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THE EFFECT OF CERVICOTHORACIC JUNCTION MANIPULATION ON GRIP STRENGTH

A dissertation submitted to the

Faculty of Health Sciences, Technikon Witwatersrand,
in partial fulfillment with the requirements for the
Master's degree in Technology
in the programme Chiropractic

by

Pedro Jose Nunes Pronto
(Student number: 9626160)

Supervisor: Dr. C Yelerton (M. Tech Chiro-S.A.)

Co-Supervisor: Ms M.S. van Rensburg (MSc)

Date 15-10-2002

Date 18-10-2002
DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Technology in Chiropractic at the Technikon Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other Technikon or University.

(Signature of Candidate)

On this ___ day of ___ 2002
ABSTRACT

The purpose of the study was to determine whether cervicothoracic joint manipulation had an effect on grip strength over a period of time.

Thirty subjects participated in this study, the requirements were lower cervical spine pain/discomfort in conjunction with a cervicothoracic joint motion restriction based on motion and static palpation. The subjects were recruited from the Technikon Witwatersrand and surrounding businesses by means of information pamphlets and word of mouth.

All the subjects received cervicothoracic joint manipulation six times each, three times in the first week, twice in the second week and finally once in the third week.

Grip strength readings, were done prior to and after all the treatments, to ascertain whether there had been an immediate change in grip strength, and whether the grip strength had changed from treatment to treatment. A Vernon Mior Neck Pain and Disability Index as well as a Numerical Pain Rating Scale 101 was completed on the subjects first, third, and sixth visit. A repeated measure student’s t-test (parametric) and a Wilcoxon Signed Rank Test (non-parametric) was performed. The results overall were shown to be statistically significant.

It has been shown that chiropractic manipulative therapy is an effective means of increasing grip strength in participants with cervicothoracic junction motion restriction. It has also been shown that patients in general benefited from this study with respect to pain intensity.
DEDICATION

To my wife Magdalini for your love, patience and motivation.
Hope there are many more happy and prosperous years ahead of us.
Thank you.
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CHAPTER ONE - INTRODUCTION
1.1 GENERAL INTRODUCTION

Muscle weakness or muscle imbalances are characteristic of many neuromusculoskeletal conditions. Deficits in strength may be due to many factors including aberrant neural involvement, fatigue, pain, strength weakness, or disease atrophy. Scientific knowledge of the effects of spinal manipulative therapy on muscle strength is absent, resulting in a restricted basis for therapy and treatment (Pollard & Ward, 1996).

A weak grip may be due to either central or peripheral nervous system disease (Bates, 1995). It has been shown that an alteration in biomechanical alignment over time, as seen with asymmetrical posture results in degenerative disease in the muscles, ligaments and bony structures (Harrison, Calliet, Harrison, Stephan, Trojanovich & Harrison, 1999).

The golgi tendon organ is a specialised receptor incorporated into the gross muscle structures, and it has an inhibitory effect on its own muscle by way of the homonymous motoneuron when its tension is excessive to the point of danger (Guyton, 1991). This may account for a decrease in muscle strength.

Benzel (1995) has demonstrated that this contributes to the overall pathological relationship between the neural elements and the surrounding bony and soft tissues. Terzis and Smith (1990) described the peripheral nerve as relatively resistant to ischaemia unlike the central nervous system. The signs and symptoms of muscle weakness, pain, paraesthesiae and sensory deficits may originate in these ischaemic nerve lesions due to chronic compression.

The aim of this study is to determine the effect of chiropractic manipulative therapy on grip strength. Participants will have to be symptomatic with regards to pain/discomfort in the lower aspect of the cervical spine and will also be required to have a cervicothoracic junction motion restriction based on motion and static palpation. The group will receive cervicothoracic junction joint manipulation over a period of three weeks. During this time change in grip strength and neck disability will be noted.
A short lever low amplitude, high velocity thrust (Gattennan, 1990), will be applied to the restricted cervicothoracic junction in the group. An isometric dynamometer will be used to determine whether there has been an increase in the isometric muscle strength and hence an increase in grip strength.

This study may indicate that patients treated with chiropractic manipulative therapy to the cervicothoracic junction will show an increase in grip strength.

1.2 AIM OF THE STUDY

The aim of this study is to determine whether chiropractic manipulative therapy can have a sustained stimulatory effect on the nervous system and hence increase grip strength over six treatments. The study also aims to provide sportsmen and women an alternative or reduction in the use of drugs, such as anti-inflammatories and analgesics.

Pain intensities in the Vernon Mior Neck Pain and Disability Index and the Numerical Pain Rating Scale 101 will also be noted.

1.3 BENEFITS OF THE STUDY

The current study may provide:

- A more effective means of rehabilitation.
- Chiropractors with an adjunctive or alternative means of increasing patient grip strength.
- An improvement in the wellbeing of patients.
CHAPTER 2 - LITERATURE REVIEW
2.1 CHIROPRACTIC MANIPULATIVE THERAPY

2.1.1 The chiropractic hypothesis

Gatterman (1990) describes chiropractic therapy as being based on the hypothesis that reversible joint lesions of the spine produce far-ranging effects on the human body. Chiropractors rely on spinal manipulation or adjustments as their primary therapeutic tool in reversing the subluxation complex. Modern chiropractic adheres to the idea that biomechanical dysfunction can have a profound effect, not only on the musculoskeletal system, but also on all other systems of the body. While the restoration and normalization of joint dysfunction is the mechanism of chiropractic therapy, the ultimate goal is to promote homeostasis of the body.

2.1.2 Vertebral adjustment

Haldeman (1992) defines spinal manipulative therapy as all procedures where the hands are used to mobilize, adjust, stimulate or otherwise influence the spinal and paraspinal tissues with the aim influencing the patient's health. Haldeman (1992) suggests that chiropractic care has been intimately associated with the manual skill referred to as the chiropractic adjustment. This procedure may be considered to be a more specific form of the generic term, spinal manipulative therapy. It also includes an awareness of the patient's environmental, nutritional, psychological and social status.

2.1.3 Vertebral subluxation/joint fixation

According to Schafer and Faye (1990) a subluxation is currently defined as an incomplete dislocation, a displacement in which the articular surfaces have not lost contact, or a partially reduced (spontaneously) dislocation. A spinal fixation has been described as the element in which a subluxation holds the vertebra in its abnormal placement and hinders its normal movement (Gatterman, 1990).
2.1.4 Components of the subluxation complex

Gattennan (1990) indicates that the components of the vertebral subluxation include:

- **Neuropathophysiology**: which states that the subluxation complex is based on the model that joint fixation compromises neural elements, which produces irritation and/or compression of these structures. Nerve irritation results in increased neuronal activity through facilitation, while pressure that produces nerve compression leads to tissue degeneration.

- **Kinesiopathology**: which refers to the restriction of the vertebral segment due to factors such as muscle hypertonicity, joint stabilization, muscle spindle-muscle spasm cycles, arthrokinetic reflex, joint sprain-muscle spasm cycle as well as articular adhesion.

2.2 THE VERTEBRAL SUBLUXATION COMPLEX (VSC)

Central to the philosophy, science and practice of chiropractic is the vertebral subluxation. According to the definition agreed on by the nominal and Delphi panels of the Consortium for Chiropractic research, subluxation is defined as a motion segment in which the alignment, movement integrity, and/or physiologic function are altered although contact between the joint surfaces remains intact (Lantz, 1995).

The Vertebral Subluxation Complex is defined as a theoretical model of motion segment dysfunction (subluxation) that incorporates the complex interaction of pathologic changes in nerve, ligamentous, vascular and connective tissue. The current model of the VSC appreciates that when a spine is dysfunctional, all tissues are involved in such an interconnected way that it is impossible to discern where one tissue involvement ends and another begins. Common to all aspects of subluxation are some forms of kinesiological dysfunction and some form of neurological involvement (Lantz, 1995).
The neurological component of the VSC has traditionally been the cornerstone of chiropractic theory. The nervous system has been viewed as the mediator of health and vitality to all individual organs and tissues. In the diagnostic evaluation, motor function, reflexes, altered sensation and pain responses are primary indicators of neurologic function (Lantz, 1995). (See figure 2.1)

Figure 2.1: Organisational Model of the Vertebral Subluxation (Lantz, 1995)
2.3 THE ANATOMY OF THE SPINE

The anatomy of the human spine can best be understood if the functions are considered first. The spine has three functions: support of the body, protection of the spinal cord and the spinal roots, and the movements of the trunk. These functions are carried out by a series of movable bones, called vertebrae and the soft tissues that surround these bones (Cramer & Darby, 1995).

2.3.1 Functional anatomy

For descriptive purposes, the cervical spine can be divided and perceived as consisting of four units, each with a unique morphology that determines its kinematics and its contribution to the functions of the complete cervical spine. In anatomical terms the units are the atlas, the axis, the C2-C3 junction and the remaining typical cervical column. In metaphorical functional terms these can be perceived as the cradle, the axis, the root, and the column (Bogduk & Mercer, 2000).

According to Benzel (1995) the lordotic posture of the mid and lower cervical spine may aid in injury prevention. Most axial loads are imparted symmetrically to the spine rather than with a significant flexion component, which would cause asymmetrical load application.

Altered static alignment of the head, thorax and pelvis may be responsible for abnormal juxtapositions and subluxations as viewed on anterior-posterior X-rays, stress films and abnormal spinal dynamics (Troyanovich, Harrison & Harrison, 1998). Alterations in posture, especially in the sagittal plane, have both direct and indirect effects on the central nervous system and its associated structures (Harrison et al., 1999).

Harrison et al. (1999), explain that alteration in biomechanical alignment over time, as seen with asymmetrical posture, results in degenerative disease in the muscles, ligaments and bony structures.
2.3.2 The Cervicothoracic junction

For purposes of this study the cervicothoracic junction as proposed by the researcher consists of the following segments: C6, C7, T1 and T2.

2.4 THE CERVICAL VERTEBRAE

The seven cervical vertebrae are the smallest movable vertebrae and identifiable by their transverse processes, which are perforated by a foramen. The third, fourth, fifth and sixth vertebrae are "typical" vertebrae and the first, second, and seventh are "atypical" vertebrae (Williams & Warwick, 1980).

2.4.1 Typical cervical vertebrae

A typical cervical vertebrae has a relatively small and transversely broad body; the vertebral foramen is comparatively large and triangular rather than round. In conformity with this the pedicles project somewhat laterally as well as backwards, and the laminae are angled markedly from them in a medial direction. Superior and inferior vertebral notches are almost equal in depth, the pedicles being attached about midway between upper and lower borders of the body (Williams & Warwick, 1980).

The laminae are relatively long and narrow, with a thin upper border. The spinous process is short and bifid, with terminal tubercles often unequal in size. The superior and inferior articular processes form an articular pillar, which bulges laterally at the junction of pedicle and lamina (Williams & Warwick, 1980).

The intervertebral disc has two primary functions, to allow and limit mobility between adjacent vertebrae by acting as a contained hydraulic material. Like the intervertebral disc, the zygapophyseal joints respond to multiple load vectors.
Together with the disc, zygapophyseal joints resist compressive forces in the subaxial cervical spine. The share of the compressive load resisted by the two-zygapophyseal joints at any cervical level depends on the orientation of the joint and eccentricity of the external compressive force (Yoganadan, Kumaresan & Pintar, 2001).

The transverse process of adult anatomy is morphologically a compound structure containing the foramen transversarium (Williams & Warwick, 1980). (See figure 2.2)

![Figure 2.2: The Typical Cervical Vertebrae (Williams & Warwick, 1980)](image)

### 2.4.2 Atypical vertebrae - The seventh cervical vertebrae

The seventh cervical vertebra is often called the vertebra prominens; it has a long spinous process, which is visible through the skin at the lower end of the nuchal furrow. The seventh cervical spinous process is thick, almost horizontal, and ends in a single tubercle, to which the lower end of the ligamentum nuchae is attached (Williams & Warwick, 1980).

The seventh cervical vertebra presents a foramen processus transversus, but is not transversed by the vertebral artery. The seventh cervical vertebra does, however, transmit a vein and the gray ramus communicans from the cervicothoracic ganglion to the seventh cervical nerve. In other respects this vertebra is typical cervical with thoracic tendencies (Coetzee, 1987). (See figure 2.3)
2.4.3 Unco-Vertebral joints

Located in the vertebral body - disc - vertebral body medium, from C2 to T1, are clefts (formerly known as Lushka's joints/ Unco-Vertebral joints). The clefts are not formed at birth, and therefore do not constitute joints. They arise late in childhood; become more evident in the young adult; and increase in size with advancing age, extending to meet in the midline to produce a transverse fissure across the back of the disc. They arise in the annulus fibrosus between the uncinate processes of the lower vertebral body laterally and the saddle contour of the caudolateral aspect of the upper vertebral body medially (Yoganadan, Kumaresan & Pintar, 2001). (See figure 2.4)
2.5 BIOMECHANICS OF THE LOWER CERVICAL SPINE

In the neutral position, the vertebral bodies are connected by an intervertebral disc, which is in the position of equilibrium with the fibers of the annulus uniformly stretched. They are also connected by articular processes whose articular surfaces are oblique inferiorly and posteriorly. At this level of the vertebral column these facets are slightly concave anteriorly in the parasaggital plane and their centre of curvature lies a long way inferiorly and anteriorly (Kapandji, 1974).

During extension the overlying vertebral body tilts and slides posteriorly. The intervertebral space is compressed posteriorly, the nucleus pulposus is driven slightly anteriorly and the anterior fibers of the annulus fibrosus are stretched. As the posterior sliding of the vertebral body does not occur above the centre of curvature of the articular facets of the articular processes, the interspace of the joints between the processes is widened anteriorly (Kapandji, 1974).

The superior articular facet not only slides inferiorly and posteriorly on the inferior facet but also tilts posteriorly with the formation of an angle $x'$ equal to the angle of extension $x$ and to the angle $x''$ between the normals to the two articular facets. Extension is limited by the tension developed in the anterior longitudinal ligament and by the impact of the superior articular process of the lower vertebrae on the transverse process of the upper vertebrae and especially by the impact of the posterior arches through the ligaments (Kapandji, 1974).

During flexion the upper vertebral body tilts and slides anteriorly, compressing the intervertebral space anteriorly and driving the nucleus posteriorly and stretching the posterior fibres of the annulus. This tilting of the upper vertebrae is helped by the anterior ledge on the superior plateau of the lower vertebrae, which allows the beak-like projection of the lower plateau of the upper vertebrae to move past (Kapandji, 1974).
Just as with extension, flexion of the vertebrae does not occur around the centre of curvature of the facets of the articular processes. As a result the inferior facet of the upper vertebra moves superiorly and anteriorly and the interspace is opened out posteriorly by an angle $\gamma'$ which is equal to the angle of extension $\gamma$ and the angle $\gamma''$ between the normals to two articular facets. Flexion is not limited by bony impact but only by the tension developed in the posterior longitudinal ligament, the capsular ligament of the joint between the articular processes, the ligamenta flava, the ligamentum nuchae and the posterior cervical ligament (Kapandji, 1974).

In the horizontal plane, axial rotation is inexorably coupled with ipsilateral lateral flexion. Lateral flexion and rotation in the lower cervical vertebral column is governed by the orientation of the facets of the articular processes, which prevents pure rotation or pure lateral flexion. (Kapandji, 1974). (See figure 2.5)

Figure 2.5: Biomechanics of the Lower Cervical Spine (Kapandji, 1974)
In the cervical spine, rotation about the Z-axis is coupled to rotation about the Y-axis, and vice versa. In other words during lateral bending the cervical centra tend to rotate toward the concavity while the spinous processes swing in a larger arc towards the convexity. For example during cervical bending to the right the right facet of the superior vertebra slides down the facet plane and toward the posterior and the left facet slides up the facet incline and anteriorly. This coupling phenomenon is exaggerated in circumstances in which an unusual ratio of axial rotation and lateral bending produces a subluxation or unilateral facet dislocation. At C7, there is 1° of rotation for every 7.5° of lateral flexion, a 2:15 ratio (Schafer & Faye, 1990).

2.5.1 Movements at the Unco-Vertebral joints

In the above text we have only discussed movements at the joints between the articular processes and the intervertebral discs but in the cervical spine movement also occurs a two small additional joints the Unco-Vertebral joints (Joints of Lushka) (Kapandji, 1974).

During flexion and extension, when the body of the upper vertebra slides anteriorly or posteriorly, the articular facets of the Unco-Vertebral joints also slide relative to each other. Thus these uncinate processes "guide" the vertebral body into this anteroposterior movement (Kapandji, 1974).

During lateral flexion the interspaces of the Unco-Vertebral joints open out by an angle a' or a" equal to the angle of lateral flexion a, and to the angle formed between the two horizontal lines nn' and nm' joining the transverse processes. There is also contralateral displacement of the nucleus and the stretching of the capsule of the contralateral Unco-Vertebral joint (Kapandji, 1974). (See figure 2.6)
2.6 THE THORACIC VERTEBRAE

The twelve thoracic vertebrae show a gradual increase in size downwards, like other vertebrae, an expression of the increasing load carried from head to sacrum. All are distinguished by their costal facets on the sides of their bodies, and all but the last two or three by facets on their transverse processes. The first and the ninth to twelfth thoracic vertebrae possess certain peculiarities and are considered separately to the others (Williams & Warwick, 1980).
2.6.1 Typical thoracic vertebrae

The body of the typical thoracic vertebra is cylindrical except where the vertebral foramen encroaches upon it behind; its transverse and anteroposterior dimensions are therefore almost equal. On each side it bears two costal facets; the superior pair are usually larger and are at the upper border in front of the root of the pedicle. The inferior facets are at the lower border immediately in front of the vertebral notch (Williams & Warwick, 1980).

The vertebral foramen is relatively small, and its circular outline can be linked with the fact that the pedicles do not diverge, as in the cervical vertebrae and that the thoracic part of the spinal cord is smaller and more nearly circular. The laminae are hence also short, and they are thick, broad, and overlap each other from above downwards. The superior articular processes, thin plates of bone, project upwards at the junctions of pedicles and laminae. They are almost flat and face back, and a little laterally and upwards (Williams & Warwick, 1980).

The inferior processes are downward projections of the laminae, their facets directed forwards and a little medially and upwards. The transverse processes are substantial and club-shaped projections from the vertebral arch at junctions of pedicles and laminae. They point laterally and somewhat backwards; they bear, anteriorly near their tips, oval facets, which articulate with the tubercles of the corresponding ribs (Williams & Warwick, 1980). (See figure 2.7)

Figure 2.7: Typical Thoracic Vertebrae (Williams & Warwick, 1980)
2.6.2 The first thoracic vertebrae

The first thoracic vertebra is distinguished by the upper costal facets on its body. These are circular, articulating with the whole of the facet on the head of each rib. The inferior facets are small and semi-lunar; they articulate, as is usual through the thoracic series, with a demifacet on the head of the rib. The spine is thick, long and horizontal, and is commonly as prominent as that of the seventh cervical vertebrae (Williams & Warwick, 1980). (See figure 2.8)

![Figure 2.8: The First Thoracic Vertebrae (Williams & Warwick, 1980)](https://example.com)

2.7 BIOMECHANICS OF THE THORACIC SPINE

Flexion and extension of the thoracic spine are limited (Schafer & Faye, 1990).

Schafer & Faye (1990) described thoracic extension from full flexion as taking place in two phases:

**Phase I**

The articular surfaces glide posteriorly and inferiorly, the interspinous spaces close, and the stretched posterior annulus of the disc returns to its normal shape as the individual achieves the erect position. There is no appreciable change in the anterior aspect of the disc’s annulus or its nucleus.
Phase II

It is not until the shingle-like facets, transverse processes, and the spinous processes reach their limit as the spine is extended posterior to the midline that the anterior discs and anterior intercostal spaces begin to widen. On forced extension, the articular processes impact. The vertebrae then push between their ribs, and the rib heads and their angles are moved slightly aside by the transverse processes.

Although lateral flexion is hampered by the rib cage, the average person should be able to touch the ipsilateral knee during lateral flexion with the fingertips. During lateral flexion in either the neutral or forward flexed position, there is generally thought to be some coupled rotation where the upper vertebral bodies swing toward the concave side of the curve and the spinous processes rotate toward the convexity as in the cervical spine. This sidebending-rotation requires transverse process movement anteriorly, pushing against the rib on the convex side and posterior transverse process movement pulling away from a rib on the concave side (Schafer & Faye, 1990).

Rotation of the thoracic spine, possibly coupled with some vertebral body tilting, is somewhat greater than flexion and extension that are about equal in range. There are a few degrees of coupled flexion during upper thoracic rotation. It is evident, that the involved vertebrae rotate and flex with their attached ribs, which also glide laterally on their neighbour below (Schafer & Faye, 1990).

2.8 SPINAL NERVES

The most important role of the nervous system is to control various bodily activities including that of skeletal muscle contraction throughout the body (Guyton, 1991).

The dorsal and ventral roots of the spinal cord form the spinal nerves. There are 31 spinal cord levels (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, 1 coccygeal), thus 31 corresponding pairs of spinal nerves are found.
Each spinal nerve contains afferent fibers that convey sensory input from the periphery and efferent fibers arising from spinal motor neurons. The spinal nerve may contain up to four types of fibers. Two of these are sensory and have their cell bodies in the dorsal root ganglion, and two are motor and have their cell bodies in the spinal cord gray matter. (Haines, 1997). (See figure 2.9)

Figure 2.9: The Spinal Nerve (Haines, 1997)

The dorsal rami of the spinal nerves supply the skin of the medial two thirds of the back from the top of the head to the coccyx, the deep (intrinsic) muscles of the back and the zygapophyseal vertebral joints. Each dorsal ramus supplies the strip of skin, muscle and the zygapophyseal joints located at the level of its origin. The ventral rami of spinal nerves supply the rest of the spinally innervated muscles, skin and joints of the neck, trunk and extremities (Reid, 1992).

2.8.1 Motor components of the spinal nerve

The spinal cord gives rise to two types of motor fibers: (1) those that directly innervate skeletal (striated) muscle, and (2) autonomic fibers that synapse on a second neuron, usually located in an autonomic ganglion. The motor cells that innervate skeletal muscle are located in the ventral horn.
These cells and their peripheral processes are classified as general somatic efferent (GSE). GSE cells from the ventral hom also supply innervation to the specialized intrafusal muscle fibers of the muscle spindles, sensory structures that detect muscle length and various aspects of contraction dynamics (Haines, 1997).

Large motor neurons in the ventral hom are organized in two general, but overlapping, patterns. First, cells innervating proximal muscles are located medially, and cells innervating more distal muscles are located progressively more laterally. This explains why the ventral hom is smaller and narrower at thoracic than cervical and lumbar levels. At thoracic levels the ventral hom contains more motor neurons for only the axial muscles of the trunk, whereas at cervical and lumbar levels it also contains the more lateral groups of motor neurons that innervate the limbs. Second, within the ventral hom at C4 to T1 and L1 to S2, motor neurons innervating extensors tend to be more ventrally located, whereas those innervating flexors tend to be found more dorsally (Haines, 1997).

Motor fibers, general somatic efferent and general visceral efferent exit in the ventral root and pass into the spinal nerve. General somatic efferent fibers continue through the spinal nerve and are conveyed by the progressive branching of peripheral nerves to the skeletal muscles of the body (Haines, 1997). (See figure 2.9)

### 2.9 Anatomy of the Nerves of the Hand and Forearm

Three major nerves - the median, ulnar, and radial - supply both motor and sensory innervation to the hand and forearm (Martin & Collins, 1998).

#### 2.9.1 The Median nerve

The median nerve is formed in the axilla by a coalescence of branches from the lateral and the medial cords of the brachial plexus, with contributions from C5, C6, C7, e8, and T1.
The median nerve travels down the anteromedial aspect of the arm deep to the biceps muscle adjacent to the brachial artery. It continues across the elbow into the forearm superficial to the brachialis muscle in the central portion of the ann. At the elbow, the median nerve lies medial to the brachial artery, which in turn lies medial to the biceps tendon (Martin & Collins, 1998).

The median nerve passes deep to the lacertus fibrosus and enters the forearm between the superficial and deep heads of the pronator teres muscle. After passing through the pronator teres, the median nerve passes deep to the flexor digitorum superficialis under the flexor digitorum superficialis (FDS) arch. At approximately this level, the median nerve gives off the anterior interosseous nerve, which travels along the anterior surface of the interosseous membrane in the interval between the flexor pollicis longus and the flexor digitorum profundus (Martin & Collins, 1998).

The anterior interosseous nerve provides motor input to the radial half of the flexor digitorum profundus, the flexor pollicis longus, and the pronator quadratus. After passing beneath the FDS arch, the median nerve travels down the forearm in the plane between the flexor digitorum superficialis and flexor digitorum profundus to the most distal portion of the forearm. At that point, it becomes more superficial among the tendons of these muscles (Martin & Collins, 1998).

At the wrist, the median nerve lies just deep to and between the flexor carpi radialis and palmaris longus tendons (if present). In the distal forearm, the median nerve gives off a superficial branch, the palmar cutaneous branch of the median nerve, which provides sensation to the proximal palm of the hand. The median nerve then passes through the carpal tunnel accompanied by the flexor tendons to the fingers. Somewhat variably at this level, the median nerve gives off the recurrent motor branch to the thenar eminence (Martin & Collins, 1998).
The motor branch characteristically follows a recurrent course from distal to proximal to innervate the abductor pollicis brevis, the opponens pollicis, and the superficial head of the flexor pollicis brevis. Immediately on leaving the carpal tunnel, the median nerve divides into three common palmar digital nerves. The first branch divides proximally to supply the proper palmar digital nerves to the thumb and the radial aspect of the index finger (Martin & Collins, 1998).

The second and third branches divide more distally and give branches to the ulnar aspect of the index finger, the radial and ulnar aspects of the long finger, and radial aspect of the ring finger. In the fingers, the digital nerves are located just palmar to and central to the digital arteries. Clearly defined neurovascular bundles may be defined to a level distal to the distal interphalangeal joints (Martin & Collins, 1998). (See figure 2.10)

Figure 2.10: The Median nerve (Martin & Collins, 1998)
2.9.2 The Ulnar nerve

The ulnar nerve is formed in the axilla from the medial cord of the brachial plexus with contributions from C8 to T1. It runs down the medial aspect of the arm piercing the medial intermuscular septum dorsally at the mid-arm. It then continues distally between the septum and the triceps muscle, accompanied by the superior ulnar collateral artery (Martin & Collins, 1998).

The nerve passes into the forearm via the cubital tunnel, whose entrance is formed by the medial epicondyle and the olecranon. Within the tunnel, the nerve passes between the two heads of flexor carpi ulnaris. It then continues along the undersurface of this muscle down to the distal wrist. Proximally, the nerve gives off motor branches to the flexor carpi ulnaris and to the ulnar half of the flexor digitorum profundus (Martin & Collins, 1998).

Proximal to the wrist, the nerve gives off a dorsal sensory branch that passes dorsally from under the flexor carpi ulnaris. It then divides to provide sensory branches to the ulnar side of the dorsum of the hand and the dorsum of the ring and the little finger out to the level of the proximal interphalangeal joints. In the distal forearm, the ulnar nerve gives off a palmar sensory branch that gives sensation to the ulnar surface of the palm. The ulnar nerve is joined by the ulnar artery in the mid-forearm (Martin & Collins, 1998).

At the distal wrist, the ulnar artery and nerve lie side by side beneath the tendon of the flexor carpi ulnaris, with the ulnar artery radial to the nerve. Both artery and nerve pass into the hand through Guyon’s canal between the pisiform and hook of hamate. Within the canal, the nerve divides into superficial and deep branches (Martin & Collins, 1998).
The superficial branch supplies motor innervation to the palmaris brevis muscle and sensation to the hypothenar eminence. It then divides into digital branches, with a proper digital nerve to the ulnar aspect of the little finger and a common digital nerve, which divides into proper digital nerves, to the radial aspect of the little finger and the ulnar half of the ring finger (Martin & Collins, 1998).

The deep branch of the ulnar nerve accompanies the deep branch of the ulnar artery. Together they pass between the abductor digiti minimi and the flexor digiti minimi brevis, and then pass through the opponens digiti minimi muscle. The deep branch of the ulnar artery continues in a plane dorsal to the flexor tendons. The deep palmar arch and the deep branch of the ulnar nerve follows along with it, giving motor branches to the small and ring finger lumbricals, all of the interossei, adductor pollicis, and the deep head of the flexor pollicis brevis (Martin & Collins, 1998). (See figure 2.11)

Figure 2.11: The Ulnar nerve (Martin & Collins, 1998)
2.9.3 The Radial nerve

The radial nerve is formed in the axilla from the posterior cord of the brachial plexus with contributions from C4 to T1. The nerve passes medial to lateral deep to the triceps along the posterior aspect of the middle third of the humerus, accompanied by the profunda brachii artery. In the spiral groove, the radial nerve gives off the posterior antebrachial cutaneous nerve, which provides sensation to the dorsal forearm. Distal to the spiral groove, the radial nerve pierces the lateral intermuscular septum at the junction of the middle and distal thirds of the humerus and passes across the elbow anterior to the lateral epicondyle between the brachialis and brachioradialis muscles (Martin & Collins, 1998).

Deep to the brachioradialis muscle, the radial nerve gives off motor branches to the brachioradialis and extensor carpi radialis muscles, and then divides to form the superficial sensory branch radial nerve and the deep radial (posterior interosseous) nerve. The superficial radial nerve continues along the undersurface of the brachioradialis muscle into the distal forearm (accompanied by the radial artery in the middle third of the forearm) (Martin & Collins, 1998).

It exits from under the brachioradialis at approximately the musculo-tendinous junction at the distal third of the forearm and passes dorsally over the wrist. At that point, it divides into multiple branches that provide sensation to the radial side of the dorsum of the hand and fingers to approximately the level of the proximal interphalangeal joints. In the proximal forearm, the posterior interosseous branch of the radial nerve gives off motor branches to the extensor carpi radialis brevis and the supinator. It then passes deep into the forearm between the superficial and deep heads of the supinator muscle (Martin & Collins, 1998).

After passing through the supinator, branches are given to the extensor digitorum communi, extensor digiti minimi, extensor carpi ulnaris, extensor and the extensor indicis proprius. The terminal branches of the posterior interosseous nerve provide deep sensation to the dorsum of the carpus (Martin & Collins, 1998). (See figure 2.12)
2.10 SKELETAL MUSCLES

Skeletal muscles according to Moore (1992) produce movements of the skeleton and are often called voluntary muscles. Skeletal muscle is made up of a series of many smaller functional motor units. These motor units in tum consist of muscle fibers, which receive their innervation collectively from a single lower motor neuron emanating from the spinal cord. The strength or force of contraction of skeletal muscle mostly depends upon the number and size of the motor units recruited by a stimulus, and the frequency of action potentials to that motor unit and hence the rate at which they are activated (Pollard & Ward, 1996).

The motor neurons that supply the motor units have many synaptic inputs within the spinal cord.
Most inputs are from spinal interneurons (both excitatory and inhibitory) making up the interneuronal pool, while only a few inputs are from cerebral motor centers. All of these inputs can be responsible for the activation of the motor units. Recently the importance of the spinal cord segmental neurology, as well as inflammation in a related area, causing and sustaining a level of hyperexcitability in the spinal cord has been brought to the fore. This has been shown to bring about alterations in both short term and relatively permanent changes in the neural characteristics of the cord and can also result in changes to peripheral structures (Pollard & Ward, 1996).

2.11 MYOTOMES

According to Magee (1997), it is possible to determine the muscle power and possible neurological weakness originating from the nerve roots in the cervical spine by testing the myotomes. Myotomes are tested by resisted isometric contractions with the joint at or near the resting position. This type of movement consists of a strong, static (isometric), voluntary muscle contraction, and is used to determine whether the contractile tissue is the tissue at fault.

2.11.1 Cervical myotomes

Magee (1997) describes the cervical myotomes as follows:

- Neck flexion controlled by C1 and C2 myotome
- Neck lateral flexion controlled by C3 myotome
- Shoulder elevation controlled by C4 myotome
- Shoulder abduction controlled by C5 myotome
- Elbow flexion and/or extension controlled by C6 myotome
- Elbow extension and/or wrist flexion controlled by C7 myotome
- Thumb extension and/or ulnar deviation controlled by C8 myotome
- Abduction and/or Adduction of hand intrinsics controlled by T1 myotome
2.12 STAGES OF GRIP

According to Bates (1995), grip requires the action of muscles innervated by the nerve roots C7, C8 & T1. This may show that chiropractic manipulative therapy of the cervicothoracic junction may possibly increase grip strength.

The basic function in gripping is the finger flexion activated by the finger flexors in the forearm. However, in order to maintain a straight wrist, the wrist extensors have to be activated to counteract the wrist torque caused by the finger flexion tendons. Hence gripping activity involves flexion as well as extension muscles in the forearm (Hagg & Milderad, 1997).

2.12.1 Grip strength measures

Manual muscle testing has been described as a method of evaluating nerve function (Walther, 1981). A weak grip may be due to either central or peripheral nervous system disease (Bates, 1995).

Magee (1997) defines the four stages of grip as follows:

Stage I
Opening of the hand which requires the simultaneous action of the intrinsic muscles of the hand and the long extensor muscles.

Stage II
Closing of the fingers and thumbs to grasp the object and adapt to the object's shape, which involves intrinsic and extrinsic flexor and opposition muscles.

Stage III
Exerted force, which varies depending on the weight, surface characteristics, fragility and use of the object, again involving the intrinsic, extrinsic and opposition muscles.
StageN
Release in which the hand opens to let go of the object, involving the same muscles as for opening the hand.

2.13 THEORIES OF THE ADJUSTMENT

2.13.1 Reflex Theories of the Adjustment

The reflex theory proposes that the subluxation be considered an aberrant biomechanic relation within the spine, such aberrant relations are assumed to stimulate receptors in the spinal and the paraspinal tissues such as muscle ligaments and facets. The impulses generated by the stimulation of spinal structures presumably activate neural reflex centers within the spinal cord or higher centers. This causes somatovisceral responses in sympathetic and para-sympathetic nerves or somatic-somatic responses resulting in muscle spasm (Haldeman, 2000).

There are multiple sensory receptors in muscle, ligaments, facet joints, paraspinal skin, the meninges, and the outer fibres of the intervertebral disc. These receptors are responsive to mechanical (position, motion, and tissue distortion), inflammatory (nociceptive) and temperature changes (Haldeman, 2000).

Previous observation of reflexive activity has been shown in spinal musculature distant to the site of spinal manipulation (Lehman & McGill, 2001). Spinal manipulation treatments show a consistent reflex response of multireceptor origin and may cause clinically observed benefits, including a reduction in pain and a decrease in hypertonicity of muscles (Davis, 2001).
The golgi tendon organ is another specialized receptor incorporated into the gross muscle structures, and it has an inhibitory effect on its own muscle by way of the homonymous motoneuron when its tension is excessive to the point of danger (Guyton, 1991).

There is good evidence that displacement of vertebrae modulate nerve activity in afferent nerves innervating muscle spindles and other low (mechanical) threshold receptors, such as the golgi tendon organs (Bolton, 2000). The signs and symptoms of muscle weakness, pain, paraesthesiae and sensory deficits may originate in ischaemic nerve lesions due to chronic compression (Terzis & Smith, 1990). It has been shown that damaged or irritated neurons are activated at much lower thresholds in response to mechanical deformations. Mechanical stress maintained in the nervous tissue because of abnormal spinal positions after sustained neuronal activity may predispose to a variety of pathological processes and neuronal disorders (Troyanovich, Harrison & Harrison, 1998).

2.13.2 Neurologic effects of manipulation

Colloca, Keller, Gunsburg, Vandeputte and Fuhr (2000) theorised that spinal manipulative therapy stimulates or modulates the somatosensory system, and it may then evoke the neuromuscular reflexes.

Pickar and Wheeler (2001) postulate that spinal manipulation affects impulse-based neural activity by altering the inflow of sensory information to the spinal cord. Mechanical forces introduced into the vertebral column may stimulate or inhibit receptive nerve endings in paraspinal tissues (including skin, muscles, tendons, ligaments, joints and the intervertebral disc).

Thus, spinal manipulation may remove an aberrant sensory input, or possibly add a new input. The manipulation-induced changes in sensory input are thought to affect central neural integration within motor, nociceptive and autonomic neuronal pools, and thereby elicit changes in efferent somatomotor and visceromotor activity (Pickar & Wheeler, 2001).
Colloca and co-workers (2001) have described a hypothetical mechanism for the neurological effects of spinal manipulation:

• Spinal manipulation increases joint mobility by producing a barrage of impulses in muscle spindle afferents, decreasing the activity of facilitated $\gamma$-motoneurons.

• $\gamma$-motoneuron discharge is elevated in muscles of vertebral segments in need of spinal manipulation. This impairs joint mobility by allowing the myotatic stretch reflex to detect very small changes in muscle length.

• The impulses from muscle spindle afferents in response to the spinal manipulation reduce the gain of the $\gamma$ loop.

• This resets the $\gamma$ bias by producing a high frequency discharge in the muscle spindle and golgi tendon organ afferent.

• Muscle spindles and golgi tendon organs therefore respond to spinal manipulative-like loads. The chiropractic subluxation affects reflex neural activity. Stimulation of muscle spindles from a given limb muscle evokes a monosynaptic excitatory potential in a a-motoneuron to the same muscle.
3.1 INTRODUCTION TO METHODOLOGY

This chapter serves to explain and describe the way in which this research project was constructed and carried out.

3.1.1 Study design and selection criteria

Candidates for the study were recruited from the Technikon Witwatersrand and businesses surrounding the Technikon Witwatersrand campus, through information pamphlets and word of mouth (Appendix A). The candidates had to be healthy and between the ages of 18 and 40 years, this was to ensure that there was not a major discrepancy in the grip strength of the candidates. Patients could be male or female.

The requirement for inclusion into the study was pain/discomfort in the lower cervical spine and the presence of a cervicothoracic junction motion restriction based on motion and static palpation.

Each candidate was required to sign a consent form (Appendix B). They were fully informed of the treatment protocol and they consented that they were willing to allow chiropractic spinal adjustments as well their grip strength measurements to be performed. They were also informed that they may withdraw from the study at any time should they wish to, and that all treatment was free of charge.

3.1.2 Treatment protocol

Thirty candidates were required to participate in the study. There was one group in the study. This group was treated using adjustments to the cervicothoracic junction. Each candidate was treated 6 times over a period of three weeks. Three times in the first week, twice in the second week and finally once in the third week.
Each candidate underwent a full cervical spine regional examination (Appendix C), which included orthopaedic tests, neurological testing, posture assessment, observation, palpation, range of motion and a vascular examination to rule out any contraindications to manipulative therapy. The cervical spine regional also served as a means of ruling out any other cause for their pain, other than the presence of a cervicothoracic junction movement restriction.

All candidates underwent a prone adjusting technique known as a Thumb Movement: Bench TM (States, 1991). (See figure 3.1)

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**Figure 3.1: The Thumb Movement: Bench TM**

- **L:** RP: LP: RI-L1: RL-LL: 5-T3. Laterality is opposite to the side of posteriority.
- **PP:** Prone antigravity: headpiece lowered; head turned to side homolateral to posteriority (away from doctor).
- **DP:** Fencer's stance facing cephalad: contralateral to posteriority, (homolateral to laterality). Cephalad foot even with patient's shoulder.
- **CH:** Cephalad hand: pad of thumb on lateral aspect of SP of listed vertebra: forearm parallel to floor.
- **IH:** Caudad hand: palm cups car.
- **T:** CH takes contact: IH indicate to patient to rotate head. IH tractions cephalad and into further rotation. CH thrusts straight across.
- **OTE:** If patient cannot rotate head full 90 degrees, modify technic by using IH to traction head lightly out of headpiece.
On the first visit a full cervical spine regional was completed. Each candidate was required to complete the Vernon Mior Neck Pain and Disability Index (Appendix D), and the Numerical Pain Rating Scale 101 (Vernon, 1996) (Appendix E). All candidates were also required to do a grip strength measurement before and after the treatment for both hands and the results were noted in the Jamar Hand Dynamometer Reading sheet (Appendix H). This allowed for a comparison pre- and post- manipulative therapy.

On each of the subsequent visits, candidates were also required to do grip strength measurements as before. However the candidates were only asked to complete the Vernon Mior Neck Pain and Disability Index and the Numerical Pain Rating Scale 101 (Vernon, 1996) on their first, third and finally on the sixth treatment.

3.2 DATA COLLECTION AND INTERPRETATION

3.2.1 Subjective data collection

The candidates were required to complete two questionnaires in order to collect subjective data this was in the form of the Vernon Mior Neck Pain and Disability Index and the Numerical Pain Rating Scale 101 (Vernon, 1996).

3.2.2 Vernon Mior Neck Pain and Disability Index

Vernon and Mior developed the 'Neck Pain and Disability Index' at the Canadian Memorial Chiropractic College (Vernon, 1996) (Appendix D). The Vernon Mior questionnaire is a method of assessing percentage disability specifically targeting activities of daily living, which are most affected by neck pain. Test-Retest reliability resulted in good statistical significance at 0.89. The total Cronbach's alpha, which is a measure of internal reproducibility, was 0.80 (Vernon, 1996).
The instructions for answering the questionnaire appeared at the top of the page. The patients were to answer every section and mark only one box in each section. Only that box that most closely described the patient's immediate condition was to be marked (Vernon, 1996).

Scoring, interpreting and reporting the Neck and Disability Index involved the following (Vernon, 1996):

In each section scores of 0 (statement 1) to 5 (statement 6) were possible. Thus, if all sections were completed a score of 50 that is 100% was possible.

Example: \[ \frac{18 \text{ (Total scored)}}{50 \text{ (Total possible)}} \times 100 = 36\% \]

If one section was missed out, scoring was done as follows:

Example: \[ \frac{16 \text{ (Total scored)}}{45 \text{ (Total possible)}} \times 100 = 35.5\% \]

With respect to interpretation of these total scores, the following overall ratings were used:

<table>
<thead>
<tr>
<th>0-20%</th>
<th>Minimal disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-40%</td>
<td>Moderate disability</td>
</tr>
<tr>
<td>40-60%</td>
<td>Severe disability</td>
</tr>
<tr>
<td>60-80%</td>
<td>Crippled</td>
</tr>
<tr>
<td>80-100%</td>
<td>Bed bound or exaggerating</td>
</tr>
</tbody>
</table>

The scoring method was never discussed or explained to the participants, to avoid influencing responses on subsequent questionnaires.
3.2.3 The Numerical Pain Rating Scale 101

The Numerical Pain Rating Scale 101 (NPRS) (Vernon, 1996) (Appendix E) is a refined Visual Analogue Scale (VAS) and was preferred over the unrefined VAS as it was easier to use with patients. With the NPRS (Vernon, 1996), patients were required to measure the pain severity of their headaches by selecting and marking one of eleven boxes ranging from 0 (no pain) to 10 (excruciating pain). The NPRS 101 (Vernon, 1996) is a valid and reliable measure of pain intensity (Cassidy, Quon, Lafrance & Yong Hing, 1992).

3.2.4 Objective data collection

The patients were required to use the Jamar Hand Dynamometer so that an objective reading of grip strength could be established. The Jamar Dynamometer consists of a gripping handle and a force gauge that measures the force in pounds (and kilograms) generated by the patient (Martin & Collins, 1998). The Jamar Dynamometer is a hydraulic device that measures mechanical forces or torque's by the elastic deformation produced (Bellace, Healy, Besser, Byron and Hohman, 2000). It has been shown to be the most common instrument used to evaluate grip strength (Taylor & Shechtman, 2000). The Jamar dynamometer was developed by Bechtol (Bellace et al., 2000).

Objective data was gathered using the Jamar Dynamometer to measure the candidates grip strength (Bellace et al., 2000) (Appendix G). The patients were asked to stand with their arm adducted, forearm flexed to ninety degrees in the neutral position and with the wrist neutrally rotated. Patients were then asked to squeeze the dynamometer three times with each hand, standing in the above position alternating the hands right to left.

The grip strength measurements were recorded in kilograms and are tabulated for comparison and statistical analysis (Appendix I and J). Readings were taken on all of the visits and repeated three times for reliability (Appendix H).
The ability to generate force while gripping requires the integration of the intrinsic muscles of the hand and the extrinsic muscles of the hand and wrist. The test retest reliability has been shown to be acceptable (Martin & Collins, 1998).

3.2.5 Cervicothoracic junction fixation

For the purpose of the study patients underwent motion palpation as well as static palpation. Motion palpation as described by Schafer & Faye (1990) of the cervicothoracic junction is in a seated position, and is recorded as a restriction of motion either in anterior rotation, posterior rotation and or lateral flexion.

Static palpation as determined by States (1985) of the cervicothoracic junction, is palpated in a seated posture, and is recorded as a right or left posterior and or inferior.

3.2.6 Statistical Analysis

The data was analyzed using the Sigma Stat Programme. A repeated measure student's t-test was performed initially on all the data, when the normality failed a non-parametric test was done namely the Wilcoxon Signed Rank Test. These tests were performed to ascertain statistical significance. The closer the value of p to zero, the less chance of probability that the results was due to chance.
4.1 THE AVERAGE AGE OF ALL THE PATIENTS

In the following section the average age of all the patients will be described. (See figure 4.1)

The age of the patients ranged from 21 to 38, the average age of the thirty patients was 25. This shows that the population sample was relatively young overall.

In the population sample there were 17 females and 13 males. Their average ages will be demonstrated below (See figure 4.2 and figure 4.3).
As seen above the average age of the female population sample was 25.2, as opposed to the male population whose age was slightly lower at 24.7.
4.2 GRIP STRENGTH

This section deals with the grip strength readings of the patients, the grip strength readings will be discussed as follows:

1. The overall grip strength readings of the right hand will be demonstrated first (See figure 4.4). Following this the grip strength readings of the right hand of the females will be demonstrated (See figure 4.5), followed by the grip strength readings of the right hand of the males (See figure 4.6)

2. The overall grip strength readings of the left hand will be demonstrated first (See figure 4.7). Following this the grip strength readings of the left hand of the females will be demonstrated (See figure 4.8), followed by the grip strength readings of the left hand of the males (See figure 4.9)

4.2.1 The overall grip strength: The right hand

![Grip Strength Graph]

Figure 4.4: The overall grip strength of the right hand

The above figure shows that there was a significant increase in the overall grip strength of the right hand from treatment 1 (T1) to treatment 6 (T6).
The average increase of grip strength of the patients for the right hand has been shown to have increased from 38.05 kilograms to 43.60 kilograms, resulting in an overall increase in grip strength for the right hand of 5.55 kilograms.

Thus when analyzing the overall grip strength it was found that there was a statistically significant difference ($t = -5.40$ and $p < 0.0001$). (See Appendix I & Appendix L)

4.2.2 The grip strength of Females: The right hand

In this section the average grip strength readings of the right hand of all the female patients will be discussed. (See figure 4.5)

![Figure 4.5: The grip strength of the right hand of the Females](chart)

The above figure shows that there was a significant increase in the grip strength of the female patients from treatment 1 to treatment 6. The average increase of grip strength of the patients for the right hand has been shown to have increased from 30.20 kilograms to 34.14 kilograms, resulting in an overall increase in grip strength for the right hand of 3.94 kilograms.
Here again when analyzing the female right hand grip strength it was found that there was a statistically significant difference ($t= -4.67$ and $p = 0.0003$). (See Appendix I & Appendix L)

4.2.3 The grip strength of Males: The right hand

In this section average grip strength readings of the right hand of all male patients will be discussed. (See figure 4.6)

![Figure 4.6: The grip strength of the right hand of the Males](image)

The above figure shows that here too there was a significant increase in the grip strength of the male patients from treatment 1 to treatment 6. The average increase of grip strength of the patients for the right hand has been shown to have increased from 48.31 kilograms to 55.97 kilograms, resulting in an overall increase in grip strength for the right hand of 7.67 kilograms.

Once again when analyzing the male right hand grip strength it was found that there was a statistically significant difference ($t= -3.68$ and $p = 0.0031$). (See Appendix I & Appendix L)
4.2.4 The overall grip strength: The left hand

The above figure shows that there was a significant increase in the overall grip strength of the left hand from treatment 1 to treatment 6. The average increase of grip strength of the patients for the left hand has been shown to have increased from 35.94 kilograms to 39.70 kilograms, resulting in an overall increase in grip strength for the left hand of 3.76 kilograms. The author has observed that a difference of 1.80 kilograms exists between the overall grip strength of the left hand and that of the right hand.

Thus when analyzing the overall grip strength it was found that there was a statistically significant difference ($t = -3.05$ and $p = 0.00$). (See Appendix J & Appendix L)
4.2.5 The grip strength of Females: the left hand

In this section the average grip strength of the left hand of all the female patients will be discussed. (See figure 4.8)

![Grip Strength Graph]

**Figure 4.8: The grip strength of the left hand of the Females**

The above figure shows that although there was an increase in the grip strength, it was not as marked as that of the right hand of the female patients from treatment 1 to treatment 6. The average increase of grip strength of the female patients for the left hand has been shown to have increased from 28.73 kilograms to 30.10 kilograms, resulting in an overall increase in grip strength for the left hand of 1.35 kilograms. This grip strength has been shown to be 2.60 kilograms less than that of the right hand.

Thus when analyzing the female left hand grip strength it was found that there was a statistically significant difference, but not as much as that of the right hand ($t = -2.31$ and $p = 0.0347$). (See Appendix J & Appendix L)
4.2.6 The grip strength of Males: the left hand

The average grip strength readings of the left hand of all the males will be discussed in this section. (See figure 4.9)

Figure 4.9: The grip strength of the left hand of the Males

The above figure shows that a significant increase in the grip strength of the male patients was found, as opposed to that of the females from treatment 1 to treatment 6. The average increase of grip strength of the patients for the left hand has been shown to have increased from 45.38 kilograms to 52.28 kilograms, resulting in an overall increase in grip strength for the left hand of 6.90 kilograms. It is observed that only a small difference occurs between the left and right hand, a mere 0.77 kilograms.

Analyzing the male left-hand grip strength, it was found that there was a statistically significant difference ($t = -4.39$ and $p = 0.0009$). (See Appendix J & Appendix L)
4.3 PAIN RATING SCALES

In this section below the pain rating scales will be discussed, firstly the Vernon Mior Neck Pain and Disability Index will be discussed (See figure 4.10) and then the section will be concluded with the discussion of the Numerical Pain Rating Scale 101 (See figure 4.11)

4.3.1 Vernon Mior Neck Pain and Disability Index: Overall

![Bar Chart]

Figure 4.10: The Vernon Mior Neck Pain and Disability Index: Overall

In the figure above it is seen that the percentage of pain as perceived by the participants decreased significantly from 15% at treatment one to 9% at treatment two and finally to 5% at treatment six.

The change that occurred with treatment has been shown to be statistically significant (t = 8.07 and p < 0.0001). (See Appendix K & Appendix L)
4.3.2 Numerical Pain Rating Scale 101: Overall

In the figure above a reduction/improvement in the numerical Pain Rating Scale 101 scores has been seen from treatment one to treatment three and finally to treatment six. The values decreased from 3.50 to 2.3 and finally to 1.3 respectively.

The change that occurred with treatment has been shown to be statistically significant ($t = -3.78.0$ and $p = 0.00$). (See Appendix K & Appendix L)

When referring to the results it can be said that there was an increase in the grip strength and a reduction in pain as noted by the Vernon Mior check Pain and Disability Index as well as the numerical Pain Rating Scale 101.
CHAPTER FIVE - DISCUSSION
5.1 INTRODUCTION

The results of this study will be discussed with reference to the previous chapter and the aim of the study as proposed in the first chapter. As there have been very little on the topic of cervicothoracic junction manipulation and grip strength the author will refer to other studies to try and explain the outcomes of this study.

5.2 GRIP STRENGTH RESULTS

The overall result of the study showed an increase in the grip strength of the participants, however it was seen that not all participants benefited from this study, that is to say that not all the participants had an increase in their grip strength. The following sections will attempt to explain the phenomenon as described in the above text.

5.2.1 Grip Strength Results - Overall

As described in the previous section, an overall increase in grip strength was found. Pollard and Ward (1996) explain that it is known that neural integrity is vital to muscle function, but yet the contribution of manipulation to muscle function has received little coverage, even though some claims exist that suggest that manipulation modulated neural activity.

Anderson (1994), hypothesized that muscular non development may be as a result of a spinal dysfunction in the lower cervical spine. However he did not rule out disuse and painful neglect as a cause for the muscular wasting. Anderson (1994), in his study indicated a good response, this was evident in the muscle strength and size becoming more symmetrical as measured by changes in grip strength.
It has been shown that testing muscle strength before and after a manipulative procedure said to be able to normalize a dysfunctional state may result in a change in muscle strength (Pollard & Ward 1996).

This has been shown to be the case in the majority of the study participants. Although the participants in the current study were of a relatively young age, it has been shown that if a cervicothoracic junction manipulation is delivered to the motion restricted area, it is bound to affect the grip strength.

The current study however, did not only show an increase in grip strength at all times there were participants who in actual fact had a decrease in their grip strength. Lehman and McGill (2001), have shown the opposite of the study conducted by Anderson (1994), they found that a reduction in muscle activity immediately following a manipulation during a static task was found. This study by Lehman and McGill (2001), however was conducted on the paraspinal muscles and not on the muscles of the forearm as done in the study being discussed.

Thus it was found that the grip strength in the patients overall did increase. The author proposes that the effect of manipulation on strength can have a beneficial effect, that is an increase, and so further investigation into this phenomenon may be warranted.

5.3 THE PAIN QUESTIONNAIRES

5.3.1 The Vernon Mior Neck Pain and Disability Index

The outcome was favorable overall with reference to the Vernon Mior Neck Pain and Disability Index.
It was shown that there was a statistical significant improvement overall. This indicates that there is much to gain with a treatment protocol spanning six treatments which rids a patient of a long-standing mechanical fixation.

There was however a case in which the participant had a slight increase (4%) in the pain at treatment six as compared to that of the first treatment. This can best be explained as a negative reaction to the manipulation, but the author feels that if the treatment protocol was increased to include a one-month follow-up the pain may have subsided. Comparatively there were three participants who experienced an increase in pain between the first and third treatments. A negative reaction to the manipulation could be a causative factor, or it may be that the body was readjusting to the "normal" biomechanics.

5.3.2 The Numerical Pain Rating Scale 101

Again the outcome with reference to the Numerical Pain Rating Scale 101 was favorable and it was shown to be statistically significant.

In the case of the Numerical Pain Rating Scale 101 it was found that all participants benefited, and no increase in pain was documented from treatment one to treatment six. The scale is less complicated and only requires the participant to rate his/her pain as a number out often with makes this scale very subjective, however the Vernon Mior Neck Pain and Disability Index has a series of set questions which may be a less subjective means of rating pain, and this fact may have accounted for the discrepancy encountered.

Again it was found that there were three participants who had an increase in pain from treatment one to treatment three. However it is interesting to note that these were not the same three individuals previously mentioned. As in the above explanation a negative reaction to the manipulation or a readjustment to the "normal" biomechanics could have been the precipitating factor.
CHAPTER SIX - CONCLUSIONS AND RECOMMENDATIONS
6.1 CONCLUSIONS

The aim of this study was to determine whether chiropractic manipulative therapy can have a sustained stimulatory effect on the nervous system and hence increase grip strength over six treatments. Pain intensities in the Vernon Mior Neck Pain and Disability Index and the Numerical Pain Rating Scale 101 were also noted.

The results indicate an increase in grip strength has been achieved in the overall study population. It is also important to note that pain intensity decreased, as indicated by the Vernon Mior Neck Pain and Disability Index as well as the Numerical Pain Rating Scale 101.

Thus in conclusion it can be noted that over six treatment sessions the average grip strength of the participants increased and pain intensity as an overall average for the participants decreased.

In light of the above it may be said that chiropractic manipulative therapy may have a stimulatory effect on the nervous system and hence increase grip strength for this study group.

6.2 RECOMMENDATIONS

Validation and improvement of the above results may possibly be achieved through the following recommendations:

- The utilization of a more comfortable and "less slippery" dynamometer could be of benefit to the participants, as this was the most common complaint.
• A future study could include a soft tissue group (possible myofascial pain and dysfunction syndrome) for the forearm, as a comparison to chiropractic manipulative therapy of the cervicothoracic junction.

• A larger sample group with the inclusion of a control group could be used to provide more significant information.

• The study could possibly be done over a longer period of time, with larger intervals between treatments.

• Readings on the dynamometer could be done at all five levels of measurement; this would add more data to the research.

• Electromyographic readings could be done in conjunction with the grip strength readings, for a comparison of the objective reading.

• Readings on the dynamometer should be done at approximately the same time of day; this could prevent the variability of the readings.

• Forearm stretching for all patients prior to grip strength readings could be done as a means of "warming" up the muscles, prior to squeezing the hand dynamometer.
REFERENCES


Appendix A : Advertisement Poster

FREE CHIROPRACTIC TREATMENT !!!

DO YOU HAVE PAIN

IN YOUR LOWER NECK?

Would you like to participate in a Chiropractic research study on the effect of chiropractic manipulative therapy On Grip Strength?

All treatment is FREE, and is conducted in the supervised Technikon Witwatersrand Chiropractic Day Clinic, by a 6th year chiropractic intern.

IF INTERESTED, PLEASE CALL

PEDRO

082-877-4262
THE EFFECT OF CERVICOTHORACIC JUNCTION MANIPULATION ON GRIP STRENGTH

Dear Participant

The purpose of this study is to determine the effect of cervicothoracic junction manipulation on Grip Strength. There is to be only one group in the research study. All members of the group will receive a manipulative thrust to the affected area.

The possible benefits include the return of normal function to the cervicothoracic junction and a possible increase in grip strength.

The possible side effects include some post treatment discomfort, which is a normal occurrence in some patients, but should only last a day or two.

Participation in the study is voluntary and you are free to refuse to participate or to withdraw your consent and to discontinue participation at any time. Such refusal or discontinuance will not affect your regular treatments or medical care in any way. A signed copy of this consent will be made available to you.

I have fully explained the procedures, identifying those, which are investigational, and have explained their purpose. I have asked whether any questions have arisen regarding the procedures and have answered these questions to the best of my ability.
I have been fully informed as to the procedures to be followed, including those which are investigational and have been given a description of the attendant discomforts, risks and benefits to be expected and the appropriate alternate procedures. In signing this consent form I agree to this method of treatment and I understand that I am free to withdraw my consent and discontinue my participation at any time. I also understand that if I have any questions at any time, they will be answered.

Date: ___________ Researcher: ___________

Date: ___________ Patient: ___________

Or Guardian/Next of kin: ___________
Appendix C: Cervical Spine Regional Examination

TECHNIKON WITWATERSRAND
CHIROPRACTIC DAY CLINIC
REGIONAL EXAMINATION
CERVICAL SPINE

Date: _________

Patient: ___________________  File No: _________

Clinician: ___________________  Signature: _________

Intern: ___________________  Signature: _________

OBSERVATION

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

RANGE OF MOTION

Flexion = 45° - 90°
Extension = 55° - 70°
L/R Rotation = 70° - 90°
L/R Lateral flexion = 20° - 45°
PALPATION

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

\[ I = \text{pain-free limitation} \quad II = \text{painful limitation} \]
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. Lhennitte'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 - Pee Minor
    • Costoclavicular test

Remarks: ___________
### VASCULAR

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<td>CAROTIDS</td>
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<tr>
<td>SUBCLAVIAN ARTERIES</td>
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<td></td>
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<td>WALLENBERG’S TEST</td>
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### COMMENTS:

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

### MOTION PALPATION

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<td>Lat. Neck Flexion</td>
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<td></td>
</tr>
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<td>C4</td>
<td>Shoulder Elevation</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>Shoulder Abduction</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>Elbow Flexion</td>
<td>5</td>
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</tr>
<tr>
<td>C7</td>
<td>Elbow Extension</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>C8</td>
<td>Elbow Flexion at 90°</td>
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<td>T1</td>
<td>Forearm Pronation</td>
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<td>Forearm Supination</td>
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<tr>
<td></td>
<td>Wrist Extension</td>
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<tr>
<td></td>
<td>Wrist Flexion</td>
<td>7</td>
<td></td>
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<td></td>
<td>Finger Flexion</td>
<td>8</td>
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<td></td>
<td>Finger Abduction</td>
<td>T 1</td>
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<tr>
<td></td>
<td>Finger Adduction</td>
<td>T 1</td>
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</tbody>
</table>
Appendix D: Vernon-Mior Neck Pain and Disability Index

Patient Name: ___________________________ Date: ____________________

Please read instructions:
This questionnaire has been designed to give the doctor information as to how your neck pain has affected your ability to manage in everyday life. Please answer every section and mark in each section only the ONE box, which applies to you. We realise you may consider that two of the statements in anyone section relate to you, but just mark the box, which most closely describes your problem.

<table>
<thead>
<tr>
<th>SECTION 1 - PAIN INTENSITY</th>
<th>SECTION 6 - CONCENTRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have no pain at the moment.</td>
<td>I can concentrate fully when I want to without difficulty.</td>
</tr>
<tr>
<td>The pain is <em>mild</em> at the moment.</td>
<td>I can concentrate fully when I want to with slight difficulty.</td>
</tr>
<tr>
<td>The pain is <em>moderate</em> at the moment.</td>
<td>I have a fair degree of difficulty in concentrating when I want to.</td>
</tr>
<tr>
<td>The pain is <em>severe</em> at the moment.</td>
<td>I have a great deal of difficulty in concentrating when I want to.</td>
</tr>
<tr>
<td>The pain is <em>worst imaginable</em> at the moment.</td>
<td>I cannot concentrate at all.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 2 - PERSONAL CARE (Washing, Dressing, etc.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I can look after myself normally without causing extra pain.</td>
<td>I can do as much work as I want to.</td>
</tr>
<tr>
<td>I can look after myself normally but it causes extra pain.</td>
<td>I can only do my usual work, but no more.</td>
</tr>
<tr>
<td>It is painful to look after myself and I am slow and careful.</td>
<td>I can do most of my usual work, but not all.</td>
</tr>
<tr>
<td>I need some help but manage most of my personal care.</td>
<td>I cannot do my usual work.</td>
</tr>
<tr>
<td>I need help every day in most aspects of self care.</td>
<td>I cannot do any work at all.</td>
</tr>
<tr>
<td>I don't get dressed, wash with difficulty and stay in bed.</td>
<td>I cannot do any work at all.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 3 - LIFTING</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I can lift heavy weights without extra pain.</td>
<td>I can drive my car as long as I want with slight pain in my neck.</td>
</tr>
<tr>
<td>Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, for example on a table.</td>
<td>I can drive my car as long as I want with moderate pain in my neck.</td>
</tr>
<tr>
<td>Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.</td>
<td>I can drive my car as long as I want because of moderate pain in my neck.</td>
</tr>
<tr>
<td>I can lift very light weights.</td>
<td>I cannot drive my car at all.</td>
</tr>
<tr>
<td>I cannot lift or carry anything at all.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 4 - READING</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I can read as much as I want without any pain in my neck.</td>
<td>I can drive my car without any neck pain.</td>
</tr>
<tr>
<td>I can read as much as I want with slight pain in my neck.</td>
<td>I can drive my car as long as I want with moderate pain in my neck.</td>
</tr>
<tr>
<td>I can read as much as I want with moderate pain in my neck.</td>
<td>I cannot drive my car at all because of severe pain in my neck.</td>
</tr>
<tr>
<td>I can hardly read at all because of severe pain in my neck.</td>
<td>I cannot drive my car at all.</td>
</tr>
<tr>
<td>I cannot read at all.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 5 - HEADACHES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I have no headaches at all.</td>
<td>I have no trouble sleeping.</td>
</tr>
<tr>
<td>I have slight headaches which come infrequently.</td>
<td>My sleep is slightly disturbed (less than 1 hr. sleepless).</td>
</tr>
<tr>
<td>I have moderate headaches which come infrequently.</td>
<td>My sleep is moderately disturbed (1-2 hrs. sleepless).</td>
</tr>
<tr>
<td>I have severe headaches which come frequently.</td>
<td>My sleep is greatly disturbed (3-5 hrs sleepless).</td>
</tr>
<tr>
<td>I have headaches almost all the time.</td>
<td>My sleep is completely disturbed (&gt;7 hrs sleepless).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 7 - WORK</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I can do as much work as I want to.</td>
<td>I can do as much work as I want to.</td>
</tr>
<tr>
<td>I can only do my usual work, but no more.</td>
<td>I can only do my usual work, but no more.</td>
</tr>
<tr>
<td>I can do most of my usual work, but not all.</td>
<td>I cannot do my usual work.</td>
</tr>
<tr>
<td>I cannot do my usual work.</td>
<td>I cannot do my usual work.</td>
</tr>
<tr>
<td>I cannot do any work at all.</td>
<td>I cannot do any work at all.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 8 - DRIVING</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>I can drive my car without any neck pain.</td>
<td>I can drive my car as long as I want with slight pain in my neck.</td>
</tr>
<tr>
<td>I can drive my car as long as I want with moderate pain in my neck.</td>
<td>I cannot drive my car at all because of severe pain in my neck.</td>
</tr>
<tr>
<td>I cannot drive my car at all.</td>
<td></td>
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<table>
<thead>
<tr>
<th>SECTION 9 - SLEEPING</th>
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<tbody>
<tr>
<td>I have no trouble sleeping.</td>
<td>My sleep is slightly disturbed (less than 1 hr. sleepless).</td>
</tr>
<tr>
<td>My sleep is moderately disturbed (1-2 hrs. sleepless).</td>
<td>My sleep is moderately disturbed (1-2 hrs. sleepless).</td>
</tr>
<tr>
<td>My sleep is greatly disturbed (3-5 hrs sleepless).</td>
<td>My sleep is completely disturbed (&gt;7 hrs sleepless).</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>SECTION 10 - RECREATION</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>I am unable to engage in any of my recreation activities because of pain in my neck.</td>
<td>I am able to engage in all of my usual recreation activities.</td>
</tr>
<tr>
<td>I am able to engage in some of my usual recreation activities because of pain in my neck.</td>
<td>I am able to engage in all of my usual recreation activities with some neck pain.</td>
</tr>
<tr>
<td>I am able to engage in all of my usual recreation activities with no neck pain at all.</td>
<td>I am able to engage in most, but not all of my usual recreation activities because of pain in my neck.</td>
</tr>
<tr>
<td>I am able to engage in a few of my usual recreation activities because of pain in my neck.</td>
<td></td>
</tr>
<tr>
<td>I cannot do any recreation activities because of pain in my neck.</td>
<td>I cannot do any recreation activities at all.</td>
</tr>
</tbody>
</table>
Appendix E: Numerical Pain Rating Scale 101

Patient Name: _______________ Date: _______________

Rate the severity of your pain by checking one box on the following scale:

No pain ____________ 0 1 2 3 4 5 6 7 8 9 10 Excruciating pain
### Appendix F: S.O.A.P Note Form

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<th>PAGE:</th>
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<td>INTERN:</td>
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<td></td>
<td>CLINICIAN (PTT):</td>
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S:  
A:  

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SPECIAL ATTENTION TO:

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<td>INTERN:</td>
<td>CLINICIAN (PTT):</td>
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SPECIAL ATTENTION TO:
Appendix G: Jamar Hand Dynamometer

The Jamar Hand Dynamometer (Martin & Collins, 1998)
## Appendix H: Jamar Hand Dynamometer Readings

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<td>APPOINTMENT 2</td>
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Patient 21 - RH

Patient 22 - RH

Patient 23 - RH

Patient 24 - RH
Patient 11

Vernon Mior Neck Pain and Disability Index

Patient 12

Vernon Mior Neck Pain and Disability Index

Numerical Pain Rating Scale 101
Patient 17

Vernon Mior Neck Pain and Disability Index

Patient 18

Vernon Mior Neck Pain and Disability Index
Appendix L: Statistical Report

Left Hand All

Paired t-test:

Normality Test: Failed (P = 0.0323)

Test execution ended by user request, Signed Rank Test begun

Thursday, June 06, 2002, 17:44:47

Wilcoxon Signed Rank Test

<table>
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<tr>
<th>Group</th>
<th>N</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>30</td>
<td>o</td>
</tr>
<tr>
<td>Col 2</td>
<td>30</td>
<td>o</td>
</tr>
<tr>
<td>Tested</td>
<td>30</td>
<td>o</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>32.7</td>
<td>29.3</td>
<td>45.0</td>
</tr>
<tr>
<td>Col 2</td>
<td>35.7</td>
<td>30.3</td>
<td>50.7</td>
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</tbody>
</table>

W = 345.0  T+ = 375.5  T- = -30.5  (P = <0.0001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.00).
Left Hand Females

Paired t-test:

Normality Test: Passed (P = 0.3438)

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Col 2</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std Dev</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>28.73</td>
<td>4.78</td>
<td>1.159</td>
</tr>
<tr>
<td>Col 2</td>
<td>30.08</td>
<td>5.49</td>
<td>1.331</td>
</tr>
</tbody>
</table>

Difference | -1.35 | 2.42 | 0.586 |

\[ t = -2.31 \] with 16.0 degrees of freedom. (P = 0.0347)

95 percent confidence interval for difference of means: -2.60 to -0.110

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change (P = 0.0347)

Power of performed test with alpha = 0.0500: 0.4902

The power of the performed test (0.4902) is below the desired power of 0.8000. You should interpret the negative findings cautiously.
Left Hand Males

Paired t-test:

<table>
<thead>
<tr>
<th>Normality Test:</th>
<th>Passed</th>
<th>(P = 0.0994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>N</td>
<td>Missing</td>
</tr>
<tr>
<td>CoII</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Col 2</td>
<td>13</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std Dev</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoII</td>
<td>45.38</td>
<td>9.22</td>
<td>2.56</td>
</tr>
<tr>
<td>Col 2</td>
<td>52.28</td>
<td>11.96</td>
<td>3.32</td>
</tr>
</tbody>
</table>

| Difference | -6.90 | 5.66 | 1.57 |

\[ t = -4.39 \text{ with 12.0 degrees of freedom. (P = 0.0009)} \]

95 percent confidence interval for difference of means: -10.3 to -3.48

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change (P = 0.0009)

Power of performed test with alpha = 0.0500: 0.9824
**Right Hand All**

**Paired t-test:**

<table>
<thead>
<tr>
<th>Normality Test:</th>
<th>Passed</th>
<th>(P = 0.0649)</th>
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</thead>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoI</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>Col 2</td>
<td>29</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>StdDev</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoI</td>
<td>37.46</td>
<td>10.91</td>
<td>2.026</td>
</tr>
<tr>
<td>Col 2</td>
<td>42.45</td>
<td>13.24</td>
<td>2.459</td>
</tr>
</tbody>
</table>

| Difference | -4.99 | 4.97 | 0.924 |

t = -5.40 with 28.0 degrees of freedom. (P = <0.0001)

95 percent confidence interval for difference of means: -6.88 to -3.10

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9998
Right Hand Females

Paired t-test:

Normality Test: Passed (P = 0.7306)

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Col 2</td>
<td>17</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>StdDev</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>30.20</td>
<td>5.62</td>
<td>1.363</td>
</tr>
<tr>
<td>Col 2</td>
<td>34.14</td>
<td>6.72</td>
<td>1.631</td>
</tr>
</tbody>
</table>

Difference -3.94 3.48 0.844

t = -4.67 with 16.0 degrees of freedom. (P = 0.0003)

95 percent confidence interval for difference of means: -5.73 to -2.15

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change. (P = 0.0003)

Power of performed test with alpha = 0.0500: 0.9942
Right Hand Males

Paired t-test:

<table>
<thead>
<tr>
<th>Normality Test:</th>
<th>Passed</th>
<th>(P = 0.2056)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group N Missing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ColI 13 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Col 2 13 0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>StdDev</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColI</td>
<td>48.31</td>
<td>7.69</td>
<td>2.13</td>
</tr>
<tr>
<td>Col 2</td>
<td>55.97</td>
<td>12.34</td>
<td>3.42</td>
</tr>
</tbody>
</table>

Difference -7.67 7.51 2.08

t = -3.68 with 12.0 degrees of freedom. (P = 0.0031)

95 percent confidence interval for difference of means: -12.2 to -3.13

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change. (P = 0.0031)

Power of performed test with alpha = 0.0500: 0.9147
Vernon Mior Neck Pain and Disability Index

Paired t-test:

Normality Test: Passed (P = 0.3135)

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col 3</td>
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<td>0</td>
</tr>
<tr>
<td>Col 4</td>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std Dev</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col 3</td>
<td>14.93</td>
<td>7.37</td>
<td>1.345</td>
</tr>
<tr>
<td>Col 4</td>
<td>5.27</td>
<td>4.44</td>
<td>0.811</td>
</tr>
</tbody>
</table>

| Difference | 9.67 | 6.56 | 1.20 |

t = 8.07 with 29.0 degrees of freedom. (P < 0.0001)

95 percent confidence interval for difference of means: 7.22 to 12.1

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant change (P < 0.0001)

Power of performed test with alpha = 0.0500: 1.0000
Numerical Pain Rating Scale

Paired t-test:

Normality Test: Failed (P = 0.0027)

Test execution ended by user request, Signed Rank Test begun

Thursday, June 06, 2002, 17:40:24

Wilcoxon Signed Rank Test

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Median</th>
<th>25%</th>
<th>75%</th>
<th>Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Col 5</td>
<td>30</td>
<td>3.000</td>
<td>2.00</td>
<td>5.00</td>
<td>a</td>
</tr>
<tr>
<td>Col 6</td>
<td>30</td>
<td>1.000</td>
<td>1.00</td>
<td>2.00</td>
<td>a</td>
</tr>
<tr>
<td>Tested</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td>a</td>
</tr>
</tbody>
</table>

W = -378.0  T+ = 0.00  T- = -378.0  (P = <0.0001)

The change that occurred with the treatment is greater than would be expected by chance; there is a statistically significant difference (P = 0.00).