fewer errors in motion production (Gabriel et al, 2006). The chiropractic adjustment resulted in a reduction of neural interference, thereby resulting in the reduction of inflammation, muscle spasm and pain (Patterson, 1993).

Although statistically the results of this study appear to produce large improvements, clinically the effects were smaller and relatively equal across all three groups. In all three groups, the mean score at visit 1 placed all three groups in the mild to moderate disability range (score of 4-14). On the 7th visit, the mean scores placed all three groups in the no disability range (score of 0-4). Therefore, all three treatments successfully downgraded the participant's perception of their own pain and disability by 1 level.

5.4 Inter-Group Analysis

Inter-group analysis was conducted to compare the results of each group to each other and determine whether one group was statistically more effective that the others. This was done by means of the Kruskal-Wallis test. This test compared the results of the three groups as a whole. If there was a statistically significant difference, post-hoc testing was conducted by means of the Mann-Whitney test to determine between which groups the difference was found.

5.4.1 Cervical Range of Motion Device Inter-Group Analysis

Cervical range of motion was measured in all three groups, in 6 ranges of motion; flexion, extension, lateral flexion to the right and left and rotation to the right and left. There were no statistically significant differences between the groups.

A)CROM Flexion

All three groups showed increases in flexion range of motion. When the increases of each group were compared against one another, there was only a 3.1° variation between the groups. This change was not statistically significant.

B)CROM Extension

All three groups showed increases in extension range of motion. When the increases of each group were compared against one another, there was only a 4.4° variation between the groups. This change was not statistically significant.

C)CROM Lateral Flexion to the Right

All three groups showed increases in right lateral flexion range of motion. When the increases of each group were compared against one another, there was only a 7° variation between the groups. This change was not statistically significant.

D)CROM Lateral Flexion to the Left

All three groups showed increases in left lateral flexion range of motion. When the increases of each group were compared against one another, there was only an 8.2° variation between the groups. This change was not statistically significant.

E)CROM Rotation to the Right

All three groups showed increases in right rotation range of motion. When the increases of each group were compared against one another, there was only a 6.3° variation between the groups. This change was not statistically significant.

F)CROM Rotation to the Left

All three groups showed increases in left rotation range of motion. When the increases of each group were compared against one another, there was only a 7.2° variation between the groups. This change was not statistically significant.

5.4.2 Discussion of Inter-Group CROM Results

No statistically significant differences were found between the groups. The combination group measured the largest change in all 6 ranges of motion. The combination group also had the most consistent results.

The resistance training group recorded the lowest overall increases in range of motion. The increase in cervical range of motion in this group can be attributed to the motor learning effect. Repetitive movement in the same direction conditions neural input from both the central control of muscle action resulting in that task being performed more efficiently and with fewer mistakes (Gabrielle et al, 2006). However, the presence of an unresolved cervical facet syndrome hindered the improvements in this group. Hypomobility is a clinical feature of cervical facet syndrome (Fuhr, Colloca, Green and Keller, 1997) and as the resistance training protocol does not address this, improvements in strength are limited.

The adjustment group measured greater increases than the resistance training group in all directions except flexion. Flexion range of motion is not particularly limited by the presence of cervical facet syndrome (Fuhr, Colloca, Green and Keller, 1997) therefore the effect of the chiropractic adjustment may be lesser in this motion. The larger increases in other ranges of motion are expected as the aim of the chiropractic adjustment is to restore normal joint motion and function (Gatterman, 1990). By correcting the hyopomible joint segments the chiropractic adjustment is able to restore normal joint motion and function to that segment. In so doing, any neural interference caused by the facet syndrome is removed, allowing greater control and coordination of movement (Patterson, 1993).

By combining the effects of both these treatments in the combination group, the greatest improvements in range of motion were achieved. The resistance training improves central control of movement from the motor cortex and the adjustment restores the peripheral neural integrity of the joint, as well as removes mechanical obstructions to movement (hypomobility) caused by the facet syndrome. The effects of the two treatment protocols are synergistic and therefore allow for the greatest expression of movement.

5.4.3 Isometric Dynamometer Inter-Group Analysis

Inter-group isometric dynamometer results were analysed using the Kruskall-Wallis test. This tested the results of the three groups, at each visit, against each other. If a statistically significant difference was found, those results then underwent post-hoc testing, by the Mann-Whitney test, to determine between which two groups the difference was found.

A statistically significant difference was only found in left rotation on visit 7.

A)Isometric Dynamometer Analysis in Flexion

Results in flexion were not statistically relevant however large differences in strength gains were noted between the groups. At the 4th visit, the resistance training group had only increase by 3%, while much larger gains of 15 % and 27% were noted in the adjustment only and combination groups respectively. Therefore at the time of the 4th visit, the combination group had a nearly 8 times greater increase than the resistance training group, and almost double the strength gains seen in the adjustment only group. The adjustment only group showed a 5 times greater improvement in strength than the resistance training group at this time.

By the 7th visit, strength increases between the groups showed much smaller differences, however it was still clearly evident that the combination group showed the greater increases than both the resistance training and adjustment only groups. The adjustment only group showed a larger increase than the resistance training group.

B)Isometric Dynamometer Analysis in Extension

No statistically significant change was noted between the 3 groups. However, as with flexion, there were large increases noted. At the time of the 4th visit, the resistance training group had decreased in strength by 5% while the adjustment only and combination groups showed increases of 15% and 25% respectively. The 5% decrease in the resistance training group seems to be anomalous and does not correlate with any other findings. This anomaly may be as a result of the small sample size of the treatment groups. With only 10 participants in each group, a variance in 1 participant may affect the outcome of the whole group.

By the 7th visit the combination group had shown larger increases than both the resistance training and adjustment only groups, while the adjustment group showed a larger increase that the resistance training group.

C)Isometric Dynamometer Analysis in Right Lateral Flexion

Although there was again no statistically significant difference between the strength increases measured in the three groups, there were large changes seen. At the 4th visit, the combination group showed much larger strength gains (21%) than those seen in either the resistance training group (9%) or the adjustment only group (15%).

At the 7th visit the results were similar as the adjustment only group showed a larger increase than the resistance training group, while the combination group showed larger gains than both these groups.

D)Isometric Dynamometer Analysis in Left lateral Flexion

As with the previous groups, there were no statistically significant changes found between the 3 groups. At the 4th visit, the greatest improvement was seen in the combination group, 29%, while the resistance training and adjustment groups showed a 7% and 22% increase respectively.

At the 7th visit, the adjustment only group showed larger strength increases than the resistance training group, while the combination group showed larger increases than both these groups.

E)Isometric Dynamometer Analysis in Right Rotation

Results of right rotation showed that there were no statistically significant changes found between the 3 groups. At the 4th visit, the greatest improvement was seen in the combination group, 29%, while the resistance training and adjustment groups showed a 6% and 20% increase respectively.

At the 7th visit, the adjustment only group showed larger strength increases than the resistance training group, while the combination group showed larger increases than both these groups.

F)Isometric Dynamometer Analysis in Left Rotation

In left rotation, the results showed that there were no statistically significant changes found between the 3 groups at visit 4. At the 4th visit, the greatest improvement was seen by both the combination group and adjustment only groups, with a gain of 29%. The resistance training showed only a minor change of 1%

At the 7th visit there was a statistically significant difference. Post-hoc testing revealed that the significant difference was found between resistance training group and the combination group, with the combination group showing the greater strength increases. No statistically significant changes were seen between the resistance training and adjustment only groups or between the adjustment only and combination groups.

5.4.4 Discussion of Inter-Group Isometric Dynamometer Results

Strength gains were measured in all groups however, left rotation at visit 7 was the only interval at which the change was large enough to be statistically significant. Post-hoc testing revealed that the statistical difference lay between the combination and resistance training groups. There was no statistical difference between the combination and adjustment only groups.

Although not statistically significant, the results clearly indicate that the combination group produced the greatest strength improvements at both measurement intervals, across all 6 ranges of motion.

The adjustment only group showed larger strength gains than the resistance training group in all ranges of motion, at both measurement intervals. Although not statistically significant, these results were consistent throughout the trial. This indicates that while both treatment methods were effective, the effect of the chiropractic adjustment alone had a greater impact on strength than that of resistance training.

As discussed in the intra-group analysis, resistance training and chiropractic adjustment produce an increase in cervical strength by affecting the central and peripheral neural control of movement respectively. Chiropractic has the added benefit of correcting the hypomobility caused by the facet syndrome, which appears to exert a greater effect on overall strength gains. The inter-group results show that this added benefit is more clearly expressed in lateral flexion and rotation ranges of motion. Lateral flexion and rotation are the ranges where cervical facet syndrome shows the greatest restriction of motion (Fuhr, Colloca, Green and Keller, 1997).

In the resistance training group, minimal strength gains were measured at visit 4. At visit 7 however, there was a drastic increase in strength. The late stage gains, although large, were not sufficient to equal the overall gains of the other groups. This pattern of strength gain is aligned with the motor learning theory discussed earlier (Gabrielle et al, 2006).

The adjustment group recorded large, consistent strength gains both measurement intervals. This indicates that although the effects of the chiropractic adjustment are known to be immediate (Gatterman, 2005), repeated adjustment continually stimulates the neural structures of the adjusted motion segment. In so doing, the neural integrity of the motion segment is continuously enhanced. Continuous adjustment also corrects hypomobility and allows for the symptoms of cervical facet syndrome (inflammation and pain) to subside (Patterson, 1993). With decreased pain, inflammation and motion restriction, as well as enhanced neural integrity, strength gains continue to increase over time.

The combination group not only recorded the greatest strength gains but also showed the least variation within these strength gains, at both intervals. As explained above, the individual treatments utilized different pathways in affecting changes in cervical muscle strength. The results of the 3 groups do not differ widely enough for there to be a statistically significant margin between groups. However it is clear that the synergistic effects produced by the combination treatment, were superior to that of either individual treatment.

5.4.5 Inter-Group Vernon-Mior Neck Disability Index Analysis

There was no statistically significant difference noted between the 3 groups on the Vernon-Mior NDI. The greatest decrease in score was seen in the resistance training group, followed by the combination group. The smallest decreases were seen in the adjustment only group.

5.4.6 Discussion of the Vernon-Mior Neck Disability Index

There was no statistically significant difference between the 3 groups. While the numbers recorded may seem to show a vast change, clinically all the groups moved from the mild-moderate disability range at visit 1, to the no disability range at visit 7 (Vernon and Mior, 1992). Therefore, all 3 methods of treatment lead to an equal decrease in the participant’s perception of their pain and disability.

5.5 Conclusion

Intra-group analysis showed that all 3 treatment methods increased cervical range of motion and cervical spine strength, as well as decreased the participant's perception of their pain and disability. Although not large enough to show statistical significance in the inter-group analysis, there were clear differences in the effectiveness of the three groups.

The results of the Vernon-Mior NDI showed while all 3 groups did effectively reduce the participant's perception of their pain and disability, there was no statistical difference between the groups. The resistance training group measured the largest decrease in pain and disability in terms of range but when analysed clinically, all three groups measured equal changes.

Analysis of the CROM results indicated that in the resistance training group, smaller range of motion gains were measured in lateral flexion and rotation than those of flexion and extension. Lateral flexion and rotation are the movements most affected by cervical facet syndrome (Fuhr, Colloca, Green and Keller, 1997). The adjustment only and combination groups showed more consistent range of motion gains across the 6 movements, as the adjustment corrected any hypomobility caused by the facet syndrome. This result indicates that optimum movement cannot be expressed, regardless of strength, if a mechanical blockage is present.

The resistance training and adjustment only groups only showed significant range of motion gains in flexion, extension and lateral flexion at visit 7, while the combination group recorded such changes at visit 4. In rotation, again the resistance training group only recorded changes at visit 7 however both the adjustment only and combination groups recorded this change at visit 4. Across all ranges, the combination group was the most effective in terms of the time taken for the gains to be expressed. In rotation however, chiropractic adjustment alone was as effective. From this it is assumed that the greatest motion restrictions experienced by the participants in this trial as a result of cervical facet syndrome were in rotation.

Isometric dynamometer results proved that strength gains were achieved in all 3 treatment groups, indicating that all three methods of treatment are effective in increasing strength over a 3 week time period. The margins of strength gain were generally too small to show a statistically significant difference between the groups. However, figures 4.2- 4.7 illustrate the obvious differences that were recorded between the groups.

In the resistance training group it is clear that there were much smaller gain than those of the adjustment only and combination groups, in all ranges of motion. In flexion there was a minimal increase recorded at visit 4 and in extension there was a slight decrease recorded. However, between visits 4 and 7 there was a sharp increase in strength in both these ranges of motion. This trend is not carried through in the lateral flexion and rotation ranges of motion. Instead, here we see a relatively constant, smaller gain at visits 4 and 7. Lateral flexion and rotation are the ranges of motion affected by cervical facet syndrome (Fuhr, Colloca, Green and Keller, 1997). As the resistance training protocol did not correct the facet syndrome these results indicate that the presence cervical facet syndrome adversely affects the muscles potential for strength gain, regardless of muscle training.

In the adjustment only and combination groups, similar patterns of strength gains are illustrated in flexion (figure 4.2) and extension (figure 4.3). However, in lateral flexion (figure 4.4 and 4.5) and rotation (figure 4.6 and 4.7) this trend changes. Despite starting at a lower point than the adjustment group, the combination group exceeds the gains of the adjustment only group by visit 7.

As flexion and extension movements are not known to be affected by cervical facet syndrome, the results of these ranges of motion are akin to those of asymptomatic people. Therefore, the results show that in asymptomatic people, similar strength gains will be experienced as a result of adjustment only or a combination of adjustment and resistance training. In people affected by cervical facet syndrome the long term effects of a combination treatment will exceed those of adjustment alone.

Chapter 6

6.1 Conclusion

The aim of this study was to determine whether chiropractic adjustment had an effect on cervical muscle strength. Furthermore, it aimed to determine which of the three methods of treatment was most effective in increasing cervical strength.

The results of the study confirm that chiropractic adjustment of the cervical spine increases the muscle strength of that region. When compared with resistance training, chiropractic adjustment proved to be more effective both in terms of increasing cervical range of motion and increasing cervical strength. Range of motion and strength gains were measured in all 6 directions of movement.

Although smaller than the gains of the adjustment group, the results of the resistance training group proved that it is possible to increase muscle strength in the absence of muscle hypertrophy. These strength gains may be attributed to neural conditioning and will occur slower than those seen as a result of chiropractic adjustment.

While both individual treatment methods proved successful in increasing cervical strength, the combination of treatments proved to be more effective than either treatment alone. The strengthening effects of the chiropractic adjustment and combination treatment were measurable earlier in the treatment regimen than those of resistance training protocol.

If one were to choose single method of treatment to increase cervical strength, then chiropractic adjustment would be the obvious choice when compared to resistance training. However, a combination chiropractic adjustment and resistance training was shown to produce the greatest strength increases.

The results of this study are of particular importance in rehabilitation. This study proved that hypomobility inhibits short term strength gains. The addition of chiropractic adjustment to a resistance training protocol substantially increases cervical strength gains in the first three weeks of training. By correcting hypomobility, the chiropractic adjustment allows full expression of range of motion and neural integrity in the region. This allows for greater muscle strength gains in a shorter time period. Therefore when rehabilitating a joint, the addition of chiropractic treatment to the strengthening programme will shorten recovery time and aid the joint in returning to optimum function both in terms of range of motion and strength.

In the competitive sporting arena the addition of chiropractic treatment to an athlete’s training programme will immediately increase the athlete’s potential for strength gain. This study proved that a minimum of 31% cervical strength increase was obtained by the use of chiropractic adjustment alone in just three weeks. Comparatively, in the same time period a resistance training programme recorded a minimum of 15% and a maximum of 25% cervical strength gain. Combining the treatments resulted in a minimum cervical strength gain of 47 %. The addition of chiropractic adjustment to an athlete’s existing training programme will positively influence their performance.

In conclusion, this study has proved that when attempting to increase muscle strength, chiropractic adjustment was more effective, in the short term, than resistance training. In order to obtain optimum strength gains, a combination of chiropractic adjustment and resistance training should be used.

6.2 Recommendations

The following recommendations may improve the outcome of this study:

- A larger sample group. The small sample size of each group allowed for small variations to have a substantial effect on the outcome of the study. Larger groups may produce statistically significant differences.

- A longer period of investigation. The graphical representation of the isometric dynamometer results indicate that the strength gains had not yet plateau in any of the 3 groups. A longer time period may allow the researcher to determine at what point each treatment method reaches its maximum effect.
- The use of surface electromyography in conjunction with isometric dynamometer studies.
- A similar study may be conducted, using similar treatment protocols, on a different region of the body to determine if the results of this study are universal or restricted to the cervical spine.
- A numerical pain scale should be used as instead of a Vernon-Mior Neck Disability Index, as this will more accurately indicate the participant's perception of their pain.

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APPENDIX A:

DEPARTMENT OF CHIROPRACTIC

INFORMATION AND CONSENT FORM

I, Kate Kelly, hereby invite you to participate in my research study. I am currently a chiropractic student completing my Masters Degree at the University of Johannesburg.

This study will compare the effect of chiropractic adjustment with a resistance training protocol, to chiropractic adjustment or resistance training protocol alone, on neck strength in cervical facet syndrome.

Should you choose to participate, a case history, physical examination and cervical spine assessment will be completed. An isometric dynamometer will be used to determine the strength of your cervical spine and a CROM devise used to measure your cervical range of motion. You will also be asked to fill out a questionnaire relating to your neck pain. You will either receive a resistance training protocol (to be performed at home 3 times a week), or a chiropractic adjustment to your neck or, you will receive a combination of both these methods. You will be required to partake in 7 trial sessions, over a period of 3 weeks. The dynamometer and CROM readings will be taken at the 1^{st}, 4^{th} and 7^{th} visits. You will also be required to fill in the questionnaire on these visits. All 7 visits will be free of charge. The first visit may last up to an hour due to the taking of a history and the performing of the physical exam. The follow up visits will last approximately 20 minutes. Please be aware that for the duration of this trail you will not be permitted to take any pain killers.

The chiropractic adjustment involves the restoration of normal joint motion. The researcher, via motion palpation, will detect any hypomobile motion segments in your neck. These segments will then be adjusted. The chiropractic adjustment is a safe, non-invasive chiropractic technique.

The research study will take place at the University of Johannesburg Chiropractic Day Clinic. Your privacy will be protected, as only the doctor, the participant (you) and the clinician will be in the treatment room. Your anonymity will be ensured as your personal information will be converted into data and therefore cannot be traced back to you. Standard doctor/patient confidentiality will be adhered to at all times when compiling the research dissertation.

All procedures will be explained to you and all participation is entirely on a voluntary basis; withdrawal at any stage will not cause you any harm. With regards to this particular study, the discomforts due to neck adjustments include temporary neck pain and stiffness and possible headaches. Benefits include an increase in range of motion and possible increase in neck strength.

Results of this study will be made available to you on request.

I have fully explained the procedures and their purpose. I have asked whether or not any questions have arisen regarding the procedures and have answered them to the best of my ability.

Date: _________________________ Researcher: _____________________

I have been fully informed as to the procedures to be followed and have been given a description of the discomforts, risks and benefits expected from the treatment. In signing this consent form I agree to this form of treatment and understand my rights and that I am free to withdraw my consent and participation in this study at any time. I understand that if I have questions at any time, they will be answered.

Date: ______________________________ Participant: __________________________

Should you have any concerns or queries regarding the current study, the following persons may be contacted:

Researcher: Kate Kelly 082 780 9752

Supervisor: Dr C. Yelverton 011 559 6218

APPENDIX B: CASE HISTORY

RESEARCH

UNIVERSITY OF JOHANNESBURG

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

CASE HISTORY

Date: ________________

Patient: ______________________________ **File No:** ___________

Age: ______ **Sex:** ____________ **Occupation:** _________________

Student: __________________________ **Signature:** _________________

==

Complies with Inclusion criteria of the research:

Clinician: ___________________________
Signature: ___________________________

==

Examination:

Previous:	UJ Other	Current:	UJ Other

X-ray Studies:

Previous:	UJ Other	Current:	UJ Other

Clinical Path. Lab:

Previous:	UJ Other	Current:	UJ Other

Case status:

PTT: Conditional: Signed off: Final sign out:

Recommendations:

Students case history

1. *Source of history:*
2. *Chief complaint: (patient's own words)*

3. *Present illness:*

Location

Onset

Duration

Frequency

Pain (character)

Progression

Aggravating factors

Relieving factors

Associated Sx's and Sg's

Previous occurrences

Past treatment and outcome

4. *Other complaints:*

5. *Past history*

   General health status

   Childhood illnesses

   Adult illnesses

   Psychiatric illnesses

   Accidents/injuries

   Surgery

   Hospitalisation

6. *Current health status and lifestyle*

   Allergies

   Immunizations

   Screening tests

   Environmental hazards

   Safety measures

   Exercise and leisure

   Sleep patterns

   Diet

   Current medication

   Tobacco

   Alcohol

   Social drugs

7. *Family history:*
   Immediate family:

   Cause of death

   DM

   Heart disease

   TB

   HBP

   Stroke

   Kidney disease

   CA

   Arthritis

   Anaemia

   Headaches

   Thyroid disease

   Epilepsy

   Mental illness

   Alcoholism

   Drug addiction

   Other

8. *Psychosocial history:*

   Home situation
   Daily life
   Important experiences
   Religious beliefs

9. *Review of systems:*

   General

   Skin

   Head

Eyes

Ears

Nose/sinuses

Mouth/throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haernatologic

Endocrine

Psychiatric

APPENDIX C: PHYSICAL EXAMINATION

RESEARCH

UNIVERSITY OF JOHANNESBURG

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

PHYSICAL EXAMINATION

(NOTE: only if Cervical Spine Regional is complete)

Underline abnormal findings in **RED.** **Date:** ____________________

Patient: ________________________ **File No:** _______________

Clinician: ________________________ **Signature:** _______________

Student: ________________________ **Signature:** _______________

Height: _________ **Weight:** ________ **Temp:** __________

Rates: **Heart:** __________ **Pulse:** _________ **Respiration:** __________

Blood pressure:	**Arms:**	**L**	**R**
	Legs:	**L**	**R**

General Appearance:

____

____

____

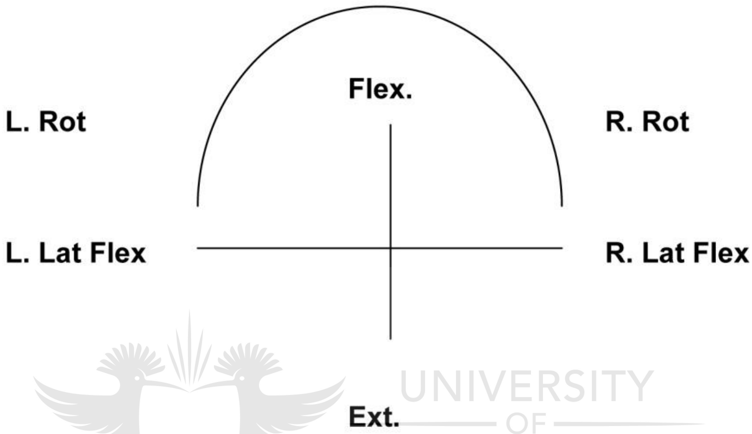
____

____

____

STANDING EXAMINATION

1. Minor's sign
2. Skin changes
3. Posture: Erect
   Adam's
4. Ranges of motion (Thoracolumbar Spine)
   T/L spine: Flexion: 90º (fingers to floor)
   Extension: 50º
   R. lat. flex: 30º (fingers down leg)
   L. lat. flex: 30º (fingers down leg)
   Rot. to R: 35º
   Rot. to L: 35º



/ = pain-free limitation **// = painful limitation**

5. Romberg's sign
6. Pronator drift
7. Trendelenburg's sign
8. Gait:
   - rhythm
   - balance
   - pendulousness
   - on toes
   - on heels
   - tandem
9. Half squat
10. Scapular winging
11. Muscle tone
12. Spasticity/Rigidity

13. Shoulder: skin
    symmetry
    ROM
    - glenohumeral
    - scapulo-thoracic
    - acromioclavicular
    - elbow
    - wrist

14. Chest measurement:

	L	R
- inspiration	cm	cm
- expiration	cm	cm

15. Visual acuity

16. Breast examination:
    Inspection: - skin
    - size
    - contour
    - nipples
    - arms overhead
    - hands against hips
    - leaning forward
    Palpation - axillary lymph nodes
    - breast incl. tail

<u>SEATED EXAMINATION</u>

1. Spinal posture
2. Head - hair
   - scalp
   - skull
   - face
   - skin
3. Eyes:
   Observation - conjunctiva
   - sclera
   - eyebrows
   - eyelids
   - lacrimal glands
   - nasolacrimal duct
   - position and alignment
   - corneas and lenses

- corneal reflex

- ocular movement

	L			R	
III	**IV**	**VI**	**III**	**IV**	**VI**

- visual fields
- accommodation
- Opthalmoscopic
- Examination - iris
  - pupils
  - red reflex
  - optic disc
  - vessels
  - general background

3

- macula
- vitreous
- lens

4. Ears:
- Inspection
  - auricle
  - ear canal
  - drum

- auditory acuity
- Weber test
- Rinne test

5. Nose:

- External
- Internal
  - septum
  - turbinates
  - olfaction

6. Sinuses (frontal & maxillary):
  - tenderness
  - transillumination

7. Mouth and pharynx:

- lips
- buccal mucosa
- gums and teeth
- roof
- tongue
  - inspection
  - movement
  - taste
  - palpation

- pharynx
  -CN X

  - inspection

- carotid arteries (thrills, bruit)
- Cranial Nerves
  - CN V
  - CN VII
  - CN VIII (nystagmus)
  - CN IX
  - CN XI
  - CN X11

8. Peripheral vasculature:
- Inspection
  - skin
  - nail beds
  - pigmentation
  - hair loss

- Palpation — - pulses: - femoral, - popliteal, - post. Tibial, - dorsalis pedis, - radial, - brachial

  - lymph nodes: - epitrochlear, - femoral (horizontal & vertical)
  - temperature (feet and legs)

- Manual compression test
- Retrograde filling (Tredelenburg) test
- Arterial insufficiency test

10. Musculoskeletal:

(i) ROM

- hip

	L	R
flex. 90/120		
ext. 15		
abd. 45		
add. 30		
int rot 40		
ext rot 45		
	L	**R**
flex. 130		
ext. 0/15		
	L	**R**
plantar Flex 45		
dorsiflex 20		
inversion 30		
eversion 20		
	L	**R**
Apparent		
Actual		

- knee

- ankle

(ii) leg length

- Co-ordination — - point to point
  - dysdiachokinesia

9. TMJ

- Inspection — - ROM
  - deviation
- Palpation — - crepitus
  - tenderness

10. Thorax

- Inspection
  - skin
  - shape
  - respiratory distress
  - rhythm (respiratory)
  - depth (respiratory)
  - effort (respiratory)
  - intercostals/supraclavicular retraction

- Palpation
  - tenderness
  - masses
  - respiratory expansion
  - tactile fremitus

- Percussion
  - lungs (posterior)
  - diaphgragmatic excursion
  - kidney punch

- Auscultation
  - (i) breath sounds
  - vesicular
  - bronchial
  - (ii) adventitious sounds
  - crackles (rales)
  - wheezes (rhonchi)
  - rubs
  - (iii) voice sounds
  - broncophony
  - whispered pectoriloquey
  - egophony

- Cardiovascular
  - auscultation (aortic murmurs)
  - Allen's test

<u>**SUPINE EXAMINATION**</u>

1. JVP
2. PMI
3. Auscultation heart
   (L. lat. Recumbent)
4. respiratory excursion
5. percussion chest
   (anterior)
6. breast palpation
7. Abdominal Examination

- Inspection
  - skin
  - umbilicus
  - contour
  - peristalsis
  - pulsations
  - hernias (umbilical/incisional)

- Auscultation
  - bowel sound
  - bruit

- Percussion
  - general
  - liver
  - spleen

- Palpation
  - superficial reflexes
  - cough
  - light
  - rebound tenderness
  - deep
  - liver
  - spleen
  - kidneys
  - aorta
  - intra-/retro-abdominal wall mass
  - shifting dullness
  - fluid wave

- Acute abdomen
  - where pain began and now
  - cough
  - tenderness
  - guarding/rigidity
  - rebound tenderness
  - rovsing's sign
  - psoas sign
  - obturator sign
  - cutaneous hyperaesthesia
  - rectal exam
  - Murphy's sign

<u>MENTAL STATUS</u>

(i) Appearance and behaviour
- level of consciousness
- posture and motor behaviour
- dress, grooming, personal hygiene
- facial expression
- affect

(ii) Speed and language
- quantity
- rate
- volume
- fluency
- aphasia (pm)

(ii) Mood

(v) Memory and attention

- orientation (time, place, person)
- remote memory

- recent memory
- new learning ability

(vi) Higher cognitive functions

- information and vocabulary
- (general and specialised knowledge)
- abstract thinking

NEUROLOGICAL EXAMINATION (LUMBAR SPINE)

DERMATOMES	**Left**	**Right**	**MYOTOMES**	**Left**	**Right**	**REFLEXES**	**Left**	**Right**
T12			**Hip Flexion (L1/L2)**			Patellar (L3, 4)		
L1			**Knee Extension (L2, 3, 4)**			Medial Hamstring (L5)		
L2			**Knee Flexion (L5/S1)**			Lateral Hamstring (S1)		
L3			**Hip Int. Rot (L4/L5)**					
L4			**Hip Ext. Rot (L5/S1)**					
L5			**Hip Adduction (L2, 3, 4)**					
S1			**Hip Abduction (L4/5)**					
S2			**Ankle Dorsiflexion (L4/L5)**					
S3			**Hallux Extension (L5)**					
			Ankle Plantar Flexion (S1/S2)					
			Eversion (S1)					
			Inversion (L4)					
			Hip Extension (L5/S1)					

APPENDIX D: CERVICAL SPINE REGIONAL EXAMINATION

RESEARCH

UNIVERSITY OF JOHANNESBURG

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

REGIONAL EXAMINATION
CERVICAL SPINE

Date: ____________________

Patient: __________________________ **File No:** ________________

Clinician: __________________________ **Signature:** ______________

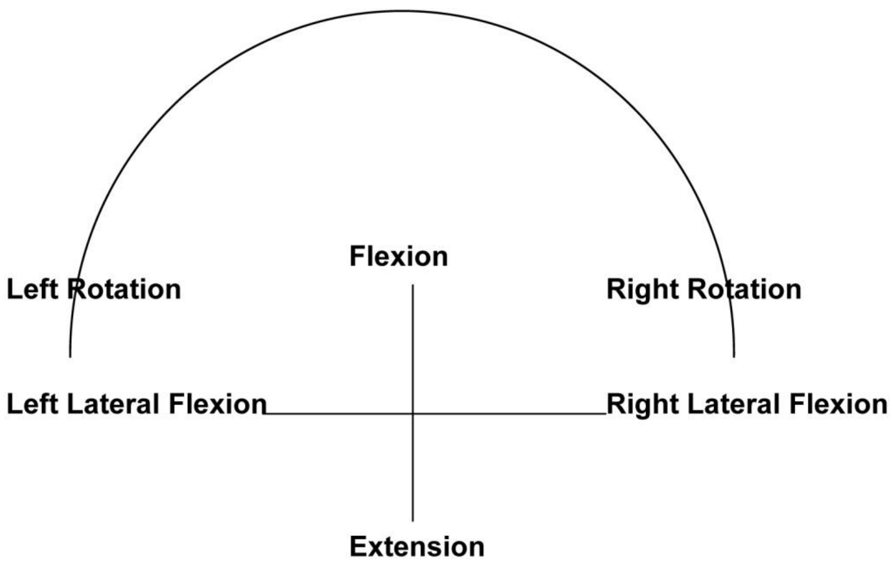
Student: __________________________ **Signature:** ______________

<u>OBSERVATION</u>

- Posture
- Size
- Swellings
- Scars
- Discolouration
- Hairline
- Bony and soft tissue contours
- Shoulder level
- Muscle spasm
- Facial expression

5. RANGE OF MOTION

Flexion	=	45º - 90º
Extension	=	55º - 70º
L/R Rotation	=	70º - 90º
L/R Lat Flexion	=	20º - 45º



/ = Pain free limitation **// = Painful limitation**

PALPATION

- Lymph nodes
- Trachea
- Thyroid gland
- Pulses/thrills
- Tenderness
- Muscle Tone
- Active MF Trigger Points
  - SCM
  - Trapezius
  - Scaleni
  - Levator Scapulae
  - Posterior Cervical musculature

ORTHOPAEDIC EXAMINATION

1. Doorbell Sign
2. Max. Cervical Compression
3. Spurling's manoeuvre
4. Lateral Compression (Jackson's test)
5. Kemp's Test
6. Cervical Distraction
7. Shoulder abduction Test

8. Shoulder depression Test

9. Dizziness rotation Test

10. Lhermitte's Sign

11. O' Donoghue Manoeuvre

12. Brachial Plexus Tension

13. Carpal tunnel syndrome:
    - Tinel's sign
    - Phalen's Test

14. TOS:
    - Halstead's test
    - Adson's test
    - Eden's (traction) test
    - Hyperabduction (Wright's) test – Pec minor
    - Costoclavicular test

Remarks:

VASCULAR	**LEFT**	**RIGHT**
BLOOD PRESSURE		
CAROTIDS		
SUBCLAVIAN ARTERIES		
WALLENBERG'S TEST		

COMMENTS:

MOTION PALPATION

Jt. Play			Left					Right				Jt. Play		
P/A	Lat	Fle	Ext	LF	AR	PR		Fle	Ext	LF	AR	PR	P/A	Lat
							C1							
							C2							
							C3							
							C4							
							C5							
							C6							
							C7							
							T1							
							T2							
							T3							
							T4							

NEUROLOGICAL EXAMINATION

DERMATOMES	Left	Right	MYOTOMES	Left	Right	REFLEXES	Left	Right
C2			**Neck Flexion** **C1/2**			Biceps C5		
C3			**Lat. Neck Flexion** **C3**			Brachioradialis C6		
C4			**Shoulder Elevation** **C4**			Triceps C7		
C5			**Shoulder Abduction** **C5**					
C6			**Elbow Flexion** **C5**					
C7			**Elbow Extension** **C7**					
C8			**Elbow Flexion at 90º** **C6**					
T1			**Forearm Pronation** **C6**					
			Forearm Supination **C6**					
			Wrist Extension **C6**					
			Wrist Flexion **C7**					
			Finger Flexion **C8**					
			Finger Abduction **T1**					
			Finger Adduction **T1**					

APPENDIX E: CONTRA-INDICATIONS TO SPINAL MANIPULATIVE THERAPY (Gatterman, 2005):

CONDITIONS
1. Vascular complications • Vertebral Artery Insufficiency Syndrome • Aneurysms
2. Tumours • Primary to the bone • Secondary (metastases to the bone)
3. Bone infections • Tuberculosis of the spine • Osteomyelitis of the spine
4. Traumatic injuries • Fractures • Instabilities • Dislocation • Unstable spondylolisthesis
5. Arthritis • Ankylosing spondylitis • Rheumatoid arthritis • Psoriatic arthritis • Reiter's syndrome • Osteoarthritis
6. Psychological considerations • Malingering • Hysteria • Hypochondriasis • Pain intolerance • Dependant personality

• Disability syndromes
7. Neurological complications • Cervical disc lesions and myelopathy 8. Nerve root damage
9. Joint instability or hypermobility

APPENDIX F: VERNON-MIOR NECK DISABILITY INDEX

SECTION 1--Pain Intensity

A. I have no pain at the moment
B. The pain is mild at the moment.
C. The pain comes and goes and is moderate.
D. The pain is moderate and does not vary much.
E. The pain is severe but comes and goes.
F. The pain is severe and does not vary much.

SECTION 2--Personal Care (Washing, Dressing etc.)

A. I can look after myself without causing extra pain.
B. I can look after myself normally but it causes extra pain.
C. It is painful to look after myself and I am slow and careful.
D. I need some help, but manage most of my personal care.
E. I need help every day in most aspects of self-care.
F. I do not get dressed, I wash with difficulty and stay in bed.

SECTION 3--Lifting

A. I can lift heavy weights without extra pain.
B. I can lift heavy weights, but it causes extra pain.
C. Pain prevents me from lifting heavy weights off the floor but I can if they are conveniently positioned, for example on a table.
D. Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.
E. I can lift very light weights.
F. I cannot lift or carry anything at all.

SECTION 4 --Reading

A. I can read as much as I want to with no pain in my neck.
B. I can read as much as I want with slight pain in my neck.
C. I can read as much as I want with moderate pain in my neck.
D. I cannot read as much as I want because of moderate pain in my neck.
E. I cannot read as much as I want because of severe pain in my neck.
F. I cannot read at all.

SECTION 5--Headache

A. I have no headaches at all.
B. I have slight headaches which come infrequently.
C. I have moderate headaches which come in-frequently.
D. I have moderate headaches which come frequently.
E. I have severe headaches which come frequently.
F. I have headaches almost all the time.

SECTION 6 -- Concentration

A. I can concentrate fully when I want to with no difficulty.
B. I can concentrate fully when I want to with slight difficulty.
C. I have a fair degree of difficulty in concentrating when I want to.
D. I have a lot of difficulty in concentrating when I want to.
E. I have a great deal of difficulty in concentrating when I want to.
F. I cannot concentrate at all.

SECTION 7--Work

A. I can do as much work as I want to.
B. I can only do my usual work, but no more.
C. I can do most of my usual work, but no more.
D. I cannot do my usual work.
E. I can hardly do any work at all.
F. I cannot do any work at all.

SECTION 8--Driving

A. I can drive my car without neck pain.
B. I can drive my car as long as I want with slight pain in my neck.
C. I can drive my car as long as I want with moderate pain in my neck.
D. I cannot drive my car as long as I want because of moderate pain in my neck.
E. I can hardly drive my car at all because of severe pain in my neck.
F. I cannot drive my car at all.

SECTION 9--Sleeping

A. I have no trouble sleeping
B. My sleep is slightly disturbed (less than 1 hour sleepless).
C. My sleep is mildly disturbed (1-2 hours sleepless).
D. My sleep is moderately disturbed (2-3 hours sleepless).
E. My sleep is greatly disturbed (3-5 hours sleepless).
F. My sleep is completely disturbed (5-7 hours sleepless).

SECTION 10--Recreation

A. I am able engage in all recreational activities with no pain in my neck at all.
B. I am able engage in all recreational activities with some pain in my neck.
C. I am able engage in most, but not all recreational activities because of pain in my neck.
D. I am able engage in a few of my usual recreational activities because of pain in my neck.
E. I can hardly do any recreational activities because of pain in my neck.
F. I cannot do any recreational activities at all.

APPENDIX G: DATA COLLECTION FORM

NAME: ____________________

FILE NO: ____________________

DATE: ____________________

<u>ISOMETRIC DYNAMOMETER READINGS</u>

Date of visit	**1st**	**4th**	**7th**
Flexion			
Extension			
Lateral flexion (right)			
Lateral flexion (left)			
Rotation (right)			
Rotation (left)			

NAME: ____________________

FILE NO: ____________________

DATE: ____________________

CROM Readings

Movement	1st	4th	7th
Flexion			
Extension			
Left Rotation			
Right Rotation			
Left Lateral Flexion			
Right Lateral Flexion			