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EFFECTIVENESS OF CERVICAL MANIPULATIVE THERAPY IN PATIENTS WITH MECHANICAL NECK PAIN AND THE EFFECT ON SLEEP

A dissertation presented to the Faculty of Health Sciences, University of Johannesburg, in partial fulfilment of the requirements of the degree of Masters in Technology, Chiropractic

by:

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DECLARATION

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

____________________________________________________________
(Signature of Candidate)

__________________________ day of ______________________________
DEdICATION

I dedicate this research to Jehovah, my Lord, God and Saviour, for always being there for me throughout all the difficulties that I’ve encountered in my life.

To my loving mother, Ouma for always believing in me and giving me a chance when no one would. I would have not made it through my studies without your love and support.

To my dearest brother, Kemedi thank you for the love and support that you have always given me. Words cannot begin to describe how grateful I am that God chose you to be my brother.

And lastly to all my family and friends, thank you for all the love and support.

In loving memory of my uncle
Sydney Leobu Mphahlele
1963-2015
ACKNOWLEDGEMENTS

To my Supervisor Dr Hay, thank you for all the guidance and support that you have given me throughout my research. I wouldn’t have done this without you.

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To all those who participated in my research, thank you. Without you this research would have not been possible.
ABSTRACT

Aim: The aim of this study was to determine the effectiveness of cervical manipulative therapy on sleep in patients with mechanical neck pain.

Methodology: The study comprised of one group of thirty participants (n=30), 21 males and 9 females, who were between the ages of 19-36, who had sleep disturbance and mechanical neck. All participants received cervical manipulative therapy (CMT), twice a week for three weeks. Subjective data was collected in the form of a Pittsburgh Sleep Quality Index (PSQI) which measured sleep quality and a Numerical Pain Rating Scale (NPRS) which measured the pain intensity. Objective data was collected using a cervical range of motion (CROM) device, twice a week for three weeks.

Procedure: Shapiro-Wilk test was used for normal distribution of data. One-way repeated measures ANOVA tests were conducted in order to investigate if any significant difference exist among the visits (visit 1, visit 4 and visit 7) for all variables measured in this study. Where statistical significant differences exists, Pairwise Comparisons were performed to check where the difference lies.

Results: One-way repeated measures ANOVA revealed the p-value (p < 0.05) to be statistically significant for the PSQI, NPRS and CROM data obtained from this study. One-way repeated measures ANOVA also revealed PSQI, NPRS and CROM to have favourable results from visit 1 to visit 7.

Conclusion: The overall results were favourable as the participants had neck pain relief, increased cervical range of motion and improvement in their sleep quality following CMT. Due to the small sample size, it is however not clear if CMT had a direct effect on sleep quality or if the improvement in the participants sleep quality was due to a reduction in the participant’s neck pain intensity.
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<tr>
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<td>Cervical Manipulative Therapy</td>
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<td>CROM</td>
<td>Cervical Range of Motion</td>
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<td>NPRS</td>
<td>Numerical Pain Rating Scale</td>
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CHAPTER ONE – INTRODUCTION

1.1 Problem Statement

According to Basner (2011), hundreds of studies, both experimental and epidemiologic have addressed the question of how much sleep human beings need. About 70% of adults report problems with their sleep with their about 32%–45% reporting difficulty falling asleep or maintaining sleep (Beaudreau, Spira, Stewart, Kezirian, Lui, Ensrud, Redline, Ancoli-Israel and Stone, 2012). Both adults and teenagers may experience sleep disorders (McPhee, 2001).

Well-established deteriorative changes in human sleep are (Chase and Weitzman, 1983):

- increased awakefulness during the sleep period;
- the dramatic reduction in the amplitude of delta activity in the sleep EEG; and
- the dramatic reduction and the complete disappearance of stage 4 sleep.

One of the effects of sleep deprivation can include increased sensitivity to pain (McPhee, 2001) with neck pain seen as the second most common musculoskeletal disorder (Ferrari and Russell, 2003). Mechanical neck pain affects about 45%-54% of the general population of Madrid Spain, constituting a significant health care problem and can result in severe pain and disability. Although the exact pathology resulting in mechanical neck pain is unknown, it has been alleged to be related to various anatomic structures such as muscles, ligaments, facet joints, uncovertebral joints, intervertebral disks or neural tissues (Martínez-Segura, Fernández-de-las-Penas, Ruiz-Sáez, López-Jiménez, and Rodríguez-Blanco, 2006).

A study was conducted that determined that cervical manipulative therapy is beneficial in the treatment of mechanical neck pain with a resultant increase in cervical range of motion (Martínez-Segura et al., 2006). Sleep disorders and musculoskeletal impairment can result in symptoms of mechanical neck pain and therefore sleep disorders should be taken

1.2 Aim of the Study

The aim of the study was to determine the effectiveness of cervical manipulative therapy on sleep in patients with mechanical neck pain. The study also aimed to determine if mechanical neck pain relief through cervical manipulative therapy in patients with sleep disturbances had any beneficial effects on sleep.

1.3 Benefits of Study

The study strived to determine if cervical manipulative therapy had any beneficial effects on sleep disturbances in patients with mechanical neck pain and any subsequent increases in cervical range of motion. Positive outcomes of the study would hopefully encourage more studies to be conducted with regards to chiropractic care and sleep; as well as to possibly broaden the number of conditions that chiropractors could confidently claim that chiropractic care has beneficial effects towards.
CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

Sleep problems are common in people of all ages (Barclay and Gregory, 2013), with a high prevalence of about 62% in the elderly (Aloba, Adewuya, Ola and Mapayi, 2007) and can be categorized into difficulty sleeping or maintaining sleep (Arora, Broglia, Thomas and Taheri, 2014).

About 50%-70% of patients with pain report poor quality sleep. Clinically a reciprocal relationship exists between pain and sleep whereby pain may precede the “poor sleep” complaints and “poor sleep” complaints may precede pain. Pain may lead to sleep fragmentation (frequently disturbed sleep) leading to musculoskeletal pain conditions such as neck pain (Bonnet and Arand, 2013; Lavigne, Smith, Denis and Zucconi, 2011) and therefore it could be assumed that there is some form of relationship between sleep and neck pain.

2.2 Sleep

Sleep is a behavioural state characterized by a reduction in motor activity, a decreased sensitivity to stimuli and stereotypic posture (Arrigoni and Fuller, 2012). Sleep is a multidirectional construct that is inclusive of the duration it takes to fall asleep, sleep duration, sleep quality and the extent to which sleep is perceived to be adequate (Hays, Martins, Sesti and Spritzer, 2005).

Sleep is an actively regulated and organized biological function consisting of three hypothesized processes: homeostatic, circadian and ultradian processes. These processes are responsible for the regulation of the sleep and wake cycle. The homeostatic process is determined by the amount of prior sleep and waking. The circadian process organizes alternations of sleep and waking over the 24-hour light-dark day cycle (Roehrs, 2000). The
ultradian process controls the alternations between the sleep states: non-rapid eye movement (NREM) and rapid eye movement (REM) sleep (Roehrs, 2000).

2.3 States of Sleep

Human sleep is composed of both rapid eye movement (REM) and non-rapid eye movement (NREM) sleep states. The REM sleep is characterized by low-amplitude high-frequency electroencephalogram (EEG) signals similar to wake and rapid eye movement; NREM sleep is characterized by high-amplitude low-frequency EEG signals and little to no eye movements (España, 2013; Phillips, Robinson and Klerman, 2013). During the sleep period, an individual may alternate between NREM to REM sleep, with occasional transitions to waking. Typically the duration of waking, NREM and REM sleep bouts vary with age and health conditions (Alam, 2013).

2.3.1 Non-rapid eye movement sleep state

Sleep onset in normal adults occurs invariably through NREM sleep which accounts for about 75%–80% of total sleep and dominates the first third of sleep time. The NREM sleep state is divided into four stages (Alam, 2013; Llewellyn and Hobson, 2015). The first two stages are considered light sleep and the third and fourth stages are considered deep sleep (Alam, 2013).

Stage one NREM sleep comprises 3%–8% of sleep time. Stage one sleep occurs most frequently in the transition from wakefulness to the other sleep stages or following arousals during sleep (Rama, Cho and Kushida, 2005). During this stage, eye movements become rolling and muscle tone diminishes (Alam, 2013).

Stage two NREM sleep comprises of 45%–55% of total sleep time. This sleep stage begins approximately 10–12 minutes after stage one NREM sleep (Rama et al., 2005). During this stage, eye movements are absent and muscle tone diminishes even further (Alam, 2013).
Stage three and four NREM sleep occupy 15–20% of total sleep time (Rama et al., 2005). Both these stages are collectively referred to as slow-wave sleep (Alam, 2013) and muscle tone is decreased in comparison to stage one NREM sleep (Rama et al., 2005).

### 2.3.2 Rapid eye movement sleep state

REM sleep accounts for 20%–25% of sleep time. The initial REM sleep episode occurs 60–90 minutes after the onset of NREM sleep (Rama et al., 2005). The 90 minutes REM sleep cycle is characteristic of night time sleep in a healthy adult (Szymusiak, 2013). Rapid eye movement stage can be divided into two phases namely a tonic and phasic stage. The tonic phase exhibits the following characteristics: a desynchronized EEG, atonia of skeletal muscle groups (no muscle twitches) and suppression of monosynaptic and polysynaptic reflexes with few or no eye movements. The phasic stage is characterized by rapid eye movements in all directions with periods of muscle twitches (Aldrich, 1999; Rama et al., 2005).

### 2.4 The NREM-REM Sleep Cycle

Non-REM and REM sleep alternate throughout the night (Owens and Witmans, 2004). The first REM sleep episode in humans is short and occurs at about 70 minutes after the onset of sleep, lasting for about 90 minutes before the onset of NREM sleep state. Following the initial REM sleep period, the sleep cycle repeats itself with the appearance of NREM sleep. At about 90 minutes after the first REM sleep episode, another REM sleep episode occurs. The REM sleep episodes that occur thereafter only last for 30 minutes. The REM sleep period is often associated with vivid dreaming and high level of brain activity whereas the NREM sleep period usually associated with reduced neuronal activity. The thought process during NREM state is usually nonvisual unlike in dreams and consists of ruminative thoughts (McCarley, 2007).
2.5 Sleep and Waking Cycle

Sleep is characterized by poor responsiveness to external stimuli and wakefulness is characterized by consciousness (Wuffi, Gatti, Wettstein and Foster, 2010). Sleep and waking are regulated by dynamic interactions between multiple sleep and wake promoting system (España, 2013).

During sleep, ventrolateral preoptic nucleus becomes active inhibiting arousal regions via GABA (γ-aminobutyric) and galanin activation. This inhibition of wake-active neurons reduces their influence on preoptic areas, thus further enhancing the activity of ventrolateral preoptic nucleus (sleep active neurons) within this region thereby promoting sleep (España, 2013; Wulff et al., 2010).

During wake, the arousal regions are most active, inhibiting sleep active ventrolateral preoptic nucleus firing (España, 2013). The activation of excitatory neurotransmitters such as orexin, serotonin, noradrenaline, acetylcholine and histamine release from their respective neurons results in the inhibition of the release of the inhibitory neurotransmitters GABA and galanin from the ventrolateral preoptic nucleus thus promoting arousal (Wulff et al., 2010).

2.6 Relationship between Sleep Disturbance and Acute and Chronic Pain

Sleep disturbance and pain are complex and multidimensional interrelated phenomenon (Landis, 2011). Sleep disturbances include any combination of problems in initiating, maintaining and benefiting from sleep (Cole, Dubois and Kosinsk, 2007). Epidemiological studies have reported disturbed sleep in patients with acute and chronic pain. Sleep and pain are two vital functions that interact in complex ways to ultimately compromise the biological and behavioural capacity of the individual. Sleep disturbance enhances sleepiness and fatigue, which are both associated with increased pain (Roehrs, 2013). A bidirectional relationship exists between pain and sleep where pain disturbs sleep and disturbed shortened sleep enhances pain (Finan, Goodin and Smith, 2013; Landis, 2011; Roehrs, Hyde, Blaisdell, Greenwald and Roth, 2006).
The impact of acute pain on sleep such as delay in sleep onset, sleep awakening, poor sleep quality or low restorative effectiveness is usually short term and reversible (Lavigne, McMillian and Zucconi, 2005).

Sleep disturbances among chronic pain patients have been reported to increase the sensitivity to pain (Kosinski, Janagap, Gajria and Schein, 2007). Poor sleep quality is reported in 50%-90% of patients following chronic pain conditions such as neck pain (Lavigne, Okura and Smith, 2008). Chronic pain last for several weeks or months and can be associated with a vicious cycle pattern whereby a day with intense pain may be followed by a night of poor sleep quality and a night of poor sleep may increase pain the next day (Lavigne et al., 2005).

2.7 Mechanical Neck Pain

Mechanical neck pain is a common problem affecting people worldwide and it does not discriminate based on gender. It is episodic in nature with complete resolution of symptoms (Dennison and Leal, 2011). Mechanical neck pain is defined as pain in the cervical spine and or shoulder area with symptoms provoked by neck postures, neck movement or palpation of the cervical muscles. It has been proposed that addressing the ongoing cycle of pain and sleep disturbances is essential for treatment for patients with mechanical neck pain (Muñoz-Muñoz et al., 2012).

Muñoz-Muñoz et al. (2012), conducted research on patients with mechanical neck pain and found that sleep disorders and musculoskeletal impairments could contribute to the symptoms of mechanical neck pain. Patients with mechanical neck pain were found to exhibit higher disability and worse sleep quality than the control group. Sleep quality was negatively associated with the intensity of neck pain and disability. It was therefore concluded that sleep disorders must be taken into account in the overall management of patients with mechanical neck pain.
2.8 Sources of Neck Pain

Any innervated structure in the neck could be a pain generator e.g. the zygapophyseal joints, the cervical intervertebral disc, the anterior and posterior longitudinal ligaments, the transverse ligaments, the posterior musculature, prevertebral muscles, dura mater of the cervical spinal cord, atlanto-occipital joint, atlanto-axial joints, vertebral artery, internal carotid artery, the vertebral bodies, the vertebral artery, etc. (Bogduk and McGuirk, 2006; Dennison and Leal, 2011).

Other sources of neck pain arising from structures outside the neck include disorders such as coronary arterial disease, acromioclavicular joint trauma and arthritis, aortic aneurysm, cholecystitis, spinal cord tumors, pancoast’s tumor, fibrositis and pancreatitis (Bland, 1994).

2.9 Causes of Mechanical Neck Pain

The following are possible causes of mechanical neck pain (Giles and Singer, 1998):

- zygapophysial joint conditions e.g. joint derangement (fixation), joint capsule tension, joint degenerative changes (synovial fold impingment and osteoarthritis), joint capsular adhesions and joint effusion with capsular distention resulting in capsular pain;
- nerve root conditions e.g. adhesions between dural sleeves and joint capsule with nerve fibrosis;
- intervertebral disc conditions e.g. disc herniation and spondylosis;
- miscellaneous conditions such as spinal and vertebral canal stenosis, myofascial genesis of pain, intervertebral canal stenosis, osseous spinal anomalies (vertebral block and bilateral cervical ribs) and intervertebral foramen venous stasis.
2.10 Functional Anatomy of the Cervical Spine

The cervical spine is composed of functional units. Each functional unit consists of two contiguous vertebrae that may be divided into an anterior column and a posterior column. The anterior column is composed of the vertebral body, longitudinal ligaments and an intervertebral disc. The posterior column is composed of the osseous canal and the zygapophyseal joints. The anterior portion is a weight-bearing, shock absorbing and a flexible structure whereas the posterior portion protects the neural elements, acts as a fulcrum and guides movement for the functional unit (Borenstein, Wiesel and Boden, 2004).

The cervical spine anatomy consists of seven cervical vertebrae and the occiput. The first two cervical vertebrae (C1-C2) compose the upper cervical segment and the lower vertebrae (C5-C7) compose the lower cervical segment (Borenstein, Wiesel and Boden, 1996).

2.10.1 The upper cervical segment

The upper cervical vertebrae include the atlas and the axis (Porterfield and DeRosa, 1995). They are both referred to as apical vertebrae due to the fact that during embryology, part of the vertebral body of the atlas was transferred to the axis forming the dens. The remaining part of the body formed the anterior arch of the atlas (Moore and Dalley, 1999).

**Atlas**

The atlas (figure 2.1) is the first cervical vertebra (C1) and it has no vertebral body and a spinous process (Borenstein *et al.*, 1996; Monkhouse, 2001; Moore and Dalley, 1996; Norkin and Levangie, 1992). The major bony regions of the atlas are the anterior arch, the lateral masses and the longer curved posterior arch (MacKinnon and Morris, 2005; Monkhouse, 2001; Porterfield and DeRosa, 1995). The anterior and posterior arches join laterally to form the lateral masses that bear the superior and inferior articular surfaces. The superior facets articulate with the occiput superiorly and with the axis inferiorly.
(Borenstein et al., 1996; Feherenback and Herring, 2007; Monkhouse, 2001; Norkin and Levangie, 1992).

The anterior arch is smaller than the posterior arch and it possesses an elevation on its anterior surface known as the anterior tubercle which gives attachment to the anterior longitudinal ligament (ALL) centrally. The anterior arch also possesses on its posterior surface a facet covered with hyaline cartilage that articulates with the anterior aspect of the dens forming a diarthrodial joint. The posterior arch is longer than the anterior arch and bears a small tubercle in the place of a spinous process (Borenstein et al., 1996). The posterior arch bears a groove for the vertebral artery on its superior surface (Moore and Dalley, 2006) which also contains the first cervical spinal nerve which is also known as the suboccipital nerve (Porterfield and DeRosa, 1995). The transverse processes of the atlas are the widest of all the cervical vertebrae and they consist of transverse foramen for the course of the vertebral artery (Borenstein et al., 1996; Gatterman, 1990).

Figure 2.1: The atlas: A - Cranial view and B - Lateral view (Borenstein, Wiesel and Boden, 2004)

Axis

The axis (C2) (figure 2.2) is the strongest cervical vertebra because the atlas carrying the skull rotates on it when shaking the head (Moore and Dalley, 2006). The axis is a pivot on which the atlas and occiput rotate (Monkhouse, 2001; Porterfield and DeRosa, 1995). It is
identified by the projection of the dens superiorly which develops embryologically from the body of the atlas and it is continuous with the body of the axis (Borenstein et al., 1996). The dens contains a small articular facet on its anterior aspect that articulates with the articular facet on the posterior surface of the anterior arch of the atlas. The posterior aspect of the dens contains a groove which is slightly buckled due to the appearance of the transverse ligament. On the tip of the dens attaches the apical ligament with the alar ligaments attaching to its sides (Norkin and Kevance, 1992; Porterfield and DeRosa, 1995; Gatterman, 1990). The axis consists of a large bifid spinous process which can be palpated deep to the nuchal ligament in the posterior groove of the neck (MacKinnon and Morris; Moore and Dalley, 1999).

Figure 2.2: The axis: A - Cranial view and B - Lateral view (Borenstein et al., 2004)

2.10.2 The lower cervical segment

The lower cervical vertebrae consist of the third to the seventh cervical vertebrae (C3-C7). They exhibit identical anatomical features (Cramer, 2014; Monkhouse, 2001; Porterfield and DeRosa, 1995) and are therefore referred to as typical vertebrae (MacKinnon and Morris, 2005; Borenstein et al., 1996, Greenstein, 1997 and Curl, 1994). The C7 vertebra is
the third atypical vertebra known as vertebral prominens (Curl, 1994; Gatterman and Panzer 1990; Greenstein, 1997 and MacKinnon and Morris, 2005) in 70% of the human population (Curl, 1994).

**Cervical vertebral body**

The body of a cervical vertebra (figure 2.3) in the lower cervical spine is elongated transversely resulting in the width being about 50 percent greater than the anterior-posterior diameter (Porterfield and DeRosa, 1995). The superior surface is concave and the inferior surface is convex (Moore and Dalley, 1999). The inferior and posterolateral aspects of the vertebral body lie in close apposition of the uncinate process of the body below forming the uncovertebral joints (Borenstein *et al.*, 1996).

![Figure 2.3: Fifth cervical vertebra: A - Cranial view; B - Dorsal view and C - Lateral view (Borenstein *et al.*, 2004)]
**Uncovertebral joints**

Uncovertebral (uncinate) processes (figure 2.3) are elevations of the lateral and posterior rims on the top surface of the vertebral bodies. When the uncinate processes of one vertebra articulate with the small indentation found on the inferior surface of the vertebra above, the articulations are referred to as uncovertebral joints. The uncovertebral joints are small synovial joints that are limited medial by the intervertebral disc and laterally by the capsular ligaments. These uncinate processes allow for flexion and extension of the cervical spine and help to limit lateral flexion (Gatterman, 2012).

**Pedicles**

The pedicles (figure 2.3) are short and bear superior and inferior articular processes that form the zygapophyseal joints. They have a height of about 7mm and width of 6mm. The pedicles project posterolaterally from the vertebral body in the cervical spine. This orientation of the pedicles results in a comparatively larger and triangular spinal canal rather than a round shape (Porterfield and DeRosa, 1995).

**Transverse processes**

The transverse processes (figure 2.3) are located on the vertebral body and the pedicles. The anterior component projects lateral from the body and the posterior segments project laterally from the pedicles. Developmentally the anterior compartment of the lateral projection is a rudimentary to a rib or costal process and the posterior projection is the true transverse process. The transverse foramen (the posterior projection) features a groove on its superior surface over which the spinal nerve of the cervical segment passes (Porterfield and DeRosa, 1995). The transverse processes also consist of transverse foramina which are oval in shape. These foramina are sometimes absent or usually smaller at C7 vertebra process than those in other cervical vertebrae. The vertebral artery courses through these transverse foramina except at C7 vertebra (Moore and Dalley, 1999).

**Spinous process**

The spinous processes (figure 2.3) of C3-C5 vertebrae are short and are bifid (Moore and Dalley, 2006) and are directed dorsally and caudally (Benzel, 1995). The spinous process of C7 is the most prominent in the cervical region and it is also known as the vertebra
prominens. During palpation C6 is the last cervical vertebra with palpable movement in flexion and extension which helps when locating C7 spinous vertebra (Cramer, 2014).

**Facet joints (Zygapophyseal joints)**

Each cervical vertebra consist of articular processes that can be subdivided into superior and inferior articular processes lined with hyaline cartilage forming the facet joints (Bland, 1994; Cramer, 2014; Curl, 1994; Porterfield and DeRosa, 1995; Taylor, 2010). The facet joints are enclosed within a loose capsule (figure 2.6) and a synovial lining. These joints contain a fibrofatty and fibrocartilaginous meniscus that separates the hyaline cartilage that covers the articular bone (Bland, 1994; Borenstein et al., 1996). The superior facets face posterior and superior and the inferior facets face anterior and inferior. These facets joints are palpated as small domes about 2cm lateral to the spinous processes (Porterfield and DeRosa, 1995).

**2.10.3 Intervertebral disc**

There are only six intervertebral discs (figure 2.4) in the cervical spine due to the fact that there is no intervertebral disc between the atlas and the axis (Bland, 1994; Ombregt, 2013). The first intervertebral disc in the neck is between C2 and C3 and from this level downwards to C7-T1 (first thoracic vertebra) level (Gatterman, 2012; Ombregt, 2013). The disc serves to unite the adjacent vertebral bodies and to hold them apart by means of the hydrostatic pressure of the centrally located nucleus pulposus (Gatterman, 2012). Each intervertebral disc is named after the vertebra that lies above. These discs are thicker
anteriorly than posteriorly resulting in the normal cervical lordosis and do not conform completely to the surfaces of the vertebral bodies with which they are connected. They are slightly smaller in width than the adjacent vertebral bodies (Ombregt, 2013). The intervertebral discs function as shock absorbers in the vertebral spine (Taylor, 2010).

The disc consists of an annulus fibrosus (figure 2.4), a nucleus pulposus and two cartilaginous endplates (Bland, 1994; Ombregt, 2013; MacKinnon and Morris, 2005). The annulus fibrosus forms the outer part of the disc and it is composed of fibrocartilaginous tissue and fibrous protein, which are arranged in concentric layers (lamellae), and run obliquely from one vertebra to another. Its peripheral fibers pass over the edge of the cartilaginous endplate to unite with the bone of each vertebral body. The most superficial fibers blend with the anterior and posterior longitudinal ligaments (Borenstein et al., 2004). Laterally the annulus fibrosus blends with the periosteum and is bound to the vertebral bone (Ross, 2002).

The nucleus pulposus (figure 2.4) of the disc is a water-rich mixture of proteoglycan gel and a lattice of collagen fibers (Ross, 2002). Water accounts for about 80% of the weight of the disc and collagen only account for 5% of the weight (Porterfield and DeRosa, 1995). The nucleus is situated posteriorly and centrally within the disc. At birth the disc contains high water content of about 88% which allows it to absorb a significant amount of stress. With age, the percentage of water decreases resulting in a reduction in the functional ability of the disc to withstand stress (Borenstein et al., 1996).

Vertebral end plates are cartilaginous plates that are approximately 1mm thick peripherally and centrally. They are composed of hyaline cartilage which is located against the vertebral body and fibrocartilage which is adjacent to the disc. The vertebral plates function to prevent the vertebral body from undergoing pressure atrophy. They also function to contain the discs within their normal anatomic borders (Gatterman, 2005).
2.10.4 Ligaments of the cervical spine

The cervical spine has a complex ligamentous system. The functions of the cervical spine ligaments are to maintain normal osseous relationships (Ombregt, 2013).

The upper cervical ligaments

The ligaments of the occipitoatlantoaxial complex (figure 2.5) are strong structures that stabilize the upper cervical spine. The occipitoatlantoaxial complex can be divided into three parts. The first part of the complex consists of ligaments connecting the occiput to atlas and axis namely the anterior atlanto-occipital membrane, the posterior atlanto-occipital membrane and the tectorial membrane. The second part consists of ligaments that connect the axis to the occiput namely the apical ligament, the longitudinal component of the cruciform ligament and the alar ligaments. The third part of the ligament complex consists of ligaments that connect the axis to the atlas which are the lateral component of the cruciform ligament (the transverse ligament), the two accessory atlantoaxial ligaments and the ligamentum flavum (Gatterman, 1990; Ombregt, 2013).

![Figure 2.5: Ligaments of the upper cervical spine (Moore and Dalley, 2006)](image-url)
**Posterior atlanto-occipital membrane.** The atlanto-occipital membrane (figure 2.6) is a thin structure that attaches the posterior arch of the atlas and the posterior rim of the foramen magnum. This ligament is broad from left to right and it spans the distance between the left and right lateral masses of the atlas. Laterally this ligament arches over the left and right grooves for the vertebral artery on the posterior arch of the atlas. This allows passage of the vertebral artery, vertebral veins, and the suboccipital nerve. The posterior atlanto-occipital membrane functions to limit flexion of the occiput on the atlas (Cramer, 2014).

**Anterior atlanto-occipital membrane.** The atlanto-occipital membrane is a broad membranous ligament that runs from the superior aspect of the anterior arch of the atlas to the anterior margin of the foramen magnum anterior to the apical ligament. The ligament functions to limit extension of the occiput on atlas (Bland, 1994; Gatterman, 2012).

**Tectorial membrane.** The tectorial membrane (occipitoaxial ligament) (figure 2.5), is a broad strong band in the vertebral column that lies immediately behind the body of the axis and its ligaments (Borenstein et al., 2004). The tectorial membrane is the superior extension of the posterior longitudinal ligament that begins by attaching to the posterior aspect of C2 vertebral body. It then crosses over the odontoid process and inserts onto the anterior rim of the foramen magnum. It consists of superficial and deep fibers. The superficial fibers blend with the cranial dura mater at the upper region of the basilar part of the occipital bone. The deep fibers consists of a median band that extends all the way to the basilar portion of the occipital bone and two lateral bands that pass medially to the atlanto-occipital joints before attaching to the occiput. This ligament limits both flexion and extension of the atlas and occiput (Cramer, 2014).

**Apical ligaments.** The apical ligament (figure 2.5), is a thin ligament that fans out from the apex of the dens into the anterior margin of the foramen magnum. It is thought to prevent some vertical translation and anterior shear of the occiput (Bland, 1994; Gatterman, 2012).

**Alar ligaments.** The alar ligaments (figure 2.5), are short, strong bundles of fibrous tissue (Ross, 2002) that consists of two portions namely the atlantoalar which attaches to the
atlas and the occipitoalar which attaches to the occiput (Bland, 1994; Porterfield and DeRosa, 1995). The left and right alar ligaments originate from the posterior and lateral aspect of the odontoid process with some of the fibers covering the entire posterior surface of the dens to the medial surface of the occipital condyle on the ipsilateral side (Cramer, 2014). These ligaments restrict motion of the head on the atlas and are often referred to as check ligament (Borenstein et al., 2004).

**Accessory atlanto-axial ligaments.** The right and left accessory atlanto-axial ligaments run from the base of the odontoid process to the to the inferomedial surface of the lateral mass of the atlas on the ipsilateral side. They serve to strengthen the posteromedial aspect of the capsule of the lateral atlanto-axial joints (Cramer, 2014).

**Cruciform ligament.** The cruciform (cruciate) (figure 2.5), ligament consists of the transverse ligament, the superior and inferior longitudinal band. The transverse ligament is a strong ligament that runs from a small medial tubercle of one lateral mass of the atlas to the same tubercle on the opposite side. The superior longitudinal band of the cruciform ligament runs from the transverse ligament to the anterior lip of the foramen magnum. The inferior longitudinal band of the cruciform ligament attaches to the body of C2, preventing the transverse ligament from riding too far superiorly (Cramer, 2014; Monkhouse, 2001).

**The lower cervical ligaments**

**Anterior longitudinal ligament.** The anterior longitudinal ligament (ALL) (figure 2.6), is a strong broad ligament that adheres to the anterior and anterior lateral aspects of the vertebral bodies (Bland, 1994; MacKinnon and Morris, 2005; Ross, 2002). The ALL runs from the anterior upper sacrum to the cervical spine where it attaches anteriorly to the body of C2, the anterior tubercle of C1 and to the basilar occipital bone. It extends superiorly as the anterior atlanto-occipital membrane connecting the anterior margin of the foramen magnum to the anterior arch of the atlas. The ALL loosely attaches to the annulus fibrosus as it crosses the disc space (Ross, 2002). It has several layers with the superficial fibers being the longest extending over three to four vertebrae. The intermediate fibers extend between two and three vertebrae and the deepest fibers run from one vertebral body to the
next. The function of the ALL is to limit extension and excessive lordosis in the cervical spine (Gatterman, 2012).

**Posterior longitudinal ligament.** The posterior longitudinal ligament (figure 2.6) lies on the posterior surface of the bodies of the vertebrae from the axis to sacrum (Borenstein et al., 2004 MacKinnon and Morris, 2005). It attaches to the posterior superior and posterior inferior margins of the vertebral bodies. It is wider than the ALL at the level of the intervertebral disc and it extends upwards as the tectorial membrane which continues cephalad as a strong broad band and attaches at the basilar part of the occiput. Its superficial fibers bridge three or four vertebrae, while deeper fibers extend between adjacent vertebrae as perivertebral ligaments close to and fused with the intervertebral disc (Gatterman, 2012).

**Ligamentum flavum.** The ligamentum flavum (figure 2.5), is a strong ligament spanning the space between laminae of adjacent vertebrae in pairs. The ligament flavum attaches to the antero-inferior surface of the lamina of the vertebra above and to the postero-superior margin of the laminae of the vertebra below (MacKinnon and Morris, 2005; Ross, 2002). Laterally the ligament flavum stretches to the zygapophyseal joints and enters the fibrous composition of the joint capsule. This ligament supports the neck in an erect posture and aids the cervical muscles to extend the flexed neck limiting motion of the zygapophyseal joints. It also retracts abrupt vertebral movements (Ross, 2002).

**Supraspinous and interspinous ligaments.** The supraspinous ligament (figure 2.5), is thin ligament composed of a high percentage of elastic tissue, and runs over the tips of the spinous processes (Borenstein et al., 2004). The interspinous ligaments are a series of ligaments that course between the spinous processes of each pair of cervical vertebrae (Cramer, 2014). They are thin and almost membranous. They connect adjacent spinous processes. Their attachments extend from the root to the apex of each spinous process, meeting the supraspinous ligament at the back and the ligamenta flavum in front. Interspinous ligaments add stability to the spine by checking excessive flexion. The supraspinous ligaments together with the interspinous ligaments are typically the first structures to rupture in extreme flexion (Gatterman, 2012).
**Intertransverse ligaments.** Each intertransverse ligament (figure 2.5), passes from one transverse process to the transverse process of the cervical vertebra below (Cramer, 2014). They connect the ipsilateral transverse processes of each vertebra (Gatterman, 2012). These ligaments are not well-defined in the cervical region and frequently are replaced by the posterior intertransverse muscles (Cramer, 2014). They become taut in contralateral lateral flexion of the cervical spine (Gatterman, 2012).

**Ligamentum nuchae.** The Ligamentum nuchae (figure 2.5), is a continuation of the supraspinous ligaments in the cervical spine. This ligament extends from the vertebral prominens (C7) to the external occipital protuberance (MacKinnon and Morris, 2005; Ross, 2002).

![Figure 2.6: Ligaments of the vertebral column (Moore and Dalley, 2006)](image)

**2.10.5 Muscles of the cervical spine**

The muscles of the neck can be defined by anatomic limits, innervation, or function. The cervical spine is the most mobile section of the spine because it contains the most elaborate and specialized muscle system of the spine (Borenstein et al., 2004).
The musculature of the neck and cervical spine can be divided into the anterolateral and posterior muscle groups. The anterolateral muscles can be subdivided into the superficial cervical, lateral cervical, anterior vertebral and lateral vertebral groups. The posterior group can be further subdivided into superficial (figure 2.7) and deep groups (figure 2.8) (Clark, 1998; Curl, 1994; Ross, 2002).

![Image](image.png)

**Figure 2.7: Posterior view of the deeper muscles of the cervical spine (Borenstein et al., 2004)**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternocleidomastoid</td>
<td>Lateral surface of</td>
<td>Sternal head:</td>
<td>Spinal root of accessory</td>
<td>Acting unilaterally: laterally flexes and rotates the head and neck</td>
</tr>
<tr>
<td></td>
<td>the mastoid process</td>
<td>anterior surface</td>
<td>nerve, C2 and C3 nerves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>of temporal bone</td>
<td>of the manubrium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and lateral half</td>
<td>of sternum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>of the superior</td>
<td>Clavicular head:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>nuchal line</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.1: Superficial and Lateral Muscles of the Neck (Moore and Dalley, 2006)**
Trapezius

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longus coli</td>
<td>Anterior tubercle of C1, vertebral bodies C1-C3, TVP of C3-C6</td>
<td>Bodies of C5-T3 vertebrae, TVP of C3-C5 vertebrae</td>
<td>Ventral rami of C2-C6 spinal nerves</td>
<td>Acting unilaterally: flexes neck with rotation to opposite side</td>
</tr>
<tr>
<td>Muscle</td>
<td>Proximal Attachment</td>
<td>Distal Attachment</td>
<td>Innervation</td>
<td>Main Action</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Splenius capitis</td>
<td>Inferior half of the ligamentum nuchae and T1-T6 spinous process</td>
<td>Lateral aspect of mastoid process and lateral third f superior nuchal line</td>
<td>Dorsal rami of middle cervical spinal nerves</td>
<td>Laterally flexes and neck to same side Acting bilaterally: extend head and neck</td>
</tr>
<tr>
<td>Levator scapulae</td>
<td>Posterior tubercle of TVP of C1-C4</td>
<td>Superior part of medial border of scapula</td>
<td>Dorsal scapular nerve C5 and cervical spinal</td>
<td>Elevates scapula and tilts its glenoid</td>
</tr>
</tbody>
</table>

Table 2.2 above demonstrates the anterior muscles of the cervical spine. These muscles have important functions in postural and segmental control by stiffening and stabilising the neck especially the mid cervical segments (Middleditch and Oliver, 2005).

Table 2.3: Lateral Vertebral Muscles (Moore and Dalley, 2006)
vertebrae | nerves C3 and C4 | cavity inferiorty by rotating scapula
---|---|---
Posterior scalene | Posterior tubercles of TVP of C4-C6 | External border of second rib | Ventral rami of cervical spinal nerves C7 AND C8 | Flexes neck laterally, elevates second rib during forced inspiration
Middle scalene | C2 TVP and posterior tubercles of TVP of C3-C7 vertebrae | Superior surface of first rib, posterior to groove for subclavian artery | Ventral rami of cervical spinal nerves | Flexes neck laterally, elevates first rib during forced inspiration
Anterior scalene | Anterior tubercles of TVP of C3-C6 vertebrae | Scalene tubercle of first rib, anterior groove for subclavian artery | Cervical spine nerves C4, C5 and C6 | Elevates first rib, laterally flexes and rotates neck

Table 2.3 above demonstrates muscles of the lateral vertebral muscles of the neck such as levator scapulae, posterior, middle and anterior scale muscles.

**Table 2.4: Superficial Layer of Intrinsic Back Muscles (Moore and Dalley, 2006)**

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splenius Capitis</td>
<td>Nuchal ligament and</td>
<td>Fibers run superolaterally</td>
<td>Posterior rami of spinal nerves</td>
<td>Unilaterally: lateral flexion of</td>
</tr>
</tbody>
</table>
Spinous processes of C7-T6 vertebrae

to mastoid process of temporal bone and lateral third of superior nuchal line of occipital bone

Bilaterally: extend head and neck

Table 2.4 above demonstrates the superficial layer on intrinsic muscle of back muscles. These muscles are involved in lateral flexion, rotation and extension of the neck as shown in the table above.

Table 2.5: Intermediate Layer of Intrinsic Back Muscles (Moore and Dalley, 2006)

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erector Spinae:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iliocoastals</td>
<td>Arises by a broad tendon from posterior part of iliac crest, posterior surface of sacrum, sacroiliac ligaments, sacral and inferior lumbar spinous</td>
<td>Lumbarum, thoracis, cervicis, fibers run superiorly to angles of the lower ribs and cervical TVPs</td>
<td>Posterior Rami of spinal nerves</td>
<td>Unilaterally: Laterally flex the vertebral column; Bilaterally: extend vertebral column and head; as back is flexed, control</td>
</tr>
<tr>
<td>Longissimus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
processes and supraspinous ligament

ribs between tubercles and angles to TVPs in thoracic and cervical regions; and to mastoid process of temporal bone

movement via eccentric contraction

The intermediate layer of intrinsic back muscles are demonstrated in table 2.6 above. These include the spinalis, iliocostal and longissimus muscles collective known as the erector spinae.

Table 2.6: Suboccipital Muscles (Moore and Dalley, 2006)

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Proximal Attachment</th>
<th>Distal Attachment</th>
<th>Innervation</th>
<th>Main Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus capitus posterior major</td>
<td>Spinous process of C2 vertebra</td>
<td>Lateral part of the inferior nuchal line of occipital bone</td>
<td>Posterior Rami of C1 (suboccipital nerve)</td>
<td>Act on head directly or indirectly</td>
</tr>
</tbody>
</table>
Table 2.6 above shows the suboccipital muscles of the cervical spine. These muscles function to extend and rotate the occiput on C1 as stated in the table above.

2.11 Blood Supply of the Cervical Spine

The vertebral artery (figure 2.8) the major source of blood supply found on each side of the neck (Borenstein et al., 1996). The first part of the vertebral artery arises from the subclavian artery and it passes upwards to enter the transverse foramen of C6 vertebra. The second ascends through C6 to C1 transverse foramina accompanied by vertebral venous and small sympathetic nerves plexus. The third part curves behind the lateral mass of C1 on to its posterior arch. The fourth part pierces the dura and arachnoid to enter the cranial cavity and the subarachnoid space at the foramen magnum (Talor and Twomey, 2002). After passing through the foramen magnum, the vertebral arteries join to form the basilar artery (Borenstein et al., 1996; Clark, 1998; Monkhouse, 2001). The vertebral arteries give off branches that supply the bone, joints, muscles and neural elements (Borenstein et al., 1996, Monkhouse, 2001).
The venous drainage of the cervical vertebral bodies consists of anterior and posterior internal vertebral plexus and basivertebral veins which drain the vertebral bodies (Clark, 1998). The vertebral veins have plentiful connections with segmental neck veins and with the internal vertebral venous plexus in the epidural space. The epidural venous sinuses are large and valveless, so blood from their connecting veins can flow in different directions within them (Taylor and Twomey, 2002).

2.12 Innervation of Cervical Spine

The nerve supply to the spinal column (figure 2.9) is derived from the spinal nerve once it passes out of the neural foramina. The cervical spine consists of eight cervical nerves. The first cervical nerve (C1) exits between the atlas and the occiput. The second to the eighth cervical nerves (C2-C8) exit from the neural foramina so that the lower cervical nerve root exits after crossing the intervertebral disc numbered one higher e.g. C5 cross crosses the C4-C5 intervertebral disc (Borenstein et al., 1996). The cervical nerves may also be named according to their spinal exit above their corresponding vertebrae e.g. C1 nerve exits above C1 vertebrae, C2 nerve vertebral exits above C2 vertebrae and so on. The eighth
cervical nerve (C8) exits between the seventh cervical vertebrae and the first thoracic vertebrae (Porterfield and DeRosa, 1995).

The spinal nerve is a mixed nerve which contains motor fibers, sensory axons of the dorsal root ganglia as well as preganglionic fibers from the autonomic nervous system. The main spinal nerve gives of three branches before continuing into the brachial plexus. These branches are the primary posterior rami, primary anterior rami and the sinuvertebral nerve of Luschka. The primary anterior and posterior rami supply the muscles of the spine and chest wall (Borenstein et al., 1996). In the neck, the sinuvertebral nerve (recurrent meningeal nerve) originates from the ventral ramus and it receives a contribution from the gray communicating ramus and other sympathetic nerves that run with the vertebral artery. This nerve supplies the posterior aspect of the intervertebral disc, posterior longitudinal ligament, anterior spinal dura mater, posterior vertebral bodies, and uncovertebral joints and it supplies these structures at the level at which it enters the vertebral canal (Borenstein et al.; Cramer, 2014; Gatterman, 2005).

The sensory supply of the facet joints is derived from the medial branch of the posterior primary division at the level of the joint. Each joint receives a branch from the posterior primary division of the level above. The sinuvertebral nerves of C1-C3 have large branches that ascend to the posterior cranial fossa. These branches supply the atlanto-axial joint complex together with the ventral ramus of C2, tectorial membrane, components of the cruciform ligament, and alar ligaments (Gatterman, 2005).

The outer third of the annulus fibrosus is innervated by sensory and vasomotor fibers. The sensory fibers are probably nociceptive and proprioceptive in nature. The vasomotor fibers are associated with the small vessels along the superficial aspect of the annulus fibrosus. The anterior and lateral aspects of the disc are primarily innervated by branches from the sympathethic chain and from the gray communicating rami. The posterolateral aspect of the annulus fibrosus receives direct branches from the anterior primary division and the gray communicating rami of the sympathetic chain. The posterior aspect of the disc is innervated by the recurrent meningeal nerve (Gatterman, 2005).
2.13 Biomechanics of the Cervical Spine

The cervical spine is the most mobile part of the vertebral column (Gatterman, 1990). The biomechanics of the cervical spine is determined by the shape of the vertebral bodies and the orientation of the zygapophyseal joints (Dvorak and Pope, 2007). The cervical spine moves in flexion, extension, lateral flexion and rotation. Lateral flexion and rotation cervical motion are always combined to some extend (Bland, 1994). The atlanto-occipital and atlanto-axial is responsible for 40% of flexion and extension and 60% of rotation in the cervical spine (Benzel, Currier, Dormans, and Dvořák, 2005; Clark, 1998).

2.13.1 The atlanto-occipital joint biomechanics

The atlanto-occipital (C0-C1) joint is an enarthrosis, a joint with spherical articular surfaces with three degrees of movement: flexion, extension, rotation and lateral flexion. The occipital condyles are convex shaped and articulate with the superior articular facets of the
lateral masses of the atlas which are concave anteroposteriorly (Benzel et al., 2005; Kapandji, 1974).

During flexion, the occipital condyles recede on the lateral masses of the atlas and the occipital bone simultaneously moves away from the posterior arch of the atlas. Flexion of the C0-C1 joint is associated with flexion of the atlantoaxial (C1-C2) joint resulting in the posterior arches of the atlas and axis being widely separated. Flexion is checked by the tension developed in the articular capsules, the posterior atlanto-occipital membrane, posterior cervical ligaments (Kapandji, 1974) and when the anterior margin of the foramen magnum impinges on tip of the dens (Clark, 1998).

During extension, the occipital condyles slide anteriorly on the lateral masses of the atlas and the occipital bone simultaneously moves nearer to the posterior arch of the atlas (Kapandji, 1974). During extension of C0-C1 joint, the posterior arches of the atlas and axis are approximated and extension is checked by the impact of these three bony pieces (Bland, 1994, Kapandji, 1974) and the tectorial membrane (Clark, 1998). About 25% of total extension occurs before bony impingement limits any further extension (Bland, 1994).

During rotation to the left, the right occipital condyle is displaced anteriorly on the right mass of the atlas and the lateral atlanto-occipital ligament simultaneously wraps itself around the odontoid ligament and is stretched. Rotation is checked by the tension developed in the lateral atlanto-occipital ligament (Kapandji, 1974) and the alar ligaments (Clark, 1998).

During lateral flexion to the left movement of the occipital condyles consist of slipping to the right and vice versa. The left condyle and the odontoid process are approximated without coming into contact because lateral flexion is checked by tension developed in the capsular ligament, the right lateral odonto-occipital ligament (Kapandji, 1974) and the alar ligaments (Clark, 1998).
2.13.2 The atlanto-axial joint biomechanics

The inferior articular facets of the lateral masses of the atlas are convex anteroposteriorly and these facets articulate with the superior facet of the axis which are convex anteroposteriorly (Kapandji, 1974). Flexion, extension, lateral flexion and rotation movements occur at the three atlantoaxial joints (Bland, 1994). Motion in the atlantoaxial joint is checked by the alar ligaments, tectorial membrane and cruciate ligament (Benzel et al., 2005).

During flexion, the anterior arch of the atlas moves up on the odontoid process while the inferior facet of the lateral masses rolls and slides in the superior articular facet of the axis. During flexion, there is a separation between the posterior arch of the atlas and the spinous process of the axis (Gatterman, 2004).

During extension, the anterior arch of the atlas moves down on the odontoid process while the inferior facet of the lateral masses rolls and slides in the superior articular facet of the axis. During extension, the posterior arch of the atlas and the spinous process of the axis approximate (Gatterman, 2004).

During rotation to the right, the left lateral mass of the atlas moves forward while the right lateral mass recedes and vice versa during rotation to the left. During rotation to the left, the odontoid process stays put. The osteoligamentous ring formed by the transverse ligament and axis rotates about an axis corresponding to the axis of the odontoid, relaxing the articular capsule on the left and stretching it on the right. The above motion occurs simultaneously with motion at the atlanto-axial joints bilaterally which are mechanically linked. With rotation to the right, the opposite motions would occur (Kapandji, 1974). About 50% of the total 160-180 degrees of rotation occurs at the atlantoaxial joint (Bland, 1994). Rotation is checked by the atlantoaxial articulations, the transverse ligaments and the alar ligaments (Clark, 1998).

During lateral flexion, the atlas glides laterally to the side of the tilt, narrowing the space between the odontoid process and the lateral mass of the atlas on the side ipsilateral to the
motion and widening the space contralaterally (Bland, 1994). As previously discussed above under the biomechanics of the cervical spine, lateral flexion and rotation occur as a coupled motion.

2.13.3 Biomechanics of the lower cervical spine

Each component of the lower cervical (C3-C7) mobile segment consists of an intervertebral disc, two uncovertebral joints, two facet joints (Taylor and Twomey, 2002), ligaments and capsular structures (Clark, 1998).

The inferior articular process of the axis face inferiorly and anteriorly and they correspond to the superior articular processes of C3 vertebra which face superiorly and posteriorly. The inferior articular process of C3 vertebra face inferior and anteriorly, corresponding to the superior articular process of the vertebra below (Kapandji, 1974).

During forward flexion, the anterior disc space is compressed anteriorly and it widens posteriorly with simultaneous separation of the posterior elements. The superior vertebral glides forward on the inferior vertebral with widening of the facet joints. Flexion is checked by the posterior longitudinal ligament, the posterior intervertebral ligaments, the posterior superior spine, the limited elasticity of the fascia of the extensor musculature (Borenstein et al., 2004), supraspinous, interspinous and the ligamentum flavum (Clark, 1998).

During extension, the posterior disc is compressed posteriorly and it widens anteriorly with simultaneous approximation of the posterior elements. The vertebral bodies approximate narrowing the neural foramina and the facet joints glide posteriorly. Extension is limited by the direct contact of the vertebral laminae, the facet joints, and the posterosuperior spinous process (Borenstein et al., 2004).

Cervical lateral flexion requires rotation. During lateral bending or rotation, the foramina close on the side toward which the neck moves (ipsilateral), while opening on the contralateral side (Borenstein et al., 2004). During this coupled motion, the spinous processes move contralateral to the motion which is of clinical importance because
palpation of the spinous processes can serve as an indirect indicator of disturbed motion in the motion segments (Benzel et al., 2005).

2.13.4 Biomechanics of the uncovertebral joints

The superior plateau of the vertebra below consists of cartilage-lined uncinate processes which face medially and superiorly and they correspond with the cartilage-lined semiluminar facets of the inferior plateau of the vertebra above (Kapandji, 1974).

During flexion, when the upper vertebra slides anteriorly or posteriorly, the articular facets of the unco-vertebral joints slide relative to each other. The uncinate processes functions to guide the vertebral body into anterior and posterior movement (Kapandji, 1974).

During lateral flexion, the interspace of the uncovertebral joints widens contralaterally and approximate ipsilaterally to the motion. The nucleus pulposus is displaced contralaterally and the capsule is stretched contralaterally. Pure lateral flexion does not occur and it is always associated with rotation and extension movements (Kapandji, 1974).

2.14 The Vertebral Subluxation Complex

Dysfunctions of the spine treated by chiropractors have been described as the vertebral subluxation complex. This complex is composed of the myologic, connective, vascular, neurologic and lymphatic tissue involvement. It is hypothesized that a fundamental component of the vertebral subluxation complex is the development of adhesions in the zygapophyseal joints following hypomobility of the zygapophyseal joints (Cramer, Budgell, Henderson, Khalsa and Pickar, 2006). The subluxation complex generally refers to pathological changes that occur in the spine, and its clinical character depends on the combination of injured tissues and the extent of injury (Gatterman, 2005).
2.15 Cervical Manipulative Therapy

The aim of mechanical neck pain treatment is to reduce the pain and restore normal function of the cervical spine. Cervical manipulative therapy (CMT) is one of the most used therapies in the management of mechanical neck disorders (Martínez-Segura et al., 2006). Chiropractic manipulative therapy is a relatively high velocity, low amplitude force applied to the vertebral column (Pickar and Bolton, 2012). It has been described as a passive dynamic thrust that causes an audible release (cavitation) and attempts to increase the manipulated joint’s range of motion (Ernst, 2003). A cavitation presents as an audible cracking sound following manipulation to a diarthrodial synovial joint and it is often viewed as signifying a successful manipulation. A cavitation is characterized by formation of gas bubbles within the synovial fluid through local reduction in pressure (Evans, 2002).

2.15.1 Analgesic effects of cervical manipulative therapy

Manipulative therapy can stimulate mechanoreceptors associated with synovial joints and thereby affect joint pain. There are four types of joint receptors: types I, II, III and IV receptors. Types I-III are corpuscular mechanoreceptors that detect static position of joint, acceleration and deceleration of the joint, direction of movement and over-displacement of the joint. The type IV receptors consist of a network free nerve endings that have nociceptive capabilities and are inactive under normal conditions. Restoring normal joint function through manipulative therapy will stimulate normal type I-III receptor function thereby inhibiting type IV pain receptor function with a subsequent reduction in the sensation of pain (Gatterman, 2005; Troyanovich, 1999; Wyke, 1985).

Manipulative therapy results in the breakdown of cross-linkages and any intraarticular capsular fibroadipose adhesions resulting from immobilization. Manipulation also has the ability to stretch segmental muscles, causing spindle reflexes that decrease hypertonicity of these muscles. The resultant effects of the breakage of adhesions and a decrease in muscle spasm, is an increase in spinal range of motion and pain relief (Gatterman, 2005).
2.15.2 Effects of cervical manipulative therapy on sleep

Chiropractic treatment is believed to offer relief to patients suffering from sleep disorders through mechanical manipulation. Cervical manipulative therapy may affect types I and II mechanoreceptors by exciting γ-aminobutyric acid-ergic (GABA-ergic) inhibitory neuron. This neuron interrupts the transmission of nociceptive impulses from the thalamus to the limbic system pain (Goto, Frange, Andersen, Júnior, Tufik and Hachul, 2014; Kingston, Raggio, Spencer, Stalaker and Tuchin, 2010).

At the same time the dorsal column where the A-β fibers travel also stimulates the hypothalamus. The hypothalamus houses the ventrolateral preoptic nucleus (VLPO cluster) which is a dense cluster of neurons that become active when non–rapid eye movement sleep is initiated. About 80% of these neurons contain both the GABA-synthesizing enzyme glutamic acid decarboxylase and the peptide galanin (Goto et al., 2014; Kingston et al., 2010).

Both galanin and GABA, released from the ventrolateral preoptic nucleus, are known to inhibit the locus coeruleus, a major site of norepinephrine synthesis, thereby allowing relaxation of the mind, thus promoting non-rapid eye movement (NREM) sleep. Pathways have been postulated, but no conclusive evidence exists (Goto et al., 2014; Kingston et al., 2010).

Jamison conducted research to investigate the relationship between chiropractic care and insomnia patients (patients with difficulty initiating or maintaining sleep). The study did not show any evidence of the effectiveness of chiropractic care for insomnia symptoms. Even though no clear patterns emerge between chiropractic care and sleep were noted, it has been postulated that chiropractic intervention has been found to be effective in relieving pain and stress related conditions and that after alleviating pain, restful sleep could possibly ensue. Pain is likely to have a substantial impact on sleep. Any relationship between insomnia and chiropractic care is likely to be confounded by pain (Goto et al., 2014).
CHAPTER THREE - METHODOLOGY

3.1 Introduction

The study consisted of one group of thirty participants who presented with mechanical neck pain and sleep difficulties. All the participants were between 18-40 years old and possessed a Pittsburgh Sleep Quality Index (PSQI) entry score of five and above. Objective data was collected by means of a CROM device and subjective data was collected using a numerical pain rating scale (NPRS) and PSQI. Cervical manipulative therapy was administered to all the participants, twice a week, over a three week period. This chapter serves to explain the study design and all the methods and procedures that were followed during the course of the study.

3.2 Study Design

This is a non-comparative quantitative study consisting of one group of thirty participants whereby cervical manipulative therapy was administered.

3.2.1 Participant recruitment

Participants were recruited by means of poster advertisements (Appendix A). These posters were placed on notice boards at the University of Johannesburg day clinic and around the University of Johannesburg. The study also relied on use of word of mouth to reach participants external to the University of Johannesburg.

3.2.2 Sample Selection and Size

The sample consisted of a group of thirty participants, male and female, between ages of 18-40 years, who met the inclusion criteria. The study was conducted at the University of Johannesburg under supervision of clinicians.
3.2.3 Group Allocation

The study consisted of one group of thirty participants who met the inclusion criteria. All participants received the same treatment approach and therefore randomisation was not applicable to this study.

3.2.4 Inclusion Criteria

The inclusion criteria were based on the following:

- participants who presented with mechanical neck pain, sleep problems and a Pittsburgh Sleep Quality Index (PSQI) (Appendix B) entry score of 5 and above met the inclusion criteria;
- participants should have been between ages of 18-40 years old. According to Yochum and Rowe (2005), joint degeneration becomes more prevalent in the 5th and 6th decades of life. Those younger than 18 years have not reached skeletal maturity (Gilsanz and Ratib, 2005);
- participants also presented with pain in the cervical spine with symptoms provoked by neck postures and movement, or palpation of the cervical musculature (Muñoz-Muñoz et al., 2012).

3.2.5 Exclusion Criteria

Participants who presented with any of the following were excluded from the study:

- discogenic pain, radicular pain and contraindications to cervical manipulation (Appendix D);
- participants who were on any medication such as analgesics, anti-inflammatory and sedatives;
- participants who suffered from depression, sleep apnea, and narcolepsy.
3.3 Treatment Approach

3.3.1 Initial visit

During the initial visit the following procedures were conducted:

- the participants were given consent forms (Appendix G) and information forms (Appendix F) to read and sign;
- participants completed a modified Pittsburgh Sleep Quality Index (PSQI) (Appendix B) questionnaire in order to determine if they met the PSQI entry score of five and above which was a prerequisite for participation in the study;
- case history, physical and cervical regional examination were conducted;
- participants were given a Numerical Pain Rating Scale (Appendix C) to indicate the number that best describes their pain intensity;
- cervical range of motion was measured using a cervical range of motion (CROM) device (Appendix E);
- cervical manipulation therapy was administered to the cervical spine to correct cervical spine restrictions that were detected during motion palpation of the neck.

3.3.2 Follow-up Visits

The following were conducted during follow-up visits:

- participants were re-assessed by motion palpation of the cervical spine prior to cervical manipulative therapy being administered;
- on the fourth and seventh visits, further readings were taken using a NPRS (Appendix C) and a modified PSQI (Appendix B). The ranges of motion measurements of the cervical spine were also taken using the CROM device. Cervical manipulative therapy was also administered during these visits;
• no further treatment was administered during the seventh visit which was reserved solely for taking final readings and measurements.

3.3.3 Treatment

All the participants received the same treatment approach. Their cervical spines restrictions were detected via motion palpation of the neck. These restrictions were then corrected through cervical manipulative therapy, twice a week over a six week period.

Motion palpation

Motion palpation of the cervical spine was conducted in the following manner (Marcotte, Normand and Black, 2012):

• the participants were positioned in a supine position;
• the researcher was positioned at the head of the participants;
• the researcher conducted rotatory motion palpation of the neck;
• the latero-palmar surface of the distal interphalangeal joint of the index finger contacted the articular pillar of the palpated vertebra;
• the neck was motion palpated from C0-C7 levels; and
• restricted cervical segments were then noted.

Cervical manipulative therapy

Figure 3.1: Cervical Manipulative Therapy: high velocity, low amplitude procedure (Martínez-Segura et al., 2006)
The skill of cervical manipulation lies in the researcher’s ability to deliver and control the velocity, magnitude and direction of the impulse (thrust) to the spine, once the restricted vertebral segment has been noted (Pickar, 2002).

Cervical manipulative therapy (figure 3.1) was administered in the following manner:

- the participants were positioned supine with cervical spine in a neutral position (Martínez-Segura et al., 2006);
- the researcher’s index finger of the ipsilateral hand applied contact over the posterior lateral aspect of the articular pillar homolateral to listing (dysfunctional side of identified vertebra) (Martínez-Segura et al., 2006);
- alternative contact was made on the paraspinal tissues overlying the spinous or transverse processes of the vertebra being manipulated (Pickar, 2002);
- the contralateral hand cradled the participant’s head (Martínez-Segura et al., 2006);
- gentle ipsilateral side flexion and contralateral rotation were introduced from the restricted side until slight tension was palpated in the tissues at the contact point (Martínez-Segura et al., 2006);
- cervical manipulative therapy was directed at dysfunctional levels by the researcher. A high velocity low amplitude thrust was directed superomedially in the direction of the participant’s contralateral eye (Martínez-Segura et al, 2006);
- following the thrust, a cavitation may occur (Martínez-Segura et al, 2006). However a cavitation sometimes doesn’t occur even though the restriction has been corrected (Pickar, 2002).
3.4 Subjective Data

3.4.1 Pittsburgh sleep quality index

A Pittsburgh sleep quality index (PSQI) (Appendix B) is a measurement of sleep quality consisting of 24 items questionnaire: 19 self-rated items plus additional 5-items made by the bed partner which are not included in the scoring (Beaudreau et al., 2012). The 19 self-rated questions are grouped into seven components which are weighted equally on a scale of 0-3. The seven components consist of subjective sleep quality, habitual sleep efficiency, sleep latency, sleep duration, sleep quality, sleep disturbance, sleep medication use and daytime dysfunction due to sleepiness (Buysse, Reynolds Ill, Monk, Berman and Kupfer, 1989). The addition of these seven components yields a global score which ranges from 0-21 of subjective sleep quality. A higher score is indicative of poorer sleep quality (Aloba, Adewuya, Ola and Mapayi, 2007). The PSQI takes about 5-10 minutes to complete (Beaudreau et al., 2012).

The Pittsburgh Sleep Quality Index has the following goals (Buysse et al., 1989):

- to provide a reliable, valid and standardized measure of sleep quality;
- to discriminate between “good” and “poor” sleepers;
- to provide an index that is easy for subjects to use and for clinicians and researchers to interpret;
- to provide a brief, clinically useful assessment of a variety of sleep disturbances that might affect sleep quality.

The original unmodified PSQI was proven to be reliable and valid by Buysse et al. (1989).

3.4.2 Numerical pain rating scale

The numerical pain rating scale (NPRS) (Appendix C) consists of an 11 point numerical scale from 0 to 10, with 0 indicating no pain and 10 indicating the worst pain. The NPRS was used to measure pain relief by asking patients to compare pain before and after
treatment. Participants were asked to circle or state the number that best represented their perceived pain intensity (Frampton and Hughes-Webb, 2011; Hjermstad, Fayers, Haugen, Caraceni, Hanks, Loge, Fainsinger, Aass and Kaasa, 2011).

The NPRS was proven to valid and reliable by Farrar, Troxel, Stott, Duncombeand and Jensen (2008) and Ferreira-Valente, Pais-Ribeiro and Jensen (2011).

3.5 Objective Data

3.5.1 Cervical range of motion device

Cervical range of motion device (CROM) (Appendix E) is an instrument used to measure six conventional movements (flexion, extension and right and left components of lateral flexion and rotation) of the cervical spine (Hole, Cook and Bolton, 1995) used by manipulative therapists in the clinical examination of patients (Morphett, Crawford and Lee, 2003).

The CROM device consists of a plastic frame that was placed on the participants head as if putting on a pair of glasses. The CROM device was aligned on the nose bridge and ears and the Velcro strap were fastened around the head in line with the brows. Three dial angle meters were used to take CROM measurements: the sagittal plane meter, lateral flexion meter and the rotation meter. The sagittal and the lateral meter are gravity meters and the rotation meter is magnetic and responds quickly to the shoulder mounted magnetic yoke. During rotation, shoulder substitution is eliminated as rotation is controlled by the magnetic yoke which allows for accurate measuring of the cervical rotation (Moodley and Branttingham, 2002; Morphett et al., 2003; Performance Attainment Associates, 1988).

During measurements participants were seated in an upright position on a chair with the CROM device on their heads and feet flat on the floor. A self-chosen neutral head position was established as the starting and reference positions. The CROM device was adjusted to zero in the primary plane of movement (Wibault, Vaillant, Vuillerme, Dedering and
Peolsson, 2013). Measurements of the cervical spine using a CROM device were taken in the following manner:

- **Flexion and Extension**

  During flexion, participants were instructed to tuck their chin into their chest so as to include sub occipital flexion. During extension, the participants were instructed to tilt their heads back. The head should be parallel to the ceiling (Moodley and Branttingham 2002). Readings were taken using the sagittal meter and then recorded on the CROM recording sheet (Performance Attainment Associates, 1988).

- **Lateral flexion**

  Participants were instructed to laterally flex their heads to the left and then to the right or vice versa. Their shoulders remained level and no rotation of the neck was added during lateral flexion (Moodley and Branttingham, 2002). To avoid rotation of the neck during lateral flexion, participants were asked to focus on a point on the wall straight ahead so that the lateral flexion meter would read zero at rest. Readings were recorded using the lateral flexion meter and recorded on the appropriate space on CROM recording sheet (Performance Attainment Associates, 1988).

- **Rotation**

  The sagittal and lateral flexion meters had to read zero for the rotation meter to be level. Participants were instructed to keep their shoulders level (Performance Attainment Associates, 1988). Participants were then instructed to turn their heads to the right and then to the left as far as they could (Moodley and Branttingham 2002). Readings were taken using the rotation meter and recorded on the CROM recording sheet (Performance Attainment Associates, 1988).
The CROM instrument was proven to be a valid and reliable instrument for measuring cervical range of motion by Hole, Cook and Bolton (1995) and Williams, McCarthy, Chorti, Chooke and Gates 2010).

3.6 Data Analysis

For one sample group, the following tests were used for data analysis:

- Descriptive statistics including frequencies;
- Shapiro-Wilk test for normal distribution of data;
- One-way repeated measures ANOVA tests were used to measure changes in sleep index, CROM device and pain scale measures;
- Pairwise Comparisons tests were used to establish if there was a difference between specific time periods.

3.7 Ethical Consideration

All participants that took part in this particular study were requested to read the information form (Appendix F) and sign the consent form (Appendix G) specific to this study. The information and consent forms outlined the name of the researcher, purpose of the study benefits of partaking in the study, participant assessment and treatment procedure. Any risks, benefits and discomforts pertaining to the treatment involved were also explained and that the participant’s safety was ensured. The information and consent forms also explained that the participant’s privacy would be protected as only the clinician and the participants were allowed to be in the treatment room and that anonymity would be ensured as the patient 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 without any penalties. Participants were advised that any questions that they had regarding the study would be addressed by
the researcher whose contact details were made available to the participants. The participants were required to read and sign the information and consent form, signifying that they understood all that is required of them for this particular study. Results of the study were made available on request.

With regards to this particular study, the participants were informed that they might experience post manipulative tenderness following cervical manipulative therapy that should resolve within a few days post treatment. It was also explained to the participants that cervical manipulative therapy is a safe procedure with therapeutic effects such as the relief of tension in the cervical musculature, an increase in cervical range of motion and resolution of neck pain.

If any adverse effects were experienced by the participants during the study, they were referred to the appropriate practitioner.
CHAPTER FOUR - RESULTS

4.1 Introduction

This chapter will be used to explain the results obtained from this study. The sample group consisted of one group of thirty participants. All participants received cervical manipulative therapy twice a week, over a three week period. Data was collected using the subjective methods which included PSQI and NPRS and Objective data was collected using a CROM device at the first, fourth and seventh visit. The statistical results only represented a small group of subjects and therefore no assumptions can be made with respect to the population as a whole. The p-value of the tests were set at 0.05 and it represented the level of significance of all results.

Since sample size of the current study was less than 50 (n<50), the Shapiro-Wilk test was used to test for normal distribution of data. For normal distribution of data, the p-value should be greater than 0.05 level of significance. Since the data was found to be normally distributed, a parametric test (One-way Repeated measure ANOVA test) was used to demonstrate if there was change over three trial periods. For the One-way repeated measures ANOVA tests to be statistically significant, the p-value should be less than 0.05 indicating that changed occurred across three trial periods.

Statistically significant results from Wilk’s Lambda statistic suggests that there was a significant difference along the visits (visit 1, visit 4 and visit 7), however it does not tell which visit differ from one another. Pairwise comparisons were then used to compare each pair of time points (visits) and indicate whether the differences between them are significant (Pallant, 2010).

The analysis included the following:

I. Demographic analysis for age and gender.
II. Intra-group analysis.
III. The inter-group analysis was not applicable to the study. The study was a non-comparative quantitative study which consisted of one group of thirty participants who received the same treatment protocol in the form of cervical manipulative therapy over a three week period.

4.2 Demographic Data Analysis

The study sample consisted of one group of thirty participants (n=30) comprising of 9 females (30%) and 21 males (70%). The participants were between the ages of 19-36 years with a mean value of 23.33 and std. deviation value of 4.26.

Table 4.1: Demography data for this study

<table>
<thead>
<tr>
<th>Data</th>
<th>Group 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age distribution (Years)</td>
<td>19-36</td>
</tr>
<tr>
<td>Mean age (Years)</td>
<td>23.33</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>4.26</td>
</tr>
<tr>
<td>Gender distribution</td>
<td>9 Females (30%)</td>
</tr>
<tr>
<td></td>
<td>21 Males (70%)</td>
</tr>
</tbody>
</table>

Table 4.1 above shows demographic data of the participants who participated in this study.
4.3 Subjective Analysis

4.3.1 Pittsburgh sleep quality index

Mean data analysis

According to figure 4.1 above, the mean values for PSQI visit 1 is 9.20, for visit 4 is 6.60 and for visit 7 is 4.27. The mean values from visit 1 to visit 4 declined by 28.26%. The mean values from visit 4 to visit 7 further declined by 35.30%. The overall decline in PSQI mean values from visit 1 to visit 7 was 53.59%.

A One-way repeated measures ANOVA was conducted to compare scores on the PSQI at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).

Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in PSQI between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.
4.3.2 Numerical pain rating scale

Mean data analysis

![Bar graph representing mean values for NPRS visits 1, 4 and 7](image)

Figure 4.2: Bar graph representing mean values for NPRS visits 1, 4 and 7

According to figure 4.2 above, the mean values for NPRS visit 1 is 5.80, for visit 4 is 3.48 and for visit 7 is 1.38. The mean values from visit 1 to visit 4 declined by 40%. The mean values from visit 4 to visit 7 further declined by 60.34%. The overall decline in NPRS mean values from visit 1 to visit 7 was 76.21%.

A One-way repeated measures ANOVA was conducted to compare scores on the NPRS at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).

Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in NPRS between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.
4.4 Objective Analysis

4.4.1 Flexion

Mean data analysis

Figure 4.3: Bar graph representing an increase in the mean values for flexion visits 1, 4, and 7

According to figure 4.3 above, the mean values for flexion visit 1 is 58.00 °, for visit 4 is 61.67 ° and for visit 7 is 64.87 °. The mean values from visit 1 to visit 4 increased by 5.95%. The mean values from visit 4 to visit 7 further increased by 4.93%. The overall increase in flexion mean values from visit 1 to visit 7 was 10.59%.

A One-way repeated measures ANOVA was conducted to compare scores on flexion at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk's Lambda's p-value of 0.000 (p= 0.000).
Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in flexion between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.

4.4.2 Extension

Mean data analysis

![Bar graph representing an increase in the mean values for extension visits 1, 4 and 7](image)

According to figure 4.4 above, the mean values for extension visit 1 is 63.67 °, for visit 4 is 66.80 ° and for visit 7 is 70.47 °. The mean values from visit 1 to visit 4 increased by 4.69%. The mean values from visit 4 to visit 7 further increased by 5.21%. The overall increase in extension mean values from visit 1 to visit 7 was 9.65%.

A One-way repeated measures ANOVA was conducted to compare scores on extension at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).
Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in extension between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.

### 4.4.3 Right rotation

#### Mean data analysis

![Figure 4.5: Bar graph representing an increase in the mean values for right rotation visits 1, 4 and 7](image)

According to figure 4.5 above, the mean values for right rotation visit 1 is 59.93 °, for visit 4 is 62.93 ° and for visit 7 is 66.27 °. The mean values from visit 1 to visit 4 increased by 4.77%. The mean values from visit 4 to visit 7 further increased by 5.04%. The overall increase in right rotation mean values from visit 1 to visit 7 was 9.57%.

A One-way repeated measures ANOVA was conducted to compare scores on right rotation at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).
Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in right rotation between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.

4.4.4 Left rotation

Mean data analysis

![Figure 4.6: Bar graph representing an increase in the mean values for left rotation for visits 1, 4 and 7](image)

According to figure 4.6 above, the mean values for left rotation visit 1 is 60.4°, for visit 4 is 63.0° and for visit 7 is 66.6°. The mean values from visit 1 to visit 4 increased by 4.13%. The mean values from visit 4 to visit 7 further increased by 5.41%. The overall increase in left rotation mean values from visit 1 to visit 7 was 9.31%.

A One-way repeated measures ANOVA was conducted to compare scores on left rotation at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).
Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in left rotation between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.

4.4.5 Right lateral flexion

Mean data analysis

![Bar graph representing an increase in the mean values for right lateral flexion visits 1, 4 and 7](image)

According to figure 4.7 above, the mean values for right lateral flexion visit 1 is 47.40 °, for visit 4 is 51.93 ° and for visit 7 is 56.67 °. The mean values from visit 1 to visit 4 increased by 8.72%. The mean values from visit 4 to visit 7 further increased by 8.36%. The overall increase in right lateral flexion mean values from visit 1 to visit 7 was 16.36%.

A One-way repeated measures ANOVA was conducted to compare scores on right lateral flexion at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).
Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in right lateral flexion between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.

4.4.6 Left lateral flexion

Mean data analysis

![Bar graph representing an increase in the mean values for left lateral flexion visits 1, 4 and 7](image)

According to figure 4.8 above, the mean values for left lateral flexion visit 1 is 49.33 °, for visit 4 is 53.13 ° and for visit 7 is 57.07 °. The mean values from visit 1 to visit 4 increased by 7.15%. The mean values from visit 4 to visit 7 further increased by 6.90%. The overall increase in left lateral flexion mean values from visit 1 to visit 7 was 13.56%.

A One-way repeated measures ANOVA was conducted to compare scores on left lateral flexion at visit 1 (prior to treatment), visit 4 (following treatment) and visit 7 (three-week follow-up). There was a significant change over the three trial periods as indicated by Wilk’s Lambda’s p-value of 0.000 (p= 0.000).
Pairwise Comparisons revealed that from visit 1 to visit 4 (p= 0.000), visit 4 to visit 7 (p= 0.000) and visit 1 to visit 7 (p= 0.000) to be statistically significant indicating significant changes in left lateral flexion between visit 1 and visit 4, visit 4 and visit 7 and visit 1 and visit 7.
CHAPTER 5 - DISCUSSION

5.1 Introduction

This chapter serves to discuss the results that were documented previously in chapter four. The results were obtained through statistical analysis of data from the NPRS, PSQI and CROM device.

5.2 Demographic Data

This study consisted of one group of thirty participants (n=30) between the ages of 19-36. The study comprised of 9 females (30%) and 21 male (70%) participants with an average mean value of 23.33 and standard deviation value of 4.26. The end results gathered from this study were favourable possibly due to the fact that the participants were between the ages of 19-36, to exclude any degenerative joint conditions which may have been detrimental to the overall end results of this study. As previously indicated in chapter three, joint degenerative conditions become prevalent the 5th and 6th decade of life (Yochum and Rowe, 2005); and it was imperative to keep the participants younger than 50 years of age.

The higher male percentage participation in this study is by no means an indication that men suffer from more or less sleep disturbance and mechanical neck pain than females. The study was not a comparative study between genders and therefore such comparison should not be concluded.

The prevalence of neck pain is actually higher in women than in men with around 23% of women and 15% of male suffering from neck pain (Salom- Moreno, Ortega-Santiago, Cleland, Palacios-Ceña, Truyols- Domínguez and Fernandez-de-Peñas, 2014); and 12.9% of women have a higher prevalence in sleep disturbance than men (6.2%) (Linton, Kecklund, Franklin, Leissner, Silvertsen, Lindberg, Svensson, Hansson, Sundin, Hetta, Björkelund, Hall, 2015).
Carroll, Hogg-Johnson, Van Der Velde, Haldeman, Holm, Carragee, Hurwitz, Côté, Nordin, Peloso, Guzman and Cassidy (2009), stated that women were 19% more likely than men to have persistent neck pain. There were however no gender differences in rates of improvement, aggravation or recurrence of neck pain over a 1 year period.

Carroll et al. (2009), conducted a research study on Course and prognostic factors for neck pain in the general population of Canada and found that younger age is prognostic of better recovery from neck pain in the general population of Canada. The older the patients, the worse the prognosis and that patients under 30 years of age recovered faster than those between 45 to 59 years of age (Carroll et al., 2009) and therefore it can then be concluded that the participants in this study had equal chances of recovery and that differences in gender offered no added advantage in treatment over the other.

5.3 Subjective Data

Subjective data was collected using PSQI and NPRS across the three trial periods. Shapiro-Wilk test showed data to be normally distributed and therefore, One-way repeated measures ANOVA tests (Wilks Lambda and Pairwise Comparisons) were used to demonstrate change that occurred across the three trial periods in PSQI and NPRS.

5.3.1 Pittsburgh sleep quality index

The mean values for PSQI (figure 4.1) showed a decline of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall decline of the mean values from visit 1 to visit 7 was 53.59%. This indicates that clinically, there was an improvement in PSQI from visit 1 to visit 7 signifying an overall improvement in the participants sleep quality.

For One-way repeated measures AVOVA tests, Wilks Lambda and Pairwise Comparison revealed PSQI to be statistically significant in section 4.3.1. Wilks Lambda revealed PSQI to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed PSQI to be statistical significant in between visits: from visit 1 to visit 4, visit 4 to visit 7 and
visit 1 to visit 7; with both these tests indicating that there was change in PQSI across three trial periods.

Discussion of Pittsburgh Sleep Quality Index Data

As previously discussed in chapter three, the global score for PSQI is between 0-21. The higher the global score, the worse the participants sleep quality (Buysse et al., 1988). A global score of greater than 8 was found to be indicative of poorer sleep (Muñoz-Muñoz et al., 2012). The PSQI mean values in figure 4.1 were shown to be favourable supported by the above stated research studies from Buysse et al., (1988) and Muñoz-Muñoz et al., (2012), as the group started with a mean average value of 9.20 at visit 1 and ended with a mean average value of 4.27 at visit 7.

The decline in the mean values indicates that the participants sleep quality improved from visit 1 to visit 7. The overall decline in PSQI mean values from visit 1 to visit 7 demonstrated in figure 4.1 was 53.59% signifying an overall improvement in the participants sleep quality following CMT; as it was the only form of treatment used in this study.

As discussed in chapter two, there is a bidirectional (reciprocal) relationship that exists between sleep and pain, where pain disturbs sleep and disturbed shortened sleep enhances pain (Finan et al., 2013; Jamison, 2015). Muñoz-Muñoz et al. (2012), further stated that sleep quality is negatively associated with the intensity of neck pain and disability. Due to the small sample size (n=30) in this study, it is however not clear if the improvement in the participants sleep quality was due to a direct effect of CMT on sleep or if it was secondary to the reduction of the participant's neck pain intensity following CMT as explained below in section 5.3.2.

For sleep to occur, arousal areas on the brain should be supressed and sleep active areas on the brain should be stimulated as discussed previously in chapter two. This is done by activation of the ventrolateral preoptic nucleus which when active, inhibits arousal areas on
the brain via GABA and galanin activation thus promoting sleep (España, 2013; Wulff et al., 2010).

Kingston et al. (2010), revised articles regarding CMT and sleep disturbance such as insomnia. He found that although chiropractic manipulation is believed to stimulate galanin and GABA (γ-aminobutyric acid), which are believed to relax the mind and promote NREM sleep, as discussed in sections 2.5 and 2.15.2, there is insufficient literature analysing the effectiveness of chiropractic manipulative therapy and sleep deprivation. A large sample size is required to access the validity of chiropractic manipulative therapy on insomnia.

Muñoz-Muñoz et al. (2012), following a research study he conducted on mechanical neck pain participants, concluded that sleep disorders must be taken into account in the overall management of patients with mechanical neck pain. Kingston et al. (2010), further stated that sleep disorders are multifactorial and their prognosis can be further improved by chiropractic care.

5.3.2 Numerical pain rating scale

The mean values for NPRS (figure 4.2) showed a decline of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall decline of the mean values from visit 1 to visit 7 was 76.21%. This indicates that clinically, there was a significant improvement in NPRS from visit 1 to visit 7 indicating an overall reduction in the participant’s pain intensity.

For One-way repeated measures AVOVA tests, Wilks Lambda and Pairwise Comparison revealed NPRS to be statistically significant in section 4.3.2. Wilks Lambda revealed NPRS to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed NPRS to be statistical significant in between visits: from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in NPRS over three trial periods.
Discussion of Numerical Pain Rating Scale data

Chiropractic care such as CMT results in the relief of acute and chronic mechanical neck pain following manipulation (Bryans, Decina, Descarreaux, Duranleau, Marcoux, Potter, Ruegg, Shaw, Watkin and White, 2013; Haline, 2005; Haneline and Cooperstein, 2009). In chapter two, the anatomy of the cervical spinal components was discussed. These included the facet joints, muscles, intervertebral disc and innervation which can be potential sources of mechanical neck pain (Bogduk and McGuirk, 2006; Dennison and Leal, 2011); including the four types of receptors: type I, type II, type III, type IV and the part they each represent in the pain cycle (Wyke, 1985).

Manipulative therapy causes gapping to the vertebral and facet joints. Gapping subsequently results in stretching of the muscles, ligaments, intervertebral disks and joint capsules which may activate the diffuse descending pain inhibitory system, whose neurons are located in the periaqueductal gray matter (Maigne and Vautravers, 2003).

Afferent discharges of type I, type II, and type III mechanoreceptors play a significant role in pain suppression, reflexogenic and perceptual effects when they enter neuraxis in response to manipulation. Manipulative therapy produces presynaptic inhibition of nociceptive afferents (type IV receptors) transmission through the synapses in the basal spinal nucleus because of mechanoreceptor stimulation thereby resulting in pain relief (Wyke, 1985).

Gross, Miller, D’Sylva, Bernie, Goldsmith, Graham, Haines, Brønfort and Hoving (2010), conducted a study to determine the effectiveness of manipulation alone in the treatment of neck pain function, disability, patient satisfaction and quality of life. At the end of the study, it was concluded that CMT provides pain relief, functional improvements and patient satisfaction. The effects of CMT on neck pain were however found to provide short term neck pain relief. Miller, Gross, D’Sylva, Burnie, Goldsmith, Haines, Brønfort and Hoving (2010), conducted a similar study to the above study and found that manipulation produced long term neck pain relief when combined with exercises.
According to Hooper and Halderman (2003), Cassidy et al. (1992), administered CMT to patients suffering from neck pain and found manipulation to have a significantly greater effect on pain intensity and to be superior to another manual procedure following CMT. These findings were supported by a study conducted by Martínez-Segura et al. (2006).

Manipulation may also cause the relief of neck pain by stimulating tissue receptors to modify neural activity within the central nervous system by altering reflex pathways affecting muscles. Inhibition of motor neuron pools may result in the reduction of muscle spasm thereby relieving local muscle pain (Katavich, 1998).

Mechanical stimulation of joint capsule proprioceptors and muscles spindles caused by the CMT may induce a reflex inhibition of pain and reflex muscle relaxation (Pickar, 2002). Srbely, Vernon, Lee and Polgar (2013), conducted a study on the immediate effects of manipulative therapy regional antinociceptive effects in myofascial tissues in young participants. The study revealed manipulation to provide short term segmental analgesic effects in myofascial tissues in a young population.

Figure 4.2 in this study demonstrated a decline in neck pain intensity from visit 1 to visit 7 demonstrated by a decline in the mean values. Based on these results, supported by the above discussed studies and research, it could therefore be concluded that diffuse descending pain inhibitory system was activated following CMT in this study. However it is unclear if CMT offered short term or long term neck pain relief based on the fact that the study was conducted over a three week period and no follow-up post treatment contact was made with the participants.

5.4 Objective Data

5.4.1 Cervical range of motion

Objective data of the cervical spine range of motion was measured using a CROM device during visit 1, visit 4 and visit 7. Shapiro-Wilk test revealed CROM to be normally distributed and therefore, One-way repeated measures ANOVA tests (Wilks Lambda and
Pairwise Comparisons) were used to demonstrate changes that occurred across the three trial periods in PSQI and NPRS.

**Flexion**

The mean values for flexion (figure 4.3) showed an increase of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall increase of the mean values from visit 1 to visit 7 was 10.59%. This indicates that clinically there was an increase in flexion from visit 1 to visit 7 signifying an overall improvement in the participant’s cervical flexion.

For One-way repeated measures ANOVA tests, Wilks Lambda and Pairwise Comparison revealed flexion to be statistically significant in section 4.4.1. Wilks Lambda revealed flexion to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed flexion to be statistical significant in between visits: from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in flexion over three trial periods.

**Extension**

The mean values for extension (figure 4.4) showed an increase of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall increase in the mean values from visit 1 to visit 7 was 9.65%. This clinically indicates that there was an increase in extension from visit 1 to visit 7 indicating an overall improvement in the participant’s cervical extension.

For One-way repeated measures ANOVA tests, Wilks Lambda and Pairwise Comparison revealed extension to be statistically significant in section 4.4.2. Wilks Lambda revealed extension to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed extension to be statistical significant in between visits; from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in extension over three trial periods.
**Right Rotation**

The mean values for right rotation (figure 4.5) showed an increase of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall increase in the mean values from visit 1 to visit 7 was 9.57%. This clinically indicates that there was an increase in right rotation from visit 1 to visit 7 indicating an overall improvement in the participant's cervical right rotation.

For One-way repeated measures ANOVA tests, Wilks Lambda and Pairwise Comparison revealed right rotation to be statistically significant in section 4.4.3. Wilks Lambda revealed right rotation to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed right rotation to be statistical significant in between visits; from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in right rotation over three trial periods.

**Left Rotation**

The mean values for left rotation (figure 4.6) showed an increase of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall increase in the mean values from visit 1 to visit 7 was 9.31%. This clinically indicates that there was an increase in left rotation from visit 1 to visit 7 indicating an overall improvement in the participant's cervical left rotation.

For One-way repeated measures ANOVA tests, Wilks Lambda and Pairwise Comparison revealed left rotation to be statistically significant in section 4.4.4. Wilks Lambda revealed left rotation to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed left rotation to be statistical significant in between visits: from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in left rotation over three trial periods.

**Right Lateral Flexion**

The mean values for right lateral flexion (figure 4.7) showed an increase of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall increase in the mean values from visit 1 to visit 7 was 16.36%. This clinically indicates that there was an
increase in right lateral flexion from visit 1 to visit 7 indicating an overall improvement in the participant’s cervical right lateral flexion.

For One-way repeated measures ANOVA tests, Wilks Lambda and Pairwise Comparison revealed right lateral flexion to be statistically significant in section 4.4.5. Wilks Lambda revealed right lateral flexion to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed right lateral flexion to be statistical significant in between visits: from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in right lateral flexion over three trial periods.

**Left Lateral Flexion**

The mean values for left lateral flexion (figure 4.8) showed an increase of the mean values from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7. The overall increase in the mean values from visit 1 to visit 7 was 13.56%. This clinically indicates that there was an increase from visit 1 to visit 7 indicating an overall improvement in the participant’s cervical left lateral flexion.

For One-way repeated measures ANOVA tests, Wilks Lambda and Pairwise Comparison revealed left lateral flexion to be statistically significant in section 4.4.6. Wilks Lambda revealed left lateral flexion to be statistically significant from visit 1 to visit 7, whereas Pairwise Comparisons revealed left lateral flexion to be statistical significant in between visits: from visit 1 to visit 4, visit 4 to visit 7 and visit 1 to visit 7; with both these tests indicating that there was change in left lateral flexion over three trial periods.

**Discussion of Cervical Range of Motion Data**

The participants in this study have shown an overall improvement in their cervical range of motion from visit 1 to visit 7 as demonstrated by the mean values documented at visit 1, visit 4 and visit 7 following CMT. Ageing has adverse effects on cervical range of motion (Prushansky and Dvir, 2008) and therefore favourable results may have been achieved as a result of the participants being between the ages of 19-36 years old. The increase in
cervical range of motion may have been due to the participant’s willingness to move their necks following a reduction of the participant’s neck pain following CMT.

According to Pickar (2002), a number of biomechanical changes are produced by vertebral movement during spinal manipulation altering segmental biomechanics by releasing trapped meniscoids and adhesions or by reducing the distortion of the annulus fibrosus. Manipulation results in the restoration of a buckled segment thereby reducing mechanical stress or strain on paraspinal tissues. By releasing trapped meniscoids, discal material and segmental adhesions; and by normalising a buckled segment, mechanical input resulting from manipulation may reduce nociceptive input from receptive nerve endings in innervated paraspinal tissues. A major consequence of the above mechanical changes elicited by manipulation could be the restoration of facet joint mobility and joint play.

The core concept of spinal manipulative therapy is the application of controlled load vectors to the spine in effect to restore normal behaviour and reduce harmful mechanical stresses to the local tissues. Manipulation uses controlled forces and moments applied to the spine together with inertial forces generated by acceleration of the relevant body segment mass. The aggregate sum of these loads (sum of applied treatment loads, inertial loads from accelerating the body mass and the internal muscular tensions that may arise) is transmitted to the spine in a controlled manner and is designed to unbuckle motion segments and reduce local mechanical stresses within the spinal segments (Triano, 2001).

Martínez-Segura et al. (2006), conducted a study on the immediate effects of CMT and active range of motion and found that a single cervical manipulation was effective in reducing mechanical neck pain at rest and increasing range of motion. He noticed that there is a relationship that exists between a reduction in neck pain and an increase in cervical range of motion. Hooper and Halderman (2003), further stated that in a clinical study done by Cassidy et al. (1992), manipulation was revealed to be superior in the reduction of neck pain intensity and that manipulation resulted in an increase in the participant’s cervical range of motion.
Moodley and Branttingham (2002), conducted a comparative clinical study on CMT in patients with mechanical neck pain over a 4 week period. The participants achieved an overall increase in their cervical range of motion with significant improvements in cervical extension and right lateral flexion. The participants achieved significant improvements in disability and reduction in their neck pain intensity following manipulation.

In conclusion, Pickar (2002) stated that the ultimate goal of manipulation is to restore maximal pain free movement of the musculoskeletal system. The results in this study revealed an improvement in the participant’s range of motion coupled with a reduction in their neck pain intensity as demonstrated by the mean values in chapter four. These results were supported by previously done research and clinical studies discussed above and in section 5.3.2.

5.5 Overall Discussion

The study aimed to determine whether CMT had any effect on sleep in patients with mechanical neck pain. Based on this study and previously done studies, it can be concluded that CMT may have a beneficial effect on neck pain relief with subsequent increases in cervical range of motion. It was also noted that the participants in this study had an improvement in their sleep quality following CMT. Due to the small sample size, it however remains unclear if CMT has a direct effect on sleep or if the improvement of the participants’ sleep quality was due to the resolution of the participant’s neck pain. This statement is supported by Kingston et al. (2010), who stated that a large sample size would be required to determine the validity of CMT on sleep disturbance such as insomnia.
CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The aim of the study was to determine whether cervical manipulative therapy had an effect on sleep in patients with mechanical neck pain. Studies have been done on CMT and have been proven to have a positive effect on mechanical neck pain relief. However, there is minimal literature available on CMT and sleep disturbances.

The results documented from chapter 4 in this study indicated that CMT had beneficial effects on both sleep and neck pain; however, it is unclear as to whether CMT had a direct effect on sleep or not, and this may have been due to the small sample size used in the study. Based on previous research studies, such as one done by Martínez-Segura et al. (2006), Gatterman (2005) and similar studies, it can be concluded that CMT has a beneficial effect on mechanical neck pain relief. The improvement in the participants’ sleep in this study may have been due to a reduction in mechanical neck pain.

6.2 Recommendations

The following are recommendations that may improve the study pertaining to chiropractic care and sleep for more beneficial and statistically significant results:

• A larger sample group for more accurate results. A larger sample group may give an indication of the overall effect the results may have on a larger population in society as opposed to a small sample size. This will allow for comparison to be made based on gender in different age group categories for more clarity on the effectiveness of treatment over a larger scale.

• A larger sample group will also allow for comparison to be made based on gender in different age group categories for more clarity on the effectiveness of treatment over a larger scale.
• The study sample should be inclusive of participants over the ages of 40 years. This will give more clarity on the effects of CMT on sleep in older participants compared to the young participants. Any differences will therefore be measured and interpreted clinically. Inclusion of older participants will also determine the treatment time sufficient for beneficial results, if any, between the different age groups.

• A comparative study consisting of two or more groups comparing cervical manipulative therapy on sleep to other treatment procedures and their effects on sleep. Comparative groups offer an added advantage on the analysis of the effectiveness of one treatment to another on sleep. The treatment with the most favourable results would be determined and recommended.

• A study group sample that consist solely of sleep and chiropractic manipulative therapy. There is minimal literature available regarding chiropractic manipulation and sleep. More chiropractic studies conducted on sleep would provide clarity on the overall effect of chiropractic manipulation on sleep. This would also allow the researcher to determine whether manipulative therapy has a direct or indirect effect on sleep.

• Data analysis to be collected using sleep questionnaires in conjunction with an electroencephalography (EEG) to evaluate the brain activity prior and during treatment. Any brain activity changes recorded on the EEG will then be interpreted in conjunction to the sleep questionnaire and treatment outcomes. Concerns regarding EEG costs however may incur.

• A prolonged study time to allow time for better and more accurate results. The study will be done over a prolonged period allowing for more treatment time. The resultant effects might be more accurate and statistically significant.
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APPENDIX A: Advertisement

RESEARCH STUDY

DO YOU SUFFER FROM NECK PAIN?

DO YOU HAVE TROUBLE SLEEPING?

ARE YOU BETWEEN THE AGES 18 AND 40 YEARS?

YOU ARE INVITED TO TAKE PART IN A RESEARCH STUDY TO BE CONDUCTED AT THE UNIVERSITY OF JOHANNESBURG CHIROPRACTIC CLINIC DOORNFINTEIN

EFFECTIVENESS OF CERVICAL MANIPULATIVE THERAPY IN PATIENTS WITH MECHANICAL NECK PAIN AND THE EFFECT ON SLEEP

TO PARTICIPATE PLEASE CONTACT:

MOLOGADI MATLALA
0826655148
APPENDIX B: Modified Pittsburgh Sleep Quality Index (Buysse et al., 1989)

Name: ___________________________                  Date: __________________

The Modified Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past week only. Your answers should indicate the most accurate reply for the majority of days and nights in the past week. Please answer all questions.

1. During the past week, what time have you usually gone to bed at night?

2. During the past week, how long (in minutes) has it usually taken you to fall asleep each night? __________

3. During the past week, what time have you usually gotten up in the morning?

4. During the past week, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.) ________________

<table>
<thead>
<tr>
<th>5. During the past week, how often have you had trouble sleeping because you</th>
<th>Not during the past week</th>
<th>Less than once this past week</th>
<th>Once or twice this week</th>
<th>Three or more times this week</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Cannot get to sleep within 30 minutes</td>
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<tr>
<td>b. Wake up in the middle of the night or early morning</td>
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<tr>
<td>c. Have to get up to use the bathroom</td>
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<tr>
<td>d. Cannot breathe comfortably</td>
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<tr>
<td>e. Cough or snore loudly</td>
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<tr>
<td>f. Feel too cold</td>
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<tr>
<td>g. Feel too hot</td>
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<tr>
<td>h. Have bad dreams</td>
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</tr>
<tr>
<td>i. Have pain</td>
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<tr>
<td>j. Other reason(s), please describe</td>
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</tbody>
</table>
6. During the past week, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

7. During the past week, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

<table>
<thead>
<tr>
<th>No problem at all</th>
<th>Only a very slight problem</th>
<th>Somewhat of a problem</th>
<th>A very big problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>Fairly good</td>
<td>Fairly bad</td>
<td>Very bad</td>
</tr>
</tbody>
</table>

8. During the past week, how often of a problem has it been for you to keep up enough enthusiasm to get things done?

<table>
<thead>
<tr>
<th>No bed partner or room mate</th>
<th>Partner/room mate in other room</th>
<th>Partner in same room but not same bed</th>
<th>Partner in same bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not during the past week</td>
<td>Less than once a week</td>
<td>Once or twice this week</td>
<td>Three or more times a week</td>
</tr>
</tbody>
</table>

If you have a room mate or bed partner, ask him/her how often in the past week you have had:

a. Loud snoring
b. Long pauses between breaths while asleep
<p>| | | | |</p>
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<tbody>
<tr>
<td><strong>c. Legs twitching or jerking while sleep</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>d. Episodes of disorientation or confusion during sleep</strong></td>
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<tr>
<td><strong>e. Other restlessness while you sleep, please describe</strong></td>
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</tbody>
</table>
APPENDIX C: Numerical Pain Rating Scale (McCaffery and Pasero, 1999)

DATE_______________ VISIT _________________ PATIENT_______________

0-10 VAS Numeric Pain Distress Scale
No pain Moderate pain Unbearable pain

DATE_______________ VISIT _________________ PATIENT_______________

0-10 VAS Numeric Pain Distress Scale
No pain Moderate pain Unbearable pain

DATE_______________ VISIT _________________ PATIENT_______________

0-10 VAS Numeric Pain Distress Scale
No pain Moderate pain Unbearable pain
APPENDIX D: Contra-indications to Cervical Manipulation Therapy (Peterson and Bergman, 2002)

1. Atherosclerosis of major blood vessel
2. Vertebrobasilar insufficiency
3. Aneurysm
4. Tumors
5. Fractures
6. Severe sprain
7. Osteoarthritis (late stage)
8. Uncoarthritis
9. Clotting disorders
10. Osteopenia (osteoporosis)
11. Space-occupying lesions
12. Diabetes (neuropathy)
13. Malingering
14. Hysteria
15. Hypochondriasis
16. Alzheimer's disease
APPENDIX E: CROM Instrument Reading

Name: ________________________________

Visit 1: Date __________________________

<table>
<thead>
<tr>
<th>Flexion</th>
<th>Extension</th>
<th>R Rotation</th>
<th>L Rotation</th>
<th>R Lat Flex</th>
<th>L Lat Flex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

Visit 4: Date __________________________

<table>
<thead>
<tr>
<th>Flexion</th>
<th>Extension</th>
<th>R Rotation</th>
<th>L Rotation</th>
<th>R Lat Flex</th>
<th>L Lat Flex</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

Visit 7: Date __________________________

<table>
<thead>
<tr>
<th>Flexion</th>
<th>Extension</th>
<th>R Rotation</th>
<th>L Rotation</th>
<th>R Lat Flex</th>
<th>L Lat Flex</th>
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</table>
My name is Mologadi Matlala and I am currently a Chiropractic student, completing my Masters Degree at the University of Johannesburg. I like to invite you to participate in this study entitled “Effectiveness of cervical manipulative therapy in the treatment of mechanical neck pain and the effect on sleep.”

The aim of this study is to determine the effectiveness of cervical manipulative therapy on sleep in patients with mechanical neck pain.

Participants will be recruited by means of word of mouth, posters and pamphlet advertisements. On the first consultation, a case history will be taken followed by a physical exam. Participants will be asked to complete a Pittsburgh Sleep Quality Index (PSQI) questionnaire and a Numerical Pain Rating Scale (NPRS) for sleep quality and pain intensity respectively. The study will consist of one group of thirty participants who will receive treatment in the form of cervical manipulative therapy twice a week over a three week period. A Cervical Range of Motion (CROM) instrument will be used to measure the range of motion in the neck. This will be followed by treatment in the form of cervical manipulative therapy. The study will consist of seven sessions whereby treatment will be administered two times a week. Readings will be taken on the first, fourth and seventh session. No further treatment will be administered on the seventh session. The Chiropractic adjustment involves the restoration of normal joint motion in the neck. Joints
that don’t move properly or feel restricted (stuck) will be detected via motion palpation and will be corrected via cervical manipulative therapy by the researcher. The Chiropractic adjustment is a safe, non-invasive treatment technique.

The research study will take place at the University of Johannesburg Chiropractic Day Clinic. Your privacy will be protected as only the researcher, patient (you) and clinician will be in the treatment room. Your details will remain confidential as your personal information will be converted into data through a numbering system from one to thirty 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 is without any penalty. The participants may experience tenderness following cervical manipulative therapy that should resolve in a few days post treatment. Cervical manipulative therapy has therapeutic effects which may relieve tension in the neck musculature, improve the range of motion in the neck and aid in neck pain relief. Results of this study will be made available to you on request. There will be no compensation for participating in this study.

If you have any inquiry regarding the ethical implications of this project, you may contact the chairperson of the Academic Ethics Committee of Faculty of Health Science:

Professor Marie Poggenpoel  Telephone number: 011 559 6686

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

Researcher: Mologadi Matlala  Telephone number: 082 6655148  
Supervisor: Dr C. Hay  Telephone number: 011 599 6500
APPENDIX G: Consent Form

DEPARTMENT OF CHIROPRACTIC

CONSENT FORM

I have been fully informed as to the procedures to be followed and have been given a description of the discomfort risks and benefits expected from the treatment. In signing this consent form I agree to cervical manipulative therapy 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 any questions at any time, they will be answered.

Date: ______________________           Participant: __________________________

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

**UNIVERSITY OF JOHANNESBURG**
**CHIROPRACTIC DAY CLINIC**

### CASE HISTORY

<table>
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**Age:** _____  **Sex:** ______  **Occupation:** __________

**Student:** __________  **Signature:** __________

---

**Complies with inclusion criteria of the research:**

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<th>Signature:</th>
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### Examination:

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### Recommendations:
**Students case history**

1. **Source of history:**

2. **Chief complaint: (patient's own words)**

   ![Image]

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
Haematologic
Endocrine
Psychiatric
APPENDIX I: Physical Examination

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

PHYSICAL EXAMINATION

Underline abnormal findings in RED. Date: _________________

Patient: ___________________ File No: ________________

Clinician: _________________ Signature: _________________

Student: _________________ Signature: _________________

Height: ___________ Weight: _______ Temp: ________

Rates: Heart: ___________ Pulse: ___________ Respiration: ___________

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<th>R</th>
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<td>Legs:</td>
<td>L</td>
<td>R</td>
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</tbody>
</table>

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: 90° (fingers to floor)
     - Extension: 50°
     - R. lat. flex: 30° (fingers down leg)
     - L. lat. flex: 30° (fingers down leg)
     - Rot. to R: 36°
     - Rot. to L: 35°

   L. Rot   Flex.   R. Rot
   L. Lat Flex   Ext.   R. Lat Flex

/ = 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:  
- inspiration  
- expiration  

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>cm</td>
<td>cm</td>
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</table>

15. Visual acuity

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

**SEATED EXAMINATION**

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

<table>
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<th>R</th>
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- visual fields
- accommodation
- Ophthalmoscopic  
Examination  
- iris  
- pupils  
- red reflex  
- optic disc  
- vessels  
- general background
4. Ears:
   • Inspection
   • 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
   • pharynx
   • palatine arch
   • tongue
   • inspection
   • movement
   • taste
   • palpatation

8. Neck:
   • posture
   • size
   • swelling
   • scars
   • discoloration
   • hair line
Ranges of motion (cervical spine)

The following are normal ranges of motion:

- **Forward flexion** = 45° chin to larynx or sternum
- **Extension** = 55° forehead parallel to ground
- **L/R Rotation** = 70°
- **L/R Lat Flexion** = 40°

- L. Rot
- Flex.
- R. Rot
- L. Lat Flex
- R. Lat Flex
- Ext.

- Lymph nodes
- Trachea
- Thyroid
- Carotid arteries (ethers, bruit)
- Cranial Nerves
  - CN V
  - CN VII
  - CN VIII (nystagmus)
  - CN IX
  - CN XI
  - CN XIII
9. NEUROLOGICAL EXAMINATION (CERVICAL SPINE)

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<th>Left</th>
<th>Right</th>
<th>MYOTOMES</th>
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<td>Triceps C7</td>
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<td>C5</td>
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<tr>
<td>C6</td>
<td>Elbow Flexion C5</td>
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9. Peripheral vasculature:
   • Inspection
     - skin
     - nail beds
     - pigmentation
     - hair loss
   • Palpation
     - pulses
     - femoral
     - popliteal
     - radial
     - post. Tibial
     - 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

<table>
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<tr>
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<tr>
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</table>

• knee
• ankle

(ii) leg length

- Co-ordination
  - point to point
  - dysdiakinesia

10. TMJ
- Inspection
  - ROM
  - deviation
- Palpation
  - crepitus
  - tenderness

11. Thorax
- Inspection
  - skin
  - shape
  - respiratory distress
  - rhythm (respiratory)
  - depth (respiratory)
  - effort (respiratory)
  - intercostals/supravacular retraction
- Palpation - tenderness
- masses
- respiratory expansion
- tactile fremitus
- Percussion
- lungs (posterior)
- diaphragmatic excursion
- kidney punch
- Auscultation (i) breath sounds
- vesicular
- bronchial
- (ii) adventitious sounds
- crackles (rales)
- wheezes (rhonchi)
- rubs
- (iii) voice sounds
- bronchophony
- whispered pectoriloquy
- egophony
- Cardiovascular
- auscultation (aortic murmurs)
- Allen’s test

SUPINE EXAMINATION
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
     - hemias (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
  - roving's sign
  - psoas sign
  - obturator sign
  - cutaneous hyperaesthesia
  - rectal exam
  - Murphy's sign

MENTAL STATUS

(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)

(iii) 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
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<td>Patellar (L3, 4)</td>
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<td>Knee Extension (L2, 3, 4)</td>
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<td>Knee Flexion (L5/S1)</td>
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Appendix J: Cervical Regional Examination Form

Date: ____________________

Patient: ____________________ File No: ______________

Clinician: ____________________ Signature: _____________

Student: ____________________ Signature: _____________

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

5. Range of Motion

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

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:

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COMMENTS:


### Motion Palpation

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APPENDIX K: S.O.A.P Notes

**RESEARCH**

**CHIROPRACTIC DAY CLINIC**

**SOAP NOTE:**

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**Comments:**

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