Effectiveness of cervical, thoracic and cervico-thoracic spinal manipulation on pain and spinal kinematics in non-specific neck pain – a randomised controlled trial

by

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I, Dale Brent Twiss, do hereby declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgments indicate the contrary)

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DEDICATION

I dedicate this dissertation to my incredible parents, Brian and Mylene Twiss. Even though you are not with us here mom, I know you are here in spirit and have looked down on me throughout my journey. Thank you for all the love and support you have shown and given me throughout this long journey and I hope, going forward, I am able to make you proud and repay all you have done for me. I am so blessed to have you as my parents and I will for ever be grateful for everything. Love you both with all my heart.

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ABSTRACT

Background: Neck pain is a musculoskeletal disorder that affects many people at some point in their lives**.** It has been demonstrated that up to 50% of adults in the general population may experience neck pain at some point during the year, with many going on to develop persistent chronic neck pain. Neck pain is associated with disability and activity impairment especially of the upper limb when performing functional movements. Spinal manipulation has been shown to help decrease pain intensity and disability and improve range of motion and the quality of life in individuals with non-specific neck pain. Few studies have examined range of motion beyond that of peak displacement and, thus, little is known if spinal manipulation therapy of the cervical and thoracic spine improves the quality of motion in those with neck pain.

Aim: The aim of this study was to determine the effectiveness of cervical and thoracic spinal manipulation applied alone and in a combination. The groups were compared to a control group in terms of their effect on pain intensity, disability, cervical and thoracic kinematic outcomes during cervical range of motion and two upper extremity functional limb tasks in individuals with non-specific neck pain.

Methods: The study is a quantitative, randomised, controlled, single-blinded study. Individuals with chronic non-specific neck pain between the ages of 18–50 were recruited and randomly assigned to one of four groups: control, cervical, thoracic spinal manipulation, or a combination of the two. The participants performed cervical range of motion and two upper limb tasks while motion capture technology collected cervical and thoracic spinal kinematics. A pain rating and spinal kinematics were obtained pre and post the intervention. The data were analysed using software SPSS and a *p*-value of 0.05 indicated significance.

Results: A total of 47 participants were randomised. No significant difference was recorded for pain intensity across all four of the groups ($F(3,42) = 0.41$, $p = 0.750$). Spinal kinematics improved within the groups, with no differences between the groups during the cervical range of motion task. Between the groups, in the unilateral arm task, differences were found in the lower thoracic spine during the flexion-extension cycle for jerk, with the cervical and thoracic combination group being significantly greater than cervical manipulation group alone ($F(3, 40) = 2.892$, *p* = 0.047). In the cervical and thoracic combination group, for the bilateral arm task in the upper thoracic spine flexion extension range, it was found to be significantly greater than the control group (F(3, 40) = 3.127, *p* = 0.036). In the cervical and thoracic combination group, in the lower thoracic spine during the flexion-extension cycle for the jerk measure, it was found to be significantly higher than the control group (F(3, 40) = 2.902, *p* = 0.047).

Conclusion: This study could not prove that spinal manipulation can result in a change in the spinal kinematics during cervical range of motion and two arm tasks in patients with non-specific neck pain following spinal manipulation of the cervical and thoracic spines.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Neck pain is a musculoskeletal disorder that affects about 66.7% of the population at some point in their lives (Zakharova-Luneva *et al.* 2012). In the general population it has been shown that 30–50% of adults will have neck pain in any given year, with 50%–85% of these individuals failing to have complete resolution of their symptoms. Neck pain is associated with disability and activity impairment especially of the upper limb when performing functional movements (Goode *et al.* 2010).

Neck pain has been shown to negatively impact motor control (Falla *et al.* 2004). Cervical spine manipulation has been shown to provide immediate relief of neck pain and improve range of motion (ROM) (Mayana *et al.* 2017). Similarly, manipulation of the thoracic spine has shown to result in an immediate reduction in the pain and an increase in the ROM in neck pain (Cleland *et al.* 2005). Therefore, studies indicate that both interventions are favourable for the use in neck pain patients. Although showing favourable results, the mechanism through which spinal manipulation brings about its effect are still under investigation (Gyer *et al.* 2019)

Spinal manipulation is a high-velocity low-amplitude thrust, this consists of a high velocity thrust that is applied to a synovial joint, the cervical vertebral and thoracic vertebral segments over a short amplitude (Evans 2002). Controlling the thrust's velocity, size, and direction are ways the practitioner ensures execution of a controlled and direct manipulation of the vertebra (Pickar 2002). Spinal manipulation can be utilised to stretch tissue, reduce muscle stiffness and hypertonicity (McCarthy *et al.* 2015). It is often associated with a cavitation which is the collapse of cavities that form in the synovial joints situated between the vertebrae (McCarthy *et al.* 2015). A common clinical assessment for people with neck pain is to assess the ROM that the person has, this can assess if there is the presence of any functional limitations (Elgueta-Cancino *et al.* 2022). Spinal manipulation has shown to improve the limited ROM and improve the limited function due to neck pain (Krauss *et al.* 2008).

There are different ways in which to assess ROM, inclinometer, cervical measurement systems, FASTRAK system, multi-cervical unit, 3-axis orientation sensor, visual estimation and a compass (Snodgrass *et al.* 2014). One of the most commonly used to measure ROM is a goniometer, which is an instrument which measures the angles of an object to a specific position, thus measuring how much ROM there is (Gandbhir and Cunha 2021). Motion capture has been underutilised when it comes to assessing changes in spinal kinematics following spinal manipulation, in contrast to its use in the lower extremity where it is well utilised to provide information rich data about gait kinematics (Falla *et al.* 2004). This three-dimensional approach provides information on velocity and acceleration, which speaks to the quality of motion in addition to angular displacement which provides the degree of motion (Tsang *et al.* 2014).

Another advantage of motion capture is that it allows kinematic detail to be captured while performing tasks, which can highlight movement potential deficits resulting from conditions such as neck pain (OptiTrack 2019). Studies have shown that people who suffer with neck pain differ from non-neck pain people in their ability to execute tasks such as walking, were those with neck pain were found to have increased spinal stiffness impacting their gait (Falla *et al.* 2004). In the working environment office workers were found to have decreased ability to perform office work such as working at a computer (Johnson *et al.* 2008), and difficulty in executing activities of daily living (Soysal *et al.* 2012). Thus, the need for effective treatments for neck pain are needed to reduce the disability, another study examined how increased telecommuting causes people to suffer with chronic neck pain and how manipulative therapy showed better results with regard to pain intensity and neck disability (Liu *et al.* 2023), yet there is a paucity of studies assessing whether these functional tasks change in people with neck pain following spinal manipulation.

1.2 AIMS AND OBJECTIVES

1.2.1 Aim of the Study

The aim of this study was to determine the effectiveness of cervical and thoracic spinal manipulation applied alone, or in combination, when compared to a control intervention, to assess the effect on pain intensity, cervical and thoracic kinematic outcomes (angular displacement, peak and mean velocity and jerk) obtained during cervical range of motion (CROM) and two upper limb functional tasks in participants with chronic non-specific neck pain (NSNP).

1.2.2 Objective of the Study

To determine the within and between group effect of cervical and thoracic spinal manipulation applied alone or in combination, compared to a control intervention to determine its effect on pain intensity, disability and cervical and thoracic spinal kinematics (angular displacement, peak and mean velocity and jerk) in participants with NSNP.

1.3 HYPOTHESIS

1.3.1 Null Hypothesis (Ho):

Ho: The null hypothesis states that there will be no statistically significant difference within or between group differences ($p < 0.05$) in terms of pain intensity and cervical and thoracic spinal kinematics.

1.3.2 Alternate Hypothesis (Ha)

Ha: The alternate hypothesis states that there will be a statistically significant difference ($p<0.05$) within and between the groups in terms of pain intensity and spinal kinematics in the cervical and thoracic regions

1.4 DELIMITATIONS OF THE STUDY

This study was delimited only to included people who were diagnosed as having non-specific chronic neck pain and that were adults between the ages of 18–50 years old. This was done to have a homogenous sample. From the various kinematic outcomes that could be assessed peak displacement, mean and average velocity and jerk were selected. The study was limited to assessing the effect of only one session of spinal manipulation as the aim was to assess the immediate effects of the interventions.

1.5 SIGNIFICANCE OF THE STUDY

Neck pain has an economic and personal burden and is associated with high levels of disability, resulting in a decrease of functionality due to the pain (Goode *et al*. 2010). Cervical and thoracic spinal manipulation is commonly used and has been shown to be effective in helping patients with neck pain by decrease pain intensity and disability and improving CROM (Mayana *et al.* 2017). When assessing the effects of interventions in neck pain, the traditional measures to measure CROM include a CROM device goniometer. A goniometer only records static angular movement, whereas using systems like motion capture allows for additional dynamic measures, such as velocity and acceleration, which makes it possible to assess the quality of the motion and not just the quantity of the movement (Falla *et al.* 2004). The motion capture approach has been underutilised in understanding the effect that cervical and thoracic spinal manipulation have on patients with neck pain. Thus, this study investigated the effectiveness of spinal manipulation of the cervical spine, thoracic spine alone, and in combination, on neck pain, cervical and thoracic spine kinematics in NSNP participants to contribute to the understanding of how spinal manipulation affects neck pain patients.

1.6 FLOW OF DISSERTATION

Chapter one has presented the introduction of the study, the hypothesis, delimitations of the study, significance of the study and the flow of the dissertation.

Chapter two presents the literature review. It provides an overview of neck pain, the anatomy of the cervical spine and the thoracic spine, literature on the effectiveness of manipulation, the functional tasks, pathophysiology, intervention and the assessment outcomes.

Chapter three examines the research methodology used in this study. The chapter gives the study design, sampling, measurement tools, interventions, functional tasks, the research assistant, as well as the research procedure.

Chapter four presents the results of the data that were analysed in this study. These are presented in the form of figures and tables.

Chapter five gives a discussion of the results in relation to the current literature.

Chapter six concludes the study, outlining limitations as well as recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents an overview of the literature associated with NSNP including its incidence, prevalence, pathophysiology and anatomy of the cervical and thoracic spine. Additionally, the management of NSNP by spinal manipulation of the cervical and thoracic spine are included. Finally, a discussion of the measurement tools, including kinematics is described.

2.2 NON-SPECIFIC NECK PAIN

When individuals suffer from neck pain that is not attributable to a specific anatomical cause, it is often referred to as NSNP. In many cases the neck pain is self-limiting within a few days or weeks (natural history) (Tsakitzidis *et al.* 2013). When pain does not dissipate within this timeframe and the pain lasts longer than three months it is then referred to as chronic NSNP (Institute for Quality and Efficiency in Health Care 2022). Neck pain has been on the increase throughout the world and can have a substantial impact on one's life, family and employment**.** Neck pain can result in disability (Hoy *et al.* 2010), as it limits activity which impacts quality of life. This results in costs of treatment such as pharmaceutical and non-pharmaceutical, and the workdays lost due to treatment and pain (Goode *et al.* 2010).

Risk factors for NSNP include physical factors that may be related to the work-space, such as not being able to adjust one's sitting position, working in a permanent or awkward position, additionally individual level factors, such as marital status, having a family size of more than three, being male with a low income resulting in high economic stress levels, and individuals with a BMI of more than 30kg/m have been identified as risk factors for developing NSNP (Kazeminasab *et al.* 2022). This is especially true of students who suffer from chronic neck pain, often sitting with their heads in a downward static posture (Khired 2022). Sitting for long periods of time is one of the main contributors to neck pain and results from constantly working at a desk without taking breaks (Khired 2022). The aforementioned factors, sitting in one position for long periods, marital status, family size, economic stress levels and a BMI od more than 30kg/m contribute to psychological factors such as stress and anxiety which have been reported in cross-sectional and case-control studies indicating that there is an association between the stress and anxiety created and the devolvement of neck pain (Khired 2022).

Neck pain patients seek different possible sources of relief for neck pain but frequently choose manual therapy in the form of mobilisation and manipulation to alleviate their pain and improve motion. These treatments have been shown to improve pain and functional ability (Basson *et al.* 2019). NSNP is a multifactorial condition with many possible treatments. these different forms of treatment include the pharmacological (nonsteroidal anti-inflammatory drugs, steroidal anti-inflammatory drugs, analgesics and opioids) and non-pharmacological (manual therapy, laser therapy, massage, acupuncture, yoga, aquatic therapy, and manipulation) (Kazeminasab *et al.* 2022).

2.3 INCIDENCE AND PREVALENCE OF NECK PAIN

Neck pain has shown to be the fourth leading cause of disability (Hoy *et al.* 2010). Neck pain has shown to affect about 66.7% of the population at some point in their lives (Zakharova-Luneva *et al.* 2012). In the general population, it has been shown that up 30%–50% of adults will have neck pain in any given year; with 50%–85% of these individuals not seeing complete resolution of their symptoms (Goode *et al.* 2010). When describing the demographics of local areas, the percentage of neck pain in the Sub-Saharan African region is 4.7% males and 6.7% for females. This region is only outranked by the United States which was 5.3% for males and 7.6% for females (Basson *et al.* 2019). By comparison, there is a high percentage of neck pain in Africa compared with other regions globally (Hoy *et al.* 2010).

When considering South Africa, few studies have investigated the epidemiology of neck pain. In a study done on adolescents the incidence of neck pain was found to be 53.7% and is mostly related to computer work and sitting-studying postures (Basson *et al.* 2019). When examining African countries, and South Africa specifically, the burden of neck pain seems to be higher due to the lack of proper health care for African populations, which results in these populations having to endure the pain instead of being able to receive the adequate health care that is required (Basson *et al.* 2019). When considering the differences of males and females, we also examined the age related to neck pain. A study from Safiri *et al*. (2020) showed that neck pain in males peaked at the age of 45–49 years old and neck pain in females peaked at age 45–54 years old. After these peaks, a decline in neck pain in both males and females as the age increased was evident (Hoy *et al.* 2010). According to Kazeminasab *et al.* (2022), in 2017, the age-standardised prevalence of neck pain increased to the age of 70–74 and then, after that age, the prevalence of neck pain decreased. The study also showed that in 2017, globally, there was a higher burden of neck pain for females with 166 million cases, and for males there were 122.7 million cases (Kazeminasab *et al.* 2022).

Evidence shows that the burden of neck pain on populations depends on the level of socioeconomic development. Higher socioeconomic development showed an increased burden of neck pain compared to lower socioeconomically developed populations (Hoy *et al.* 2010). Chronic neck pain can go from one extreme, of just an achy, nagging type of pain, all the way to the other extreme, as a shock-like pain that can radiate all the way down into the arms and result in weakening within the arm (Bogduk 2011).

2.4 ANATOMY

2.4.1 Cervical Spine

The cervical spine (neck) consists of seven bones aligned on top of each other and are known as the vertebrae. The cervical spine connects from the bottom of the skull to the upper back from C1 at the top until C7 at the bottom. These vertebrae are responsible for holding the head up as well as protecting the spinal cord, which passes through the vertebral foramen. It allows for movement of the head and neck through different ranges of motion (Curtis and Ammerman 2022).

The vertebrae are shaped in differently, and there are the atypical vertebra and typical vertebra.

Atypical cervical vertebra:

- C1 is referred to as the atlas. This vertebra is circular, kidney shaped, and does not contain a spinous process but does have two lateral masses that are connected anteriorly by the anterior arch and posteriorly by the posterior arch (Moore *et al.* 2017).

- C2 is referred to as the axis. There is a peg-like, dense odontoid process that is on the superior aspect of the vertebra. The atlas will sit on the odontoid process of the axis which allows for movement to occur (Moore *et al.* 2017).
- C7 is referred to as the cervical prominence, due to the long spinous process that protrudes posteriorly and is non-bifid like that of other spinous processes of the typical cervical vertebra (Moore *et al.* 2017).

The atlas and axis form the craniovertebral junction where the skull and the vertebra come together. At the atlas and the axis there is the most mobility in the spine; these areas are responsible for about 50% forward flexion and 50% rotation of the cervical spine.

Typical cervical vertebra C3 – C6:

- They contain a broad vertebral body which is concave on the superior aspect and convex on the inferior aspect. The superior borders are raised on the posterior aspect of the vertebral body to form the uncinate processes.
- The vertebral foramina are large and triangular in shape. Posteriorly, the border of the vertebral foramen is formed by two pedicles and two lamina, which are on the anterior aspect. The pedicles and the laminae join together to form the vertebral arches (Moore *et al.* 2017).
- There are two superior articular facets that are orientated superior-posteriorly and two inferior articular facets that are orientated inferior-anteriorly (Moore *et al.* 2017).
- The spinous processes of C3- C6 are short and bifid, whereas C6 and C7 are longer (Moore *et al.* 2017).
- The vertebra contains two transverse processes on the lateral aspects, one on each side.

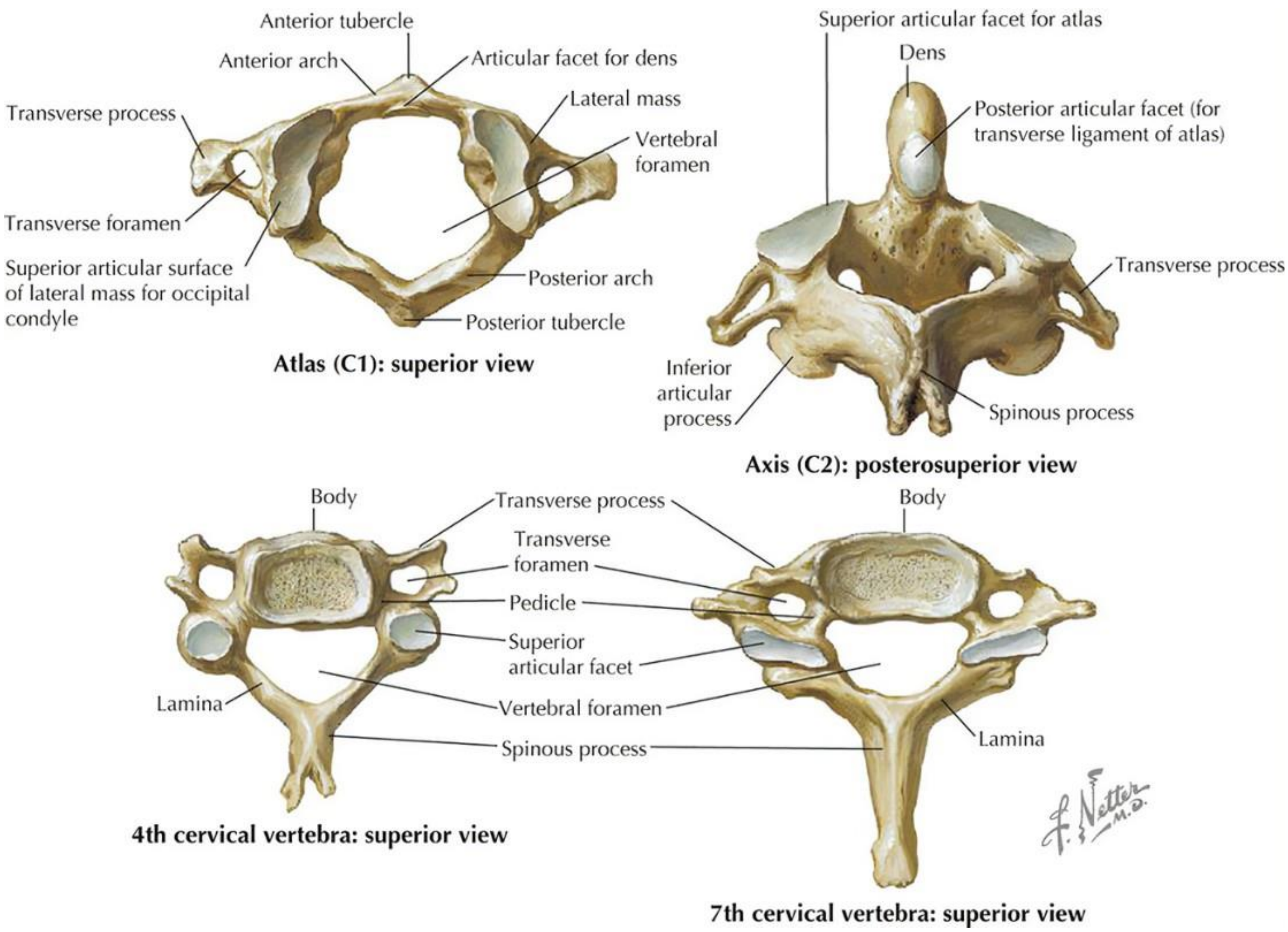

Figure 2.1 Cervical spine vertebra (Netter and Hansen 2019)

2.4.2 Thoracic Spine

The thoracic spine is situated between the cervical spine at C7 and the lumbar spine at L1, this is often referred to as the mid back. The chest cavity, which is defined by the ribs, is more rigid than that of the cervical spine due to the attachment of the ribs which attach to the spine at the costotransverse joints. The chest cavity is made up of the thoracic spine, sternum, xiphoid and ribs, these result in a rigid thoracic spine, within the chest cavity contains important internal organs of the body. The upper thoracic spine T1–T4 has similar features to that of the lower cervical spine; the mid thoracic spine T5–T8 are more typical in features. There are two main joints with regard to the thoracic spine, this is the cervico-thoracic at C7–T1 which is important as it is the transition point from cervical spine to the thoracic spine. Another is the thoraco-lumbar junction which is at T12–L1, which is the transition from thoracic spine to lumbar spine.

The attachment of the ribs to the thoracic spine and the chest cavity has resulted in reduced movement of the thoracic spine compared to that of the cervical spine. The reduced movement of the thoracic spine is found in flexion and extension and lateral flexion, the reduced movement is not found in rotation of the thoracic spine.

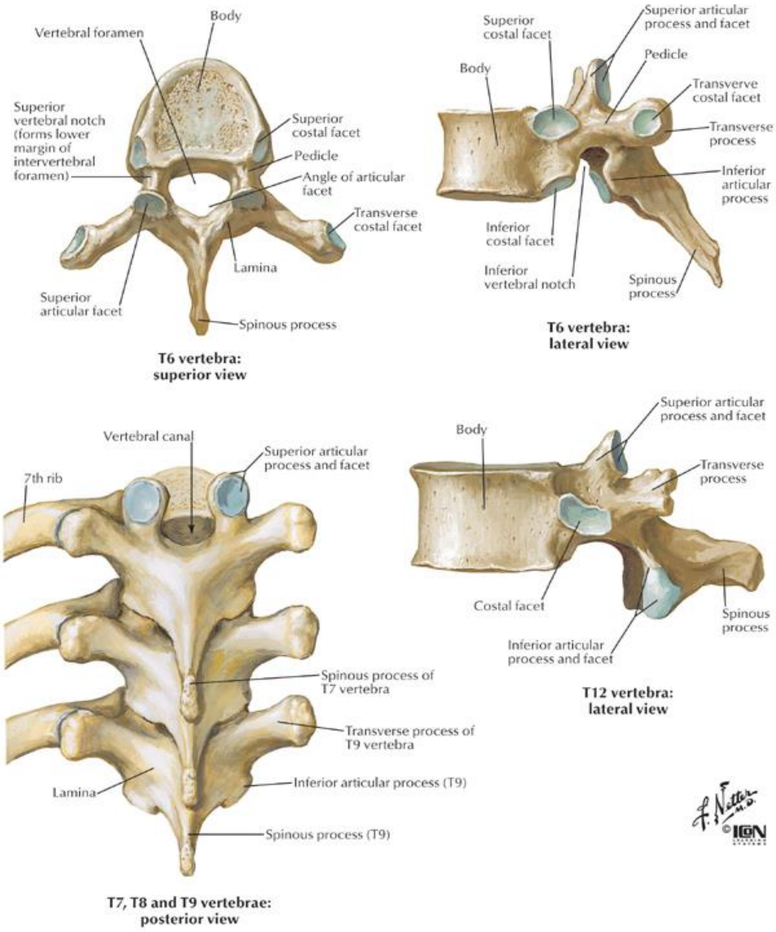

Figure 2.2 Thoracic spine vertebra (Netter and Hansen 2019)

2.4.3 Facet Joints

On the different vertebrae in both the cervical spine as well as the thoracic spine there are joints called facet joints; these joints are situated between all the vertebrae. These joints are synovial joints and consist of the inferior facets that are on the lower articular process of the superior vertebra and the superior facets of the upper articular processes of the inferior vertebra (Almeer *et al.* 2020). Within these joints is a thin joint capsule which helps to protect the joint from damage. The joint capsules within the cervical spine are thinner and looser due to the increased mobility within the cervical spine and this allows for an increased ROM within the cervical spine (Moore *et al.* 2017). The facets glide upon one another which allow for the movement within the spine as well as the size of the intervertebral disks, which dictate the amount of movement the joints can accomplish (Moore *et al.* 2017).

Within these joints a variety of sensory nerves which is why there is high prevalence of dysfunction within these joints. Along with these sensory nerves are mechanoreceptors which help with the alignment of the spine and proprioception (Cramer and Darby 2014).

2.5 PATHOPHYSIOLOGY OF NECK PAIN

Neck pain is a very common presentation but most of the time there is no known cause of the neck pain (Kazeminasab *et al.* 2022), and trying to make a diagnosis and decide on treatment can be very challenging for practitioners. One of the challenges with neck pain is that it negatively affects the proprioception of the cervical spine which then leads to cervical sensorimotor control and the proprioception of the cervical spine which plays a very important role in controlling posture as well as balance (Peng *et al.* 2020). Chronic neck pain can present in different ways. It can present as an aching type of pain where it is manageable and it can also present in a way that is extremely pain and uncomfortable such as a shock-like pain that can decrease the strength in the arm (Bogduk 2011).

The many and different causes of NSNP may be due to muscle strain, which may result from having slept incorrectly or constantly having inappropriate support when sleeping, working at a computer, or being seated at a desk for long periods of time (Johnson *et al.* 2019). Cervical spondylosis, also known as degeneration of the cervical disks, is another possible cause of neck pain. Such degeneration can occur over a long period of time as it involves wear and tear of the disks. This may cause the disks to bulge and compress on the spinal cord and the nerve roots, which can result in radiating pain down the arms (Johnson *et al.* 2019).

Studies have also shown that cervical radiculopathy can occur and is most seen in the patient's third and fourth decades of life. This type of neck pain does not only affect the neck but also causes pain to radiate to other parts of the body such as the arms, upper back and chest (Magnus *et al.* 2024). This type of neck pain is caused by irritation, inflammation or compression of the spinal nerves (cervical radiculopathy) in the neck which is predominantly caused due to inflammation from the adjacent disc, zygapophyseal or uncinate joints which in turn then impinges on the spinal nerves (Magnus *et al.* 2024). Cervical radiculopathy which occurs due to compression or irritation to the nerve roots within the cervical area can be caused by multiple factors: spondylosis as previously mentioned, instability, tumours or trauma that may have occurred in the area (Kazeminasab *et al.* 2022). The aforementioned are all different causes of neck pain from which individuals can suffer.

2.6 NECK PAIN AND MOTOR CONTROL

The central nervous system is responsible for the control of movement, balance, posture and joint stability. This is referred to as sensorimotor control. When an individual has neck pain there are deficits within the sensorimotor control, and this results in reduced joint position sense within the cervical spine and increased postural instability (Sarkilahti *et al.* 2024).

It has been shown that individuals with nonspecific neck pain have motor control impairments (Hanney *et al.* 2010), but the specific deficit of the underlying regulatory system is still unclear (Hanney *et al.* 2010). Muscle pain can affect the motor control strategies through the central mechanisms, including the painful muscles as well as the antagonistic muscles (Merkle *et al.* 2021). Chronic neck pain associated with an alteration in the cervical motor behaviour presenting as a decrease in the cross-sectional area of the deep cervical muscles and muscles at higher cervical levels (Pauw *et al.* 2016), muscular functional deficit in the strength and endurance, impacting precision, acuity and the ROM (Peng *et al.* 2020). A study assessed chronic neck pain due to whiplash, finding that there was significant alteration in the neck muscle activation and a reduced peak motor output. A low isometric endurance and maximum voluntary isometric contraction force were in the muscles of the neck and the shoulder girdle. Peak velocity was lower in individuals with chronic neck pain compared to healthy individuals, a lower peak head movement, and a reduction in smoothness of the neck movement was also reported to be reduced (Vikne *et al.* 2013.

People with chronic neck pain, while performing everyday functional tasks, have altered movement strategies (Tsang *et al.* 2014). Patients with neck pain have been found to have an increase in activity of the superficial neck muscles during upper limb functional activities and isometric contractions decrease in the muscle activation of the deep cervical flexor muscles, longus coli and longus capitis (Kim *et al.* 2016). During a unilateral arm task, it has been found that there is a delayed activation of the deep cervical flexor muscles The relationship with neck pain and motor control can be due to how individuals perceive the pain and disability experienced, this has then shown a delay in the muscle activation in the neck (Sullivan *et al.* 2008). However, few randomised controlled trials have assessed the cause-and-effect relationship that there could be between pain and motor dysfunction in people with chronic neck pain (Tsang *et al.* 2014). When nociceptors are activated, they have an increased effect on the spinal and supraspinal circuitries, which are responsible for the muscle activation. The muscle afferents are sensitive nociceptive stimuli which affect the motor neuron outputs, which means the painful muscle does not activate as fast as a healthy muscle would (Falla *et al*. 2007).

2.7 SPINAL MANIPULATION

Different studies defined spinal manipulation, including “passive handling of the spine”, and “low-amplitude highly accelerative (HVLA) thrusting movement”. HVLA means high-velocity, low-amplitude. Other studies have referred to it as “passive range of movement where a technique is applied”. These are different ways in which people have worded spinal manipulation (McCarthy *et al.* 2015).

Since the time of Hippocrates, spinal manipulative therapy (SMT) has been utilised as a therapeutic technique. It is a collection of therapies that employs manual methods to manipulate tissues in order to promote healing (Evans 2002). Spinal manipulation aims to 1) stretch tissue to overcome the possible tension that develops when the joints are placed into end ROM, 2) induce a cavitation. The cavitation phenomenon occurs when gas bubbles form in the synovial fluid and the pressure inside the joint changes pop resulting in a clicking or cracking sound. Evidence also shows that a spinal manipulation can reduce muscle hypertonicity and stiffness immediately after a spinal manipulation (McCarthy *et al.* 2015).

Spinal manipulation has both mechanical and neurophysiological effects (Bialosky *et al.* 2009). The mechanical effects are due to an external force that is applied to the spinal segment through a HVLA manipulation done by hand or a mechanical device. This movement takes the joint beyond its physiological range but not exceeding the anatomical ROM commonly referred to as the para-physiological zone (Evans 2002). During this phase a cavitation may occur. This causes the joints that were limited in movement to release and be more mobile thus improving the function within these joints (Herzog 2010). Along with the improved mobility and functionality of the joints, there is also muscle reflex response that occurs during HVLA spinal manipulation, and this showed that individuals with spastic muscles and high muscle activity prior to the manipulation had decreased or no muscle activity post the manipulation (Herzog 2010). Different theories are associated with the effect of a spinal manipulation: biomechanical and neurophysiological (Evans 2002). Changes to normal anatomy, physiological or biomechanical dynamics of the vertebra can affect how the nervous system functions (Gyer *et al.* 2019). The mechanical force that is produced during a spinal manipulation is proposed to result in biomechanical changes which may release trapped meniscoids, discal material, or adhesions within the segments, this then results in neurophysiological consequences, which are said to affect the inflow of sensory information to the central nervous system (Pickar 2002). A correlation exists between the biomechanical changes and neurophysiological affects (Bialosky *et al.* 2009). The alteration in the biomechanics of the vertebra alters the signals of mechanically or chemically sensitive neurons. Changes in the sensory input can modify the central neural integration, which can affect the motor, nociceptive and autonomic neural pools, resulting in a change of the sensory input for the somatomotor and visceromotor activity (Pickar 2002).

Neurophysiological effects such as those mentioned also show that there is a change in somatosensory processing, muscle-reflexogenic response, central motor excitability, neuroplastic brain changes, sympathetic activity, motor neuron activity and central sensitisation (Evans 2002). This suggests that after a spinal manipulation, there is a cascade of neurochemical responses and, when this occurs, it results in the pain being perceived as reduced (Gyer *et al.* 2019).

2.7.1 Cervical Spine Manipulation

When individuals suffer from NSNP, a form of management is to have some treatment done by a practitioner, and when receiving treatment from the practitioner it may involve the use of manual therapy involving manual thrust to certain areas of the body (Gomez *et al.* 2020). Previous studies have shown that during manual therapy of a high-velocity, low amplitude manipulation in different areas of the body, the peripheral joints, sacroiliac joints and the spine benefits occur. These benefits include an improvement in kinesthetics sensitivity and proprioception (Evans 2002); these effects of HVLA were seen for pain, functionality, joint position sense and neck pain disability (Gomez *et al*. 2020). It has been shown in individuals with mechanical neck pain that there are rotation restrictions at the level of C1 and C2 and restrictions at the level of C1 and C2 can affect the postural control of individuals (Peng *et al.* 2020).

Cervical spine manipulation has been shown to provide immediate relief of neck pain and improve CROM (Mayana *et al*. 2017). Similarly, manipulation of the thoracic spine has been shown to result in a reduction of pain and an increase in the ROM of individuals with neck pain (Masaracchio *et al.* 2019). It has also been shown in a study that a single cervical HVLA had a greater effect in reducing neck pain at rest as well as increasing the active ROM in the cervical spine than those that had a mobilisation (Martinez-Segura *et al.* 2006). A study done on a single session of cervical spine manipulation (CSM) for NSNP showed mixed results because there was no immediate effect on CROM, but there was a self-perception of the functional disability and mobility (Serra-Ano *et al.* 2023).

Table 2.1 represents studies that have examined CSM in treating neck pain.

Table 2.1 Studies applying cervical spine manipulation for neck pain

Author	Sample Size	Study Design	Intervention	Results
Mayana 2017	*n*=20 Chronic neck pain Age 26 – 60	RCT (Randomised controlled trial)	– Massage – CSM	Significant improvement of pain and ROM
Martinez-Segura 2006	*n*=70 Mechanical neck pain Age 20 – 55	RCT	– CSM – Control	Improved neck pain and mobility within the CSM and control group
Murphy 2009	*n*=20 Chronic NSNP Mean age – 43	RCT Pilot study	– CSM – Exercise group	Improved disability and visual analogue scale within the groups but not across the groups
Serra-Ano *et al*. 2023	*n*=25 Acute and chronic NSNP	RCT	– CSM – CSM sham group	No immediate effect in pain or CROM, there was a self-perception of improved functionality and mobility
Cassidy 1992	*n*=100 Unilateral neck pain referring to trapezius Mean age 36.1	RCT	– CSM – Mobilisation	Increased ROM for both groups, but a greater improvement in pain for the CSM group
Bronfort 2001	*n*=191 Chronic mechanical neck pain	RCT	– CSM – Exercise group	CSM and exercise groups showed a greater gain in muscle strength, endurance and ROM
Gorrell 2016	*n*=65 Mechanical neck pain of at least 1 month Mean age – 24.4	RCT	– Stretching (control) – Stretching and manual manipulation – Stretching and instrument manipulation	Decrease of pain intensity in the groups with manipulation compared to the control group. Increased rotation, lateral flexion on the side of manual manipulation. Grip strength increased on the opposite side of the instrumental manipulation
Maiers 2014	*n*=241 Mechanical neck pain Mean age – 72.3	RCT	– SMT and exercise – Home exercises alone	A 10% greater decrease in pain compared to the home exercises alone after 12 weeks of treatment.
Coulter 2019	*n*=47	Systematic review and meta-analysis	– SMT – Sham/no treatment	Various types of manipulation and mobilisation can decrease pain intensity and improve the functionality in people with chronic NSNP compared to other interventions
Madura de Camargo *et al*. 2011	*n*=37 Mechanical neck pain Mean age – 31.6	RCT	– SMT – Control group	SMT group experienced a greater increase in muscle activity and fatigue resistance

2.7.2 Thoracic Spine Manipulation

Recent evidence has reported that the use of a HVLA thrust manipulation to the thoracic spine has immediate, short-term improvements in both the pain intensity and CROM (Cross *et al.* 2011; Young *et al.* 2019; Puntumetakul *et al.* 2015), and that thoracic manipulation has shown better improvements than that of non-thrust treatment in patients with neck pain (Young *et al.* 2019).

It has been recommended that a thorough thoracic spine examination should be conducted in patients with primary neck pain, due to the bio-mechanical link between the cervical spine and the thoracic spine. A study assessing movement occurring within the cervical spine and thoracic spine during head protraction and retraction found that 30% and 10% of movement occurred at the cervicothoracic and thoracic spine respectively (Persson *et al.* 2007). This clearly demonstrates the link between the cervical and thoracic spines, showing the contribution of the thoracic spine to the overall mobility of the cervical spine and showing the coordination that occurs between the two areas (Tsang *et al.* 2013). These suggests what possibly happens but the precise rationale as to why a single thoracic manipulation helps with neck pain is not clear (Cleland *et al.* 2005). Dysfunction in the thoracic joints can serve as an underlying contributor in individuals developing neck pain and dysfunction (Masaracchio *et al.* 2019). Any restriction in the mobility of the thoracic spine is a cause of neck pain but when there is manual therapy, such as thoracic spine manipulation (TSM) applied, increased thoracic spine mobility occurs, which then improves CROM, pain intensity and dysfunction in patients with neck pain (Seo *et al.* 2022). Manipulation of the thoracic spine has been shown to result in a reduction of pain and an increase in the range of motion of individuals with neck pain (Masaracchio *et al.* 2019).

Studies have suggested that a TSM or thrust has a significantly greater short-term effect in reducing one's pain and disability than those that receive a non-thrust mobilisation in individuals that have neck pain (Cleland *et al.* 2005). Another study also suggested that because there is an intrinsic biomechanical link that occurs between the cervical spine and the thoracic spine, any disturbance that occurs within the thoracic spine could be a primary contributor to neck pain (Lau *et al.* 2010). This study showed that individuals that received thoracic manipulation had an improvement in pain, range of motion, as well as craniovertebral angle compared to a control group in individuals with neck pain (Lau *et al.* 2010).

A study which compared the effect of a single level manipulation in the thoracic spine, at T6 – T7 level, a multi-level manipulation and a control group in patients with chronic neck pain showed that there was significant improvement in pain intensity and disability at 24-hour and 1-week follow ups within the two groups receiving manipulation when compared to the control group. A significant difference in neck flexion and left lateral flexion occurred in the single level manipulation and in right neck rotation in the multi-level manipulation when these groups were compared to the control group (Puntumetakul *et al.* 2015), emphasising that thoracic spinal manipulation was able to influence CROM. Table 2.2 represents studies that have examined TSM in treating neck pain.

Table 2.2 Studies applying thoracic spine manipulation for neck pain

Author	Sample Size	Study Design	Intervention	Results
Cleland 2005	*n*=36 Mechanical neck pain Mean age 35.5	RCT	- TSM - Placebo	Immediate pain relief in the CSM group compared to the placebo group
Casanova-Mendez 2014	*n*=60 Chronic NSNP Mean age - 37	Double blinded RCT	- TSM Dog technique - TSM Toggle recoil technique	Improved neck mobility, reduced neck pain and improved mechano-sensitivity in both groups
Cross 2011	*n*=44 studies Thoracic spine manipulation, thoracic spine mobilisation	Systematic review	- Systematic review	Significant pain improvement globally and ROM post a thoracic thrust manipulation
Lau *et al.* 2010	*n*=120 Chronic mechanical neck pain Mean age – 43.9	RCT	- TSM - Control	CSM group showed a significantly greater improvement in pain intensity, craniovertebral angle, disability and neck flexion
Cleland 2007	*n*=60 Mechanical neck pain Mean age – 43.3	RCT	- TSM - Mobilisation/no thrust	Greater reduction in pain and disability in the group with the thrust compared to the group with no thrust/mobilisation
Young *et al.* 2019	*n*=43 Cervical radiculopathy Age – 18 to 65	RCT	- TSM - TSM sham	Improvement in pain, disability, cervical ROM and deep flexor endurance within the CSM group
Puntumetakul 2015	*n*=48 Chronic mechanical neck pain Mean age – 26.54	RCT	- Single level SMT - Multi-level SMT - Control Group	Improved neck pain and disability from the single and multilevel thoracic SMT. Improved neck flexion and left lateral flexion in single level thoracic SMT and right rotation in multi-level thoracic SMT compared to the control group
Seo 2022	*n*=26 Chronic neck pain office workers Mean age – 35.77	RCT	- Thoracic SMT Twice a day two times a week for 6 weeks - Thoracic Mobility Exercise 15 minutes a day two times a week for 6 weeks	Improved pain intensity and neck disability. Significant differences in cervical right lateral flexion and right rotation between the groups

2.7.3 Cervical and Thoracic Spine Manipulation

Not many studies are evident on combined cervical and thoracic manipulation used to treat neck pain patients (Dunning *et al.* 2012). One of the studies showed that there was an improvement in disability, pain and ROM in participants with neck pain that received a single session of both a cervical and thoracic manipulation (Dunning *et al.* 2012). Another study showed that with cervical and thoracic manipulation for neck pain there was a more favourable result with cervical manipulation compared to the thoracic manipulation, and there were fewer transient side effects with cervical manipulation than that of the TSM (Puentedura *et al.* 2011).

The spine is a kinetic chain: the cervical spine is connected to the thoracic spine which is in turn connected to the lumbar spine (Tsang *et al.* 2013). A dysfunction in the cervical spine could affect the thoracic spine (Sanchez 2019) and vice versa. This also occurs with treatment; treating the cervical spine can affect the thoracic spine and treating the thoracic spine can affect the cervical spine (Karas *et al.* 2016). A study about the effect of a cervical non-thrust manipulation and exercise versus a non-thrust cervical manipulation, thoracic thrust manipulation and exercise, showed that individuals that received both the cervical and thoracic manipulation had better short-term effects in terms of pain, disability and global rate of change (Masaracchio 2013).

Gregoletto and Martinez (2014) assessed the effect of two different techniques used in the manipulation of the cervical spine and the thoracic spine for mechanical neck pain; the Gonstead method was used for the cervical spine, while the diversified technique was used for the thoracic spine. The results showed an increase in cervical mobility and a subjective decrease in the pain.

Table 2.3 represents studies that have examined a combination of cervical and TSM in treating neck pain.

Table 2.3 Studies applying cervical and thoracic manipulation for neck pain

Author	Sample Size	Study Design	Intervention	Results
Dunning 2012	*n*=107 Mechanical neck pain Mean age - 42	RCT	- HVLA SM - Non-thrust mobilisation	The combination of cervical and thoracic HVLA thrust manipulation was more effective in reducing pain and disability than that of the non-thrust group
Gregolett 2014	*n*=73 Mechanical neck pain Mean age – 42.27	RCT	- SM Gonstead for cervical and Diversified for thoracic	A reduction in pain intensity and an increased cervical ROM perceived by the participants
Masaracchio. 2013	*n*=64 Mechanical neck pain Mean age – 32.5	RCT	- SM thoracic thrust, cervical non-thrust and exercise - Cervical non-thrust and exercise	Significantly greater improvement of pain on the numerical pain rating scale (NPRS) and neck disability in the group with the CSM thoracic thrust, cervical non-thrust and exercise compared to the group without the thoracic thrust
Saavedra-Hernandez 2012	*n*=82 Chronic mechanical neck pain Mean age - 45	RCT	- SM cervical spine - SM cervical, cervico-thoracic and thoracic spine	Both groups experienced similar decreases in neck pain and increases in cervical ROM, whereas for disability the group with the full spinal manipulation saw a greater decrease
Puentedura 2011	*n*=24 Primary complaint of neck pain Mean age – 33.7	RCT	- Thoracic SMT and cervical ROM exercise - Cervical SMT and cervical ROM exercises	The group that received the thoracic SMT and cervical exercises had a significant improvement in neck pain intensity and disability compared those that only received CSM and cervical spine exercises

2.8 MEASURING PAIN IN NECK PAIN

Studies used the following outcomes, pain rating and cervical ROM to assess the effect of cervical and thoracic manipulation on neck pain. Although ROM testing is informative it says little about the quality of motion as opposed to the quantity of movement (Tsang *et al.* 2014). The pain of the participants was measured by using the numerical pain rating scale (NPRS). The NPRS assessment of pain intensity is a frequently used assessment method, one of the main forms of testing in clinical pain research (Ranzatto *et al.* 2024). The NPRS uses a scale of 0–10 to represent the pain intensity felt: 0 represents no pain and 10 represents excruciating pain. The scale is broken up into mild, moderate and severe pain, mild is from 0–4, moderate 5–7 and severe 8–10 (Boonstra *et al.* 2016). The NPRS is a variation of the verbal numerical scale where participants are asked to say what their pain is from 0-10. The NPRS has the benefit in that it has been validated and is simple to use, especially if there is an acute situation (Correll 2011).

The validity of the NPRS was present in a study that tested for validity and reliability using participants with osteoarthritis in their knees, the study included 121 subjects who were tested and retested using visual analogue scales (VAS), verbal numerical scale and NPRS. All three had excellent test-retest reliability (Alghadir *et al.* 2018). Most studies were conducted in western and developed countries, but this study was done in Thailand and assessed four different types of measuring scales to assess pain intensity. 360 participants were asked to rate their pain using VAS, verbal rating scale, NRS and face pain scale-revised. The results indicated the validity for all four of the scales. Some variability was evident with the incorrect responses that were given, with the VAS having the highest and NRS having the lowest number of incorrect responses on the relevant scales. The VAS was the least preferred scale with the NRS being the most preferred (Atisook *et al.* 2021).

2.9 MEASURING CROM AND SPINAL KINEMATICS (MOTION CAPTURE)

With neck pain most individuals receive treatment from a practitioner who uses an objective form of assessing the functional ability by performing a ROM in the frontal, sagittal, as well as transverse planes. These assessments use CROM instruments but limited to single plane and not multi-planar. This does not help the functionality assessment which would be needed to assess the function with daily activities (Sukari *et al.* 2021). By measuring kinematic variables, such as velocity and acceleration, in addition to angular displacement (ROM), one can assess the quality of the movement (Guo *et al.* 2019). This is important for overall functionality, as one does not just require increased movement but quality of movement, and smoothness (Guo *et al.* 2019). These outcomes have been under-investigated in the literature.

Motion capture technology utilised cameras and software that uses reflectors that are placed on the participants' skin in the relevant marker points, the cameras and software then form a model of the participant on the computer and see the full frame of the participant and observe the task being completed (OptiTrack 2019). One of the draw backs of the motion capture is that it requires a professional software and laboratories which are expensive. With these different aspects this could be a possible reason as to why motion capture is not widely used. Motion capture is a more accurate way of assessing kinematics (OptiTrack 2019). Spinal kinematics can also be assessed using inertial measurement units but this specific method has been under-researched, specifically looking at the quality of movement through acceleration and velocity (Sheeran *et al.* 2024). Another form of assessment is through stereophotogrammetric motion analysis which has been used when assessing spinal kinematics during gait and functional tasks that were not specified (Fayad *et al.* 2022). Measuring kinematics have also been measured using an electromagnetic tracking system (Lemmers *et al.* 2018), There is a paucity of studies using motion capture to assess spinal kinematics in contrast to the lower extremity where it is well utilised to assess gait (Falla *et al.* 2004).

In addition to assessing cervical ROM, it is important to assess a neck pain patient's ability to perform everyday functional tasks, as disability affects quality of life (Rezai *et al.* 2008). Tasks such as office computer typing (Szeto *et al.* 2005), reaching for something and reading (Constand and MacDermid 2013) and sitting for prolonged periods in uncomfortable positions such as driving a car (Alshahrani *et al.* 2024) have been found to be affected in patients with neck pain (Szeto *et al.* 2005). This study found that neck pain participants had increased neck flexion when sitting in the relaxed posture while performing a computer task, but they demonstrated decreased CROM, especially in right sided lateral flexion and rotation when compared to asymptomatic office workers (Szeto *et al.* 2005). These results were supported by Xie (2018) with the use of unilateral and bilateral smartphone texting and computer typing. Tsang (2014) found that a one arm functional task, seated at a desk and moving an object from the desk up onto a shelf and back down onto the desk, was associated with altered muscle recruitment patterns in participants with neck pain, it was found that there was a compromised level of movement velocity and acceleration and that secondary muscle in the cervical spine and the thoracic spine were activated to help with the performance of the task which determine the kinematic variables within the spine (Tsang *et al.* 2014). Neck kinematics (ROM and movement velocity) have been assessed while participants played virtual games to determine if there were altered kinematics between neck pain and non-neck pain participants, where they had to 'spray' targets by moving their head (Sarig Bahat, Weiss and Laufer 2010). Those with neck pain had decreased ROM of the cervical spine and mean velocity when compared to healthy controls, highlighting that neck pain sufferers have slower movements than participants without neck pain (Sarig Bahat, Weiss and Laufer 2010)

2.10 CONCLUSION

Neck pain is a common and disability condition which presents with alterations in spinal kinematics in the cervical and thoracic spine. It is unclear if treatment, specifically SMT can impact these movement impairments. However, the literature shows that CSM alone can have a positive effect on pain, disability and ROM in people with NSNP, similar findings following thoracic spinal manipulation. A paucity of studies exists on cervical and thoracic spinal manipulation applied in isolation and combined have been compared to assess their effect on pain and spinal kinematics

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter details the methodology utilised in this study. This chapter presents the study design and discusses the participants' characteristics, data collection tools and ethical considerations that are addressed within the study.

3.2 STUDY DESIGN

The study was designed as a quantitative, randomised, controlled, single-blinded study (RCT), as it aimed to assess the effect of various interventions that were performed under controlled conditions, with a random allocation of participants to the various groups to compare their effects (Bhide *et al.* 2018). This type of study is the most noted and effective research method to determine if there is a cause/effect relation between an intervention and an outcome (Bhide *et al.* 2018).

3.3 STUDY POPULATION

The study population consisted of participants suffering from chronic, NSNP residing within the province of KwaZulu-Natal, South Africa.

3.4 LOCATION AND PERMISSION TO CONDUCT THE STUDY

The data collection took place at the Durban University of Technology Chiropractic Day Clinic. Permission was then obtained from the Chiropractic Day Clinic Director (Appendix A) to allow for data collection to be conducted within the clinic, the institutional Gatekeepers' Committee (Appendix B), to allow for data collection to take place on the Durban University of Technology grounds, and from the Institutional Research and Ethics Committee (IREC 178/22) (Appendix C) which operates in accordance with the Declaration of Helsinki 1964.

3.5 SAMPLING

3.5.1 Participant Recruitment

The participants were recruited via advertisements (Appendix D) that were placed on the Durban University of Technology premises, media (WhatsApp), flyers delivered by hand and by word of mouth. Participants that responded to the advertisements contacted the researcher and were then screened using the following questions as outlined in Table 3.1.

Table 3.1 Screening questions

Question	Answer
How old are you?	18 - 50
Have you had neck pain for more than three months?	Yes
Have you had treatment for your neck in the last three weeks?	No
Please rate your pain on a scale of 0 - 10	3 - 7
Have you had any head trauma?	No
Do you have any known neurological or orthopaedic disorders?	No
Have you had any surgery to the brain or spine?	No
Do you have any temporomandibular disorders?	No
Do you suffer from rheumatic disease?	No
Are you able to attend the Durban University of Technology Chiropractic clinic?	Yes

If the participant met the criteria an appointment was made at the Chiropractic Day Clinic. On arrival for their appointment, the participants were given a letter of information and informed consent form (appendices F and O) where the study was explained in detail. All participants were given the chance to ask any further questions and informed that if they wished to withdraw at any point, they were free to do so, with no future repercussions for them receiving treatment at this clinic.

3.5.2 Sample Size

The sample size was calculated using G-Power version 3.1.9.4 (Faul 2019) with a *p*-value of 0.05, a power of 80, and a medium effect size (0.5), using a repeated measures ANOVA test. This resulted in a sample size of 48 participants being required for the study (Matthews 2021, personal communications).

3.5.3 Characteristics of the Participants

3.5.3.1 Inclusion Criteria

- Participants had to have a diagnosis of chronic, NSNP, which was made via a case history, physical and orthopaedic examination. The examination and diagnosis were made by the researcher, who is a registered student in the programme: Master's Degree in the Technology: Chiropractic. A qualified chiropractor, who was the supervising clinician, confirmed the diagnosis. The neck pain must have been experienced for more than three months or mostly over the last twelve months (Alagingi 2022).
- Participants were aged from 18–50 years, and this allowed the exclusion of minors and those who may have potentially degenerative joint changes which typically starts after the age of 65 or more (Parenteau 2021).
- Participants whose neck pain was severe enough for them to require medical care, needed to have neck pain between 3–7 on the NPRS.

3.5.4 Exclusion Criteria

- Participants with any known neurological/orthopaedic disorders, previous trauma or surgery to the brain or spine, sensory or vestibular deficits, bony abnormalities or deformities of the trunk, suffering from rheumatic disease, or had dysfunction of the temporomandibular joint.
- Participants who had allergic contact dermatitis from the reflectors used for the motion capture, and which were stuck onto the skin, with an adhesive gel on them.
- Participants who displayed signs of central sensitisation, as determined by the Central Sensitisation Inventory (Mayer *et al.* 2012) (Appendix J), and Fear Avoidance Behaviours (FAB) as determined by the Tampa Scale of Kinesiophobia (TSK) questionnaire (Miller *et al.* 1991) (Appendix L).
- Participants who were unable to lift a 2kg object with one arm.

- Participants who had contraindications to spinal manipulation such as rheumatoid arthritis, degenerative changes, spinal instability, neurological and vascular changes such as vascular insufficiency, neck trauma and hypertension (Di Fabio 1999).
- Participants were required to sign an informed consent (Appendix F), a COVID-19 information and consent form (Appendix G, H and O), and a declaration of entry to the clinic (Appendix I). Those that refused or showed signs of SARS-COV 2 infection were excluded.

3.5.5 Participant Allocation

Once the participants were determined as eligible to proceed with the study they were randomly allocated to one of four groups:

- Group 1 - Cervical spine manipulation
- Group 2 - Thoracic spine manipulation
- Group 3 - Cervical and TSM
- Group 4 - Control

The randomisation was done by a person not involved in the study, who utilised an online random allocation software programme to allocate participants to the four groups. The person then placed the following numbers 1, 2, 3 or 4 randomly into 50 opaque envelopes. More than 50 envelopes were prepared which accounted for the uneven randomisation, which were then labelled 1 through to 50. The envelopes were concealed and only opened and seen by the research assistant thus not allowing the researcher to see to which group a participant had been allocated. For the first participant who was eligible, the research assistant selected the first envelope to reveal the allocated group; the next consecutive envelope was selected for the next participant and so the process continued. The research assistant then opened the envelope and performed the relevant manipulation or set up depending on the group. The researcher did not know to which groups the participants had been allocated, thus allowing for no bias while recording the data.

3.6 MEASUREMENT TOOLS

3.6.1 Spinal Kinematics

The OptiTrack motion capture system using OptiTrack Motive Software together with STT was used to record the cervical ROM and kinematics of the cervical and thoracic spine. This system consists of eight Prime 13 cameras, that have a resolution of 1.3 MP (1280 x 1024) and a frame rate of 240 for capturing motion in the coronal, sagittal and transverse planes. The sampling frequency of 100Hz per sensor for the kinematics is recommended (Muyora *et al*. 2017) and was utilised in this study. Cameras were calibrated to the protocol of the manufacturer (Natural Point Inc 2014). Calibration took place by using wanding. The eight cameras were wall mounted with one camera being placed on a tripod, which was then placed on a desk. The exact placing was marked in case the camera was moved which ensured correct positioning for each capture. The capture volume was set up prior to data collection by setting each cameras volume to ensure that there was minimal background noise when capturing the data. All artefacts were removed from the room and masking was applied to ensure only the reflectors were seen. This calibration was done to ensure that all cameras were receiving as much information from the relevant reflectors for optimum data collection. The ground plate was then set to complete the calibration. This gave the correct orientation of the 3-dimensional human model on the software and was done to align the Z, Y and X axes and provide depth.

In STT, the model for spine and upper body analysis was utilised. This required reflective markers to be placed on the following anatomical positions (Florez 2021) (Appendix M):

- Glabella
- Centre of the head (the middle point between the right and left ear - applied via a head gear)
- External occipital protuberance
- Acromion bilaterally
- Spinous process of the C7, T3, T7 and L1 spinous processes
- Posterior superior iliac spines (PSIS) bilaterally
- Lateral epicondyle bilaterally
- Radial styloid process bilaterally

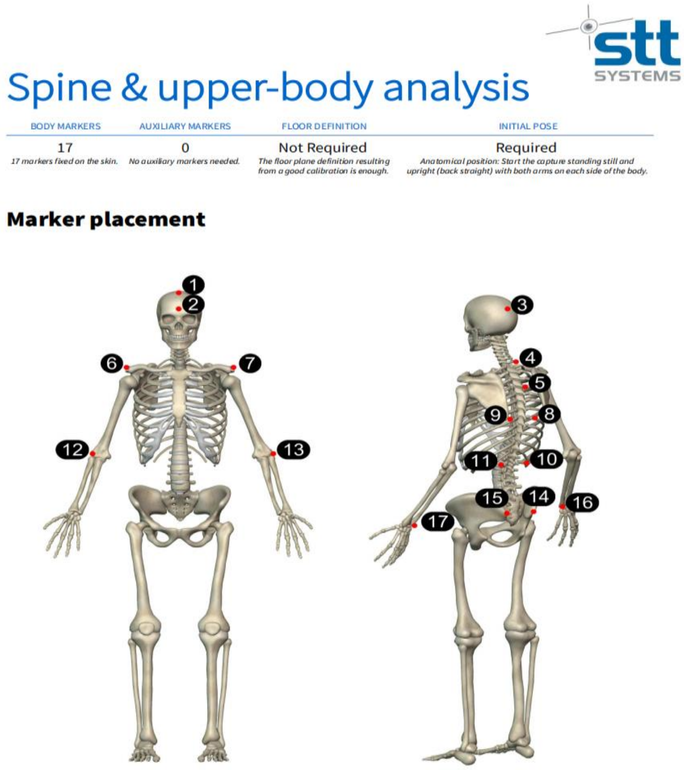

Figure 3.1 Reflector placement

The 3DMA STT-system™ received the non-labelled reflective markers from OptiTrack Motive™ tracker. The software then processed the movement data, providing 6 degrees of freedom (DoF). This transformed the markers into a 3-dimensional digital human model, in ‘real-time’. At the beginning of each capture, an anatomic calibration process was done to adjust the digital model to the anthropometry of the participant and to associate the position and orientation of each reflective marker with its corresponding body segment to complete the transformation matrix.

For the cervical and thoracic spinal kinematics, the relative orientation of the cervical and thoracic regions was based on information from the reflectors. Six-degrees-of-freedom (6DoF) tracking function collected data from each region according to the model:

- Cervical motion - external occipital protuberance to C7
- Thoracic motion upper - C7 to T7
- Thoracic motion lower - T7 to T12

A kinematical estimation model was developed in STT-systems™ and provided the following data:

- The 6DoF was the three anatomical movement planes:
    - Flexion/extension in the sagittal plane
    - Left/right rotation in the horizontal plane
    - Left/right side flexion in the frontal plane
- The three variables being investigated were:
    - Angular displacement
    - Movement velocity which was determined as the time derivative of angular displacement
    - Angular acceleration was a time derivative of angular velocity

3.6.2 Numerical Pain Rating Scale

The NPRS was used to assess the participants' subjective measure, specifically pain intensity (Krebs, Carey and Weinberger 2007). This was done using numbers to rate the pain. The individuals selected one of 1 numbers, from 0–10 (Appendix O). The number selected by the individual would depend on the intensity of the pain. If the individual had no pain, they put down 0; 1–3 indicated mild pain; 4–6 indicated moderate pain; and 7–10 indicated the individual had severe pain (Boonstra 2016). In this study, the raw score was recorded and the data were treated as numerical.

The scale was presented to the individual prior to any treatment and then again about 24 hours post treatment, which was done via the phone to assess effectiveness of treatment. The NPRS is the most common used linear form of measuring pain. The NPRS has a high test-retest reliability in both illiterate and literate patients both before and after medical consultation (Alghadir 2018). It is a measurement that is utilised for adults and in children as young as 10. It is more reliable than using a visual analogue scale (VAS), and this is seen particularly in older individuals and those who struggle with literacy (Baranidharan *et al.* 2019).

3.6.3 Recording Data

Figure 3.2 is an example how the data were recorded. For all flexion extension variables, positives are above the 0-line and negatives are below the 0-line. When there is an “away” within the variable, that is all the data from the 0-line to the peak; this is both for positive and negative variables. In cases of a “return” in the data, this is from the peak to the 0-line in both positive and negative variables. When examining lateral flexion and rotation, the positive movement refers to movement to the left and negative refers to movement to the right. A peak represents the highest recorded reading; for the arm task these are recorded as the top value. The range is the full movement from one positive peak through to one negative peak.

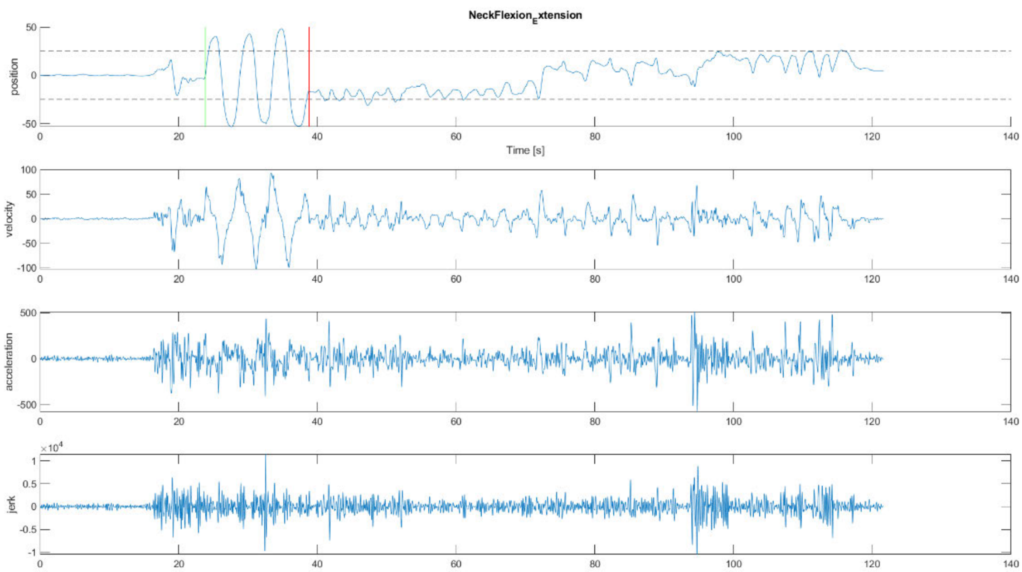

Figure 3.2 Data recording example

3.7 TASKS

3.7.1 Cervical Range of Motion

The first part of the data collection consisted of CROM assessment. The participants were instructed to sit upright on a stool, facing a dot on the wall in front of them. They were asked to not move their shoulders or trunk during the motions. The participants were then shown how to perform flexion and extension of just the head and neck. First they flexed and then extended; this was performed three times. Next the participants performed lateral flexion, first to the left then to the right, ensuring that they did not shrug their shoulder. This was once again performed three times. Lastly, the participants performed rotation, looking over their left shoulder first, then their right, ensuring that it was only their neck moving; this was also performed three times.

3.7.2 Unilateral Arm Task

The unilateral arm task was similar to that used by Tsang *et al* (2014). The participants sat in front of two shelves, where the first shelf was 70cm and the second 140cm off the ground, as can be seen in Figure 3.3. A 2kg weighted jar was placed on the first shelf and participants then grasped the object with their right hand, and raised it to the second shelf, pausing for two seconds, before bringing the object back down to the initial shelf. The task was repeated three times. During the task the participants sat on a chair placed in front of the shelves in an upright posture, with their feet flat on the floor hip width apart. The participants were asked to track the movement of the object with their head and eyes.

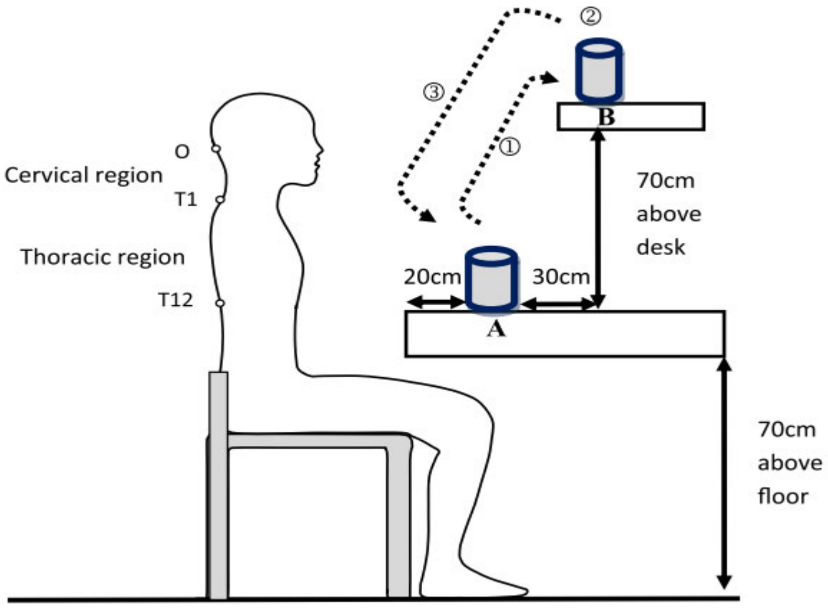

Figure 3.3 Seated functional task setup (Tsang 2014)

3.7.3 Bilateral Arm Task

The standing task involved the participant standing upright in the centre of the motion capture field with both hands placed on a bar weighing 2kg, that had been placed on a box resting on a stool. The participants then lifted the bar above their heads and then placed it back down onto the box. The task was repeated three times. During the task, the participants tracked the movement of the bar with their head and eyes. This task is a simulation of someone hanging washing on the washing line. The participants were allowed to practice the tasks, which helped ensure that each participant knew exactly what to do and make the movements as accurate as possible.

3.8 INTERVENTIONS

The research assistant assessed both the cervical spine and thoracic spine through motion palpation, to find the most restricted cervical spine segment and thoracic spine segment. Motion palpation has mixed reviews with regard to is validity, a study determined that motion palpation can be affected by the examiner due to the tactile sensibility of the hand, age affecting tactile perception, the focus of the examiner, central processing of that specific examiner, visual imagery can cause discrimination, thus it is inconclusive (Nyberg *et al.* 2013). Another study found that a reproducible test was done on motion palpation of the cervical spine in rotation and came within six degrees of the rotation which suggests it is reliable (Marcotte *et al.* 2002). Another study that assessed 48 articles found that inter examiner reliability was slight and intra examiner reliability was moderate (Haneline *et al.* 2009).

The cervical spine or thoracic spine was moved to assess which segment was not moving, which was then the restricted segment. Once the research assistant found the restricted segments, either in the cervical spine, thoracic spine or a combination, the research assistant performed the adjustment to the relevant segments.

3.8.1 Cervical Spine Manipulation

The restricted cervical spine segments were then manipulated with the use of the index/pillar push technique for the lower cervical spine segments and the index/atlas push technique for the upper cervical spine segments. These techniques are done in a supine position, the contact hand contacts the transverse process on the side of the restriction, the indifferent hand just supports the head, and the line of drive is parallel to the ground straight across. These techniques were constant for all participants receiving CSM (Bergmann and Peterson 2011). A maximum of two segments were manipulated per region. A successful manipulation was determined by the presence of a cavitation sound. If this did not occur a second attempt was allowed.

3.8.2 Thoracic Spine Manipulation

The restricted thoracic spine segments were manipulated with the use of thumb/spinous push for levels T1–T3 and bilateral hypothenar/transverse push (crossed bilateral) techniques for levels T4–T12. These techniques are done in a prone position, the contact hand contacts the transverse process on the side of the restriction, the indifferent hand is on the opposite side of the restriction as support, the line of drive is through the contact hand straight perpendicular to the ground posterior to anterior. These techniques were constant for all participants receiving TSM (Bergmann and Peterson 2011). A maximum of two segments were manipulated. A successful manipulation was determined by the presence of a cavitation sound. If this did not occur, a second attempt was allowed.

3.8.3 Cervical and Thoracic Manipulation

The most restricted segments were manipulated with the use of the aforementioned manipulations. For the cervical spine see section 3.6.1 and for the thoracic spine see section 3.6.2. A maximum of two segments were manipulated. A successful manipulation was determined by the presence of a cavitation sound. If this did not occur, a second attempt was allowed.

3.8.4 Control

The control group consisted of the participants being set up for manipulation on both cervical and thoracic segments. While the participant was set up for a manipulation there was be no force or pressure applied and so there was be no cavitation taking place. For the cervical spine please see 3.6.1 with no manipulation taking place and for the thoracic spine see 3.6.2 with no manipulation.

3.8.5 Research Assistant

The research assistant performing the assessment of motion palpation and the manipulation on the participants was a qualified practitioner with more than 15 years' experience. The practitioner was informed of the technique that was being utilised and ensured a similar technique was used for all participants. The bed on which the assessment and manipulation took place was constant for all participants to ensure that the examinations and manipulations were constant throughout. The research assistant only provided the treatments and did not take part in any other aspects of the study thus was blinded to the outcome measures.

3.9 RESEARCH PROCEDURE

On arrival at the DUT Chiropractic Day Clinic for the initial consultation the participant was explained the research and provided with an information letter and informed consent form (Appendices F, G and O). After the informed consent was signed a case history (Appendix P), and a physical and regional (Appendices Q and R) examination was done. Once meeting the study inclusion criteria, they were randomly allocated into one of the four groups using a randomised allocation chart by the research assistant.

The participants were then required to change into tight leggings/cycling shorts and a tight vest/sports bra, this was necessary to allow for visibility of the reflective markers. The reflectors were then placed on the relevant areas (Appendix L). The researcher demonstrated to the participants the tasks they were required to complete, and they were given an opportunity to practice the tasks.

On starting the capturing of the data, the participants' resting posture was assessed for 5 seconds followed by CROM, the previous outlines the functional task performed by the participant. The first task was performed seated, and the second task was done standing. The motion capture cameras and software were running during the movements tracking each marker and recording the data. After the participants had completed all the movements, they then received the allocated intervention.

The intervention was performed by a research assistant who received training to perform the relevant adjustment procedures. After manipulation of the participants, they were then reassessed through motion palpation at the segments that had been manipulated to assess for improved motion. After that was completed, the participants then repeated the movements, with the motion capture again recording the data. On completion of the study, the participants were thanked for their time. If additional treatment was required for their neck pain, they were referred to the chiropractic clinic for continued treatment. The whole process took about an hour for each participant.

3.10 STATISTICAL ANALYSIS

The IBM SPSS (SPSS, IBM Corp) was utilised to analyse the data in this study. A *p*-value less than 0.05 indicated a significant difference. Descriptive statistics were used to describe the data in terms of frequencies and count, for data such as sex and mean, standard deviation, and range for numerical data, such as pain and degrees of motion. Pair student t-tests were utilised to assess the intragroup effects, and ANCOVA was utilised to compare the four groups.

3.11 ETHICAL CONSIDERATIONS

Ethical clearance was obtained from the Durban University of Technology Institutional Research Ethics Committee (reference number IREC 178/22). This committee works in accordance with the Declaration of Helsinki (1964). Gatekeepers' (Appendix B) permission was obtained to conduct the study on Durban University of Technology premises and on any students and staff of the university as well as permission from the clinic director to conduct the study in the Chiropractic Day Clinic (Appendix A).

In this study, autonomy was adhered to by ensuring that all participants signed an informed consent and a letter of information as well as verbally confirming their understanding of the procedure. No participants were coerced while being recruited. All participant data will be stored at Durban University of Technology for five years. All participant information was kept confidential by allocating codes to each participant, ensuring no names were mentioned in the dissertation or any possible publication resulting from the research. All other participant information was stored and coded in an Excel spread sheet on a laptop with password protection.

Beneficence was accounted for as the results from this study could affect the way in which practitioners treat individuals going forward which benefits both the profession as well as the patients. Justice was accounted for as no participants were excluded from the study based on their race, gender, or occupation. Non-maleficence was paramount ensuring no harm was done to the participants, all interventions and measurement tools were tested prior to them being utilised in this study to ensure they were safe for all participants. To ensure there was justice and no discrimination within the study, participants were allowed to participate regardless of their race, gender, and culture.

CHAPTER 4

RESULTS

4.1 INTRODUCTION

This chapter contains the results that were obtained from the data analysis. The data are presented in different forms such as flow diagrams and tables, conforming to the current CONSORT guidelines for the reporting of RCT data. The IBM SPSS was utilised to analyse the data; a *p*-value that is less than 0.05 indicates significance. Paired student t-tests were used to assess the data within the group and across the groups. If any significant data were found within the groups, then the ANOVA test was utilised.

This chapter represents the data collected as a result of statistical analysis starting with the demographics of the study, gender, occupation and age. The pre and post pain rating acquired by all participants in all the groups, which showed a decrease in pain across all four groups, is evident. The chapter presents the data relating to the kinematics of the participants within each group, as well as across the groups, while performing the CROM (flexion/extension, lateral flexion and rotation), the two functional tasks, first one seated (unilateral arm task) and second one standing (bilateral arm task).

4.2 CONSORT FLOW DIAGRAM

The flow of participants through the research are presented in the consort flow diagram in

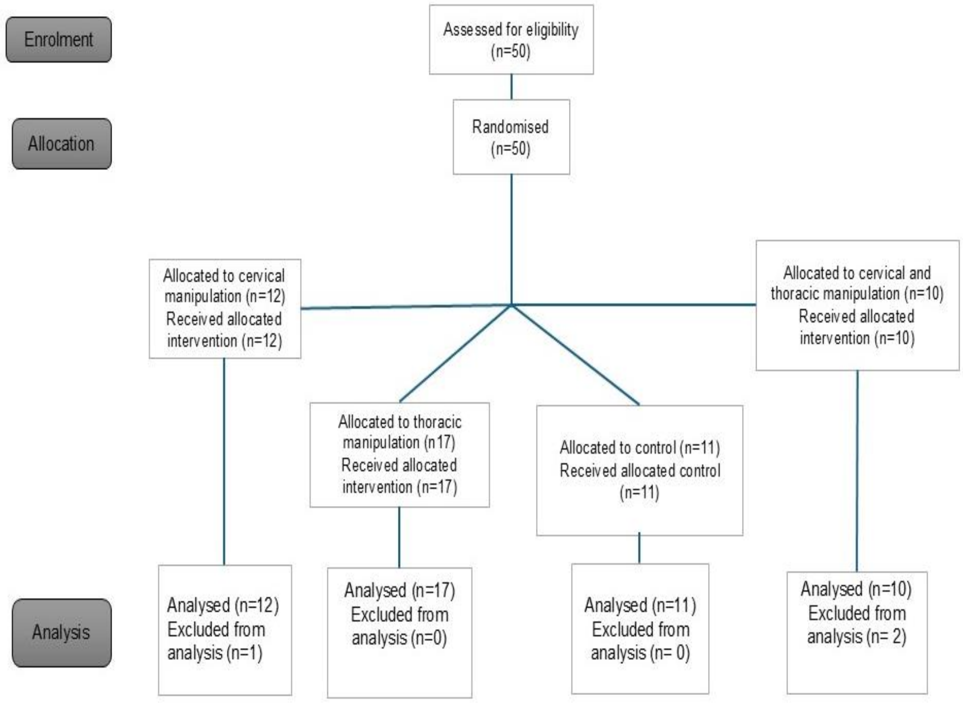

Figure 4.1 The flow of participants through the study

4.3 DEMOGRAPHIC CHARACTERISTICS

4.3.1 Sex and Occupation

Table 4.1 shows the gender and the occupation distribution of the participants within each group as well as the total for all the groups. More women enrolled in the study (57.4%, *n*=27) with almost half of the participants being students (44,68%, *n*=21). Between groups comparison showed no difference for sex (*p* = 0.209) and occupation (*p*=0.442)

Table 4.1 Sex and occupation distribution

Characteristic		**Cervical manipulation**		**Thoracic manipulation**		**Cervical and thoracic manipulation**		**Control**		**Total**	
		n	%	n	%	n	%	n	%	n	%
Sex	Male	4	36.36	5	29.41	6	75	5	45.45	20	42.6
	Female	7	63.63	12	70.58	2	25	6	54.54	27	57.4
Occupation	Student	7	33.33	8	38.09	3	14.28	3	14.28	21	44.68
	Desk work	3	20.0	4	26.66	3	20	5	33.33	15	31.91
	Labourer	1	16.66	2	33.33	2	33.33	1	16.66	6	12.76
	Standing work	0	0.0	2	40	1	20	2	40	5	10.63

4.3.2 Age

Table 4.2 shows the mean age and range of the participants per group. Between group comparison showed no difference for age (*p* = 0.970).

Table 4.2 Age distribution

	Total	M	SD	Range
Cervical spine manipulation	11	28.81	7.99	19-45
Thoracic spine manipulation	17	29.82	9.59	20-49
Cervical and thoracic manipulation	8	30.75	9.88	20-45
Control	11	29.09	9.81	20-47
Total	47			

(M=Mean, SD=standard deviation)

4.4 SUBJECTIVE MEASURES: PAIN INTENSITY

The pain intensity data of all participants pre and post recording were analysed using a paired student t-test. It was utilised for within group analysis with ANOVA assessing between group differences. The baseline scores were not significant across the groups ($p<0.05$).

4.4.1 Pain Intensity

4.4.1.1 Pain Intensity Within Group Analysis

Within the group comparisons of the pre- and post-measures it was found that all groups had a significant decrease in their report pain levels as seen in Table 4.3.

Table 4.3 Pain rating scores

Group	Measurement	M	SD	MD	*p*-value
Control	Pre	5.18	0.982	2.91 (1.814)	<0.001
	Post	2.27	1.74		
Cervical spinal manipulation	Pre	5.09	1.38	2.366 (2.111)	0.004
	Post	2.73	2.41		
Cervical and thoracic spinal manipulation	Pre	4.63	1.19	2.88	0.002
	Post	1.75	1.49		
Thoracic spinal manipulation	Pre	4.74	1.42	2.21	<0.001
	Post	2.53	1.94		

(M=Mean, SD=standard deviation, MD=mean difference)

4.4.1.2 Pain Intensity Between Group Analysis

Comparisons in groups found that there was no significant difference ($F(3, 42) = 0.41$, $p = 0.750$) between the groups for pain.

4.5 OBJECTIVE MEASURES: SPINAL KINEMATICS (VELOCITY, DISPLACEMENT, AND JERK)

The objective measures were not normally distributed, which resulted in the data being analysed using non-parametric statistical tests. The objective measures in the study examined the different spinal kinematics, displacement, velocity, and jerk of movement during the tasks performed; these variables were measured in each of the groups as well as for CROM, neck flexion/extension, neck lateral flexion and neck rotation. Furthermore, two functional tasks, seated single arm task and bi lateral standing task were performed.

4.5.1 Cervical ROM

4.5.1.1 Flexion Extension

Intragroup:

No within group effects were observed for intragroup analysis in those receiving cervical manipulation and the combine treatment. Those receiving TSM had increased flexion away velocity peak ($t(16) = -2.122$, $p = 0.049$), jerk peak ($t(16) = -2.883$, $p = 0.011$), jerk average ($t(16) = -3.057$, $p = 0.008$) and extension away jerk average ($t(16) = -2.614$, $p = 0.019$). The control group had decreased extension time ($t(10) = 2.887$, $p = 0.016$) and increased extension away velocity average ($t(10) = 2.232$, $p = 0.049$), as seen in Table 4.4.

Table 4.4 Intragroup CROM flexion extension

FLEX/EXT	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
Flexion												
Time	0.08	0.22	0.23	0.18	0.46	0.21	0.07	0.28	0.29	0.15	0.33	0.24
Peak	0.28	9.59	0.92	-1.29	7.86	0.60	-3.34	9.46	0.17	0.13	5.85	0.95
Away vel peak	-10.53	33.46	0.32	-7.60	77.84	0.75	-17.00	33.03	**0.049**	-15.48	52.47	0.43
Return vel peak	11.72	35.64	0.30	10.48	43.27	0.44	7.24	28.50	0.31	8.36	43.39	0.60
Away vel ave	-3.18	16.79	0.55	-12.84	35.23	0.25	-5.13	14.46	0.16	-8.55	14.66	0.14
Return vel ave	0.01	23.93	0.99	5.10	26.49	0.54	5.89	19.33	0.23	4.67	24.04	0.60
Away jerk peak	131.72	2395.23	0.86	-352.87	3154.59	0.72	-1604.03	2293.64	**0.011**	-2274.54	5803.38	0.30
Return jerk peak	58.73	157.50	0.24	40.38	130.31	0.33	-4.55	78.90	0.82	-35.84	232.75	0.68
Away jerk ave	-189.50	1150.03	0.60	-408.71	1633.68	0.43	-520.18	701.52	**0.008**	-554.24	1658.08	0.38
Return jerk ave	-139.08	1130.47	0.69	-329.06	1729.30	0.54	-352.66	867.05	0.11	-828.07	3676.53	0.54
Extension												
Time	0.14	0.16	**0.016**	0.17	0.39	0.19	0.14	0.29	0.06	0.14	0.38	0.32
Peak	0.11	10.57	0.97	1.33	6.81	0.53	0.66	6.83	0.69	-0.12	5.94	0.96
Away vel peak	11.23	31.49	0.26	12.79	41.80	0.33	15.35	29.96	0.05	18.96	51.71	0.33
Return vel peak	-8.87	32.62	0.39	-14.72	68.89	0.50	-11.07	38.41	0.25	-15.12	62.32	0.52
Away vel ave	12.90	19.17	**0.049**	4.37	19.95	0.48	5.69	12.53	0.08	5.29	27.25	0.60
Return vel ave	5.30	31.65	0.59	-0.67	30.92	0.94	-3.61	18.96	0.44	-9.48	34.18	0.46
Away jerk peak	-57.63	149.11	0.23	32.37	79.84	0.21	9.22	35.55	0.30	23.79	80.54	0.43
Return jerk peak	-436.35	1694.82	0.41	-587.07	3105.01	0.55	-965.78	2299.07	0.10	-2545.48	10775.93	0.53
Away jerk ave	-153.34	1114.68	0.66	-273.01	1440.84	0.54	-448.21	706.84	**0.019**	-819.82	3476.69	0.53
Return jerk ave	312.64	1783.53	0.57	33.93	2186.88	0.96	-444.22	985.64	0.08	-987.38	4095.37	0.52

(M=mean, SD= standard deviation)

Intergroup:

No group effects were found between the four treatments, as seen in Table 4.5, during cervical ROM.

Table 4.5 Intergroup analysis of flexion-extension movement during CROM

	Post Scores													
	C-Spine			C+T-Spine			T-Spine			Control			ANCOVA	
FLEX/EXT	n	M	SD	n	M	SD	n	M	SD	n	M	SD	p-value	Partial Eta Squared
Flexion														
Time	11	1.46	0.45	8	1.28	0.35	17	1.37	0.63	11	1.21	0.21	0.71	0.03
Peak	11	42.92	9.71	8	44.07	7.36	17	37.74	8.96	11	40.49	8.18	0.05	0.17
Away vel peak	11	117.43	44.33	8	121.11	19.53	17	96.42	33.50	11	115.73	32.95	0.88	0.02
Return vel peak	11	-130.66	41.91	8	-123.00	15.23	17	-103.64	36.28	11	-125.88	32.04	0.78	0.03
Away vel ave	11	61.68	25.83	8	56.90	12.31	17	46.19	15.78	11	57.23	19,27	0.59	0.05
Return vel ave	11	-83.82	30.58	8	-84.06	13.87	17	-70.10	23.72	11	-80.27	20.70	0.65	0.04
Away jerk peak	11	7328.11	2.19	8	7890.85	4.51	17	5886.19	2.87	11	6954.69	5.68	0.97	0.01
Return jerk peak	11	110.90	100.61	8	100.51	55.81	17	55.00	40.46	11	79.76	49.60	0.10	0.14
Away jerk ave	11	2623.50	1.09	8	2516.49	1.35	17	1817.23	574.75	11	2310.96	1.47	0.89	0.02
Return jerk ave	11	3115.66	2.03	8	3164.89	1,99	17	2092.42	834.05	11	2287.07	982.79	0.35	0.08
Extension														
Time	11	1.55	0.49	8	1.21	0.40	17	1.57	0.56	11	1.32	0.38	0.29	0.09
Peak	11	-39.97	10.29	8	-32.36	8.52	17	-41.04	12.16	11	-41.58	13.64	0.24	0.10
Away vel peak	11	-111.23	34.46	8	-96.56	22.64	17	-92.98	30.95	11	-113.63	24.58	0.66	0.04
Return vel peak	11	110.21	37.42	8	105.33	16.88	17	99.28	30.51	11	113.31	28.82	0.99	0.00
Away vel ave	11	-61.35	23.35	8	-46.50	12.75	17	-49.90	19.82	11	-57.53	15.78	0.57	0.05
Return vel ave	11	57.28	17.55	8	65.65	16.58	17	57.44	22.12	11	63.58	23.14	0.81	0.02
Away jerk peak	11	67.45	95.60	8	54.25	64.85	17	30.25	32.27	11	42.98	79.95	0.62	0.04
Return jerk peak	11	7164.17	1.62	8	7081.37	3.08	17	6839.88	5.09	11	6720.60	3.35	0.89	0.02
Away jerk ave	11	2522.40	1.76	8	2153.04	1.33	17	1784.26	487.65	11	1941.11	976.53	0.91	0.01
Return jerk ave	11	2368.19	872.54	8	2867.51	1.31	17	2102.25	882.09	11	2257.66	916.69	0.60	0.05

(M= mean, SD= standard deviation)

4.5.1.2 Left and Right Lateral Flexion

Intragroup:

No within group effects were found for left and right lateral flexion during cervical ROM for except for the thoracic group where there was increased right lateral flexion return velocity peak (t(16) = 2.276, *p* = 0.049), right lateral flexion return velocity average (t(16) = 2.252, *p* = 0.039), right lateral flexion return jerk average (t(16) = -2.263, *p* = 0.038), and decreased left lateral flexion time (t(16) = 2.523, *p* = 0.023) and increased left lateral flexion return velocity average (t(16) = -2.735, *p* = 0.015), as seen in Table 4.6.

Table 4.6 Intragroup CROM lateral flexion

LAT/FLEX	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
Right lat flex												
Time	0.21	0.42	0.13	0.020	0.32	0.84	0.09	0.28	0.21	0.04	0.29	0.70
Peak	2.33	8.68	0.40	-2.85	5.05	0.09	-1.28	6.65	0.44	0.84	3.87	0.56
Away vel peak	-3.00	22.16	0.66	-11.33	35.59	0.32	-1.43	18.00	0.75	-4.75	19.25	0.51
Return vel peak	0.75	27.51	0.93	15.82	29.52	0.11	6.62	11.99	**0.037**	5.41	25.92	0.57
Away vel ave	-1.60	11.63	0.66	-2.41	13.38	0.56	-1.52	10.20	0.55	0.16	7.75	0.96
Return vel ave	2.78	15.95	0.58	12.62	24.27	0.12	6.10	11.16	**0.039**	2.44	11.72	0.58
Away jerk peak	568.26	1246.21	0.16	-771.63	3595.49	0.49	233.44	1023.76	0.36	-1075.22	3202.18	0.37
Return jerk peak	-3.27	26.88	0.70	-6.59	88.42	0.81	-25.25	68.12	0.15	-13.43	48.06	0.46
Away jerk ave	188.19	622.43	0.34	-618.06	1656.49	0.24	31.17	404.79	0.76	-275.20	1027.32	0.47
Return jerk ave	-127.46	645.45	0.53	-290.72	1050.74	0.38	-314.30	572.66	**0.038**	-777.38	1970.10	0.30
Left lat flex												
Time	0.08	0.21	0.22	0.09	0.21	0.19	0.19	0.32	**0.023**	0.03	0.29	0.77
Peak	1.67	7.70	0.49	2.28	4.85	0.15	0.21	5.60	0.88	-0.15	4.23	0.93
Away vel peak	-3.12	20.89	0.63	6.55	32.93	0.52	3.45	14.52	0.34	1.76	23.77	0.84
Return vel peak	-1.28	21.32	0.85	-11.64	35.17	0.30	-7.97	16.28	0.06	-0.32	17.19	0.96
Away vel ave	-0.03	10.89	0.99	2.86	14.56	0.53	0.72	6.46	0.65	-2.36	6.56	0.34
Return vel ave	-8.16	14.81	0.10	-12.01	22.11	0.10	-6.73	10.14	**0.015**	3.84	12.48	0.41
Away jerk peak	11.69	30.81	0.24	1.32	81.56	0.96	4.64	17.39	0.29	-6.41	16.87	0.32
Return jerk peak	-250.66	1435.35	0.58	137.08	2233.13	0.84	-315.49	1054.46	0.24	-381.52	3643.77	0.78
Away jerk ave	313.68	831.59	0.24	1.39	1707.28	0.99	-32.80	534.21	0.80	-303.98	1111.59	0.47
Return jerk ave	-330.96	820.42	0.21	-152.76	948.80	0.61	-316.63	657.56	0.07	-12.62	1550.50	0.98

(Mea*n*= mean, SD= standard deviation)

Intergroup:

No between group differences were found for left and right lateral flexion during cervical ROM for left and right lateral flexion, as seen in Table 4.7.

Table 4.7 Intergroup CROM lateral flexion

	Post Scores													
	C-Spine			C+T-Spine			T-Spine			Control			ANCOVA	
LAT/FLEX	n	M	SD	n	M	SD	n	M	SD	n	M	SD	*p*-value	Partial Eta Squared
Right lat flex														
Time	11	1.27	0.39	8	1.25	0.32	17	1.25	0.44	11	1.04	0.16	0.29	0.09
Peak	11	38.89	9.38	8	37.79	10.96	17	38.06	8.36	11	38.14	4.91	0.46	0.06
Away vel peak	11	119.53	63.07	8	102.11	23.03	17	87.41	32.14	11	96.83	24.79	0.71	0.03
Return vel peak	11	-116.10	51.36	8	-98.24	22.19	17	-88.94	22.19	11	-91.64	21.58	0.47	0.06
Away vel ave	11	51.55	8.59	8	51.55	10.34	17	47.63	15.18	11	55.55	9.74	0.70	0.03
Return vel ave	11	-73.39	24.02	8	-67.94	12.59	17	-61.52	21.80	11	-62.44	15.82	0.44	0.07
Away jerk peak	11	7134.33	5.27	8	4809.09	3.30	17	4249.82	1.19	11	3867.99	1.83	0.34	0.08
Return jerk peak	11	79.03	92.05	8	67.00	66.16	17	59.93	66.81	11	35.95	27.35	0.85	0.02
Away jerk ave	11	3101.09	2.96	8	1688.72	1.02	17	1576.98	541.36	11	1567.71	763.44	0.37	0.08
Return jerk ave	11	2558.76	1.59	8	2503.33	1.97	17	1853.71	716.63	11	1803.90	725.72	0.66	0.04
Left lat flex														
Time	11	1.32	0.37	8	1.29	0.32	17	1.22	0.41	11	1.17	0.26	0.30	0.09
Peak	11	-42.33	3.59	8	-39.42	6.39	17	-38.27	9.58	11	-40.49	5.90	0.55	0.05
Away vel peak	11	-109.21	51.18	8	-91.01	19.70	17	-77.35	28.92	11	-84.93	18.52	0.71	0.03
Return vel peak	11	125.71	60.66	8	107.50	24.49	17	95.55	33.42	11	97.87	26.82	0.70	0.04
Away vel ave	11	-56.75	29.01	8	-43.04	5.44	17	-40.20	13.72	11	-45.84	17.41	0.71	0.03
Return vel ave	11	77.66	27.57	8	73.98	16.72	17	65.14	22.55	11	70.90	18.44	0.27	0.09
Away jerk peak	11	77.21	140.52	8	26.46	17.72	17	13.55	9.26	11	26.44	33.75	0.66	0.04
Return jerk peak	11	6210.63	3.21	8	5787.93	4.09	17	4787.71	1.36	11	4476.03	1.62	0.99	0.00
Away jerk ave	11	2772.16	2.49	8	1920.55	1.06	17	1635.65	649.09	11	1644.62	649.09	0.69	0.04
Return jerk ave	11	2576.80	1.54	8	2391.57	1.66	17	1963.71	756.19	11	1993.50	1.13	0.89	0.02

(M= mean, SD= standard deviation)

4.5.1.3 Left and Right Rotation

Intragroup:

No intragroup effects were found for left and right rotation during CROM except for, the thoracic group where there was increased right rotation away velocity peak (t(16) = -2.122, p = 0.049), right rotation away jerk peak (t(16) = -2.883, p = 0.011) and right rotation away jerk average (t(16) = -3.057, p = 0,008), within the control group having decreased left rotation time (t(10) = 2.887, p = 0.016), and increased left rotation away velocity average (t(10) = 2.232, p = 0.049) and left rotation away jerk average (t(10) = -2.614, p = 0.019), as seen in Table 4.8.

Table 4.8 Intragroup CROM rotation

ROT	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
Right rot												
Time	0.085	0.22	0.23	0.18	0.46	0.21	0.07	0.28	0.29	0.15	0.33	0.24
Peak	0.28	9.59	0.92	-1.29	7.86	0.60	-3.34	9.46	0.17	0.13	5.85	0.95
Away vel peak	-10.53	33.46	0.32	-7.60	77.84	0.75	-17.00	33.03	**0.049**	-15.48	52.47	0.43
Return vel peak	11.72	35.64	0.30	10.48	43.27	0.44	7.24	28.50	0.31	8.36	43.39	0.60
Away vel ave	-3.18	16.79	0.55	-12.84	35.23	0.25	-5.13	14.46	0.16	-8.55	14.66	0.14
Return vel ave	0.01	23.93	0.99	5.10	26.49	0.54	5.89	19.33	0.23	4.67	24.04	0.60
Away jerk peak	131.72	2395.30	0.86	-352.87	3154.59	0.72	-1604.03	2293.64	**0.011**	-2274.54	5803.38	0.30
Return jerk peak	58.74	157.50	0.24	40.38	130.31	0.33	-4.55	78.90	0.82	-35.84	232.75	0.68
Away jerk ave	-189.50	1150.03	0.60	-408.71	1633.68	0.43	-520.18	701.52	**0.008**	-554.24	1658.08	0.38
Return jerk ave	-139.08	1130.47	0.69	-329.06	1729.30	0.54	-352.66	867.05	0.11	-828.07	3676.53	0.54
Left rot												
Time	0.14	.16	**0.016**	0.17	0.39	0.19	0.14	0.293	0.06	0.14	0.38	0.32
Peak	0.11	10.57	0.97	1.33	6.81	0.53	0.66	6.83	0.69	-0.12	5.94	0.96
Away vel peak	11.23	31.49	0.26	12.79	41.80	0.33	15.35	29.96	0.05	18.96	51.71	0.33
Return vel peak	-8.87	32.62	0.39	-14.72	68.89	0.50	-11.07	38.41	0.25	-15.12	62.32	0.52
Away vel ave	12.90	19.17	**0.049**	4.37	19.95	0.48	5.69	12.53	0.08	5.29	27.25	0.60
Return vel ave	5.30	31.65	0.59	-0.67	30.92	0.94	-3.60	18.96	0.44	-9.48	34.18	0.46
Away jerk peak	-57.63	149.11	0.23	32.37	79.84	0.21	9.22	35.55	0.30	23.79	80.54	0.43
Return jerk peak	-436.35	1694.82	0.41	-587.07	3105.01	0.55	-965.78	2299.07	0.10	-2545.48	10775.93	0.53
Away jerk ave	-153.34	1114.68	0.66	-273.01	1440.84	0.54	-448.21	706.84	**0.019**	-819.82	3476.69	0.53
Return jerk ave	312.64	1783.53	0.57	33.92	2186.88	0.96	-444.22	985.64	0.08	-987.38	4095.37	0.52

(M= mean, SD= standard deviation)

Intergroup:
No between group effects were found for left and right rotation of cervical ROM, as seen in Table 4.9.

Table 4.9 Intergroup CROM rotation

	Post Scores													
	C-Spine			C+T-Spine			T-Spine			Control			ANCOVA	
ROT	n	M	SD	n	M	SD	n	M	SD	n	M	SD	Sig.	Partial Eta Squared
Right rot														
Time	11	1.40	0.37	8	1.29	0.13	17	1.51	0.51	11	1.28	0.21	0.54	0.05
Peak	11	63.95	9.23	8	62.28	11.48	17	66.79	9.29	11	62.78	7.82	0.51	0.06
Away vel peak	11	221.64	92.63	8	232.95	46.92	17	186.79	63.56	11	206.51	59.31	0.95	0.01
Return vel peak	11	-211.82	73.69	8	-219.83	38.81	17	-172.41	56.89	11	-195.99	60.51	0.68	0.04
Away vel ave	11	118.43	56.79	8	100.14	16.18	17	87.01	25.82	11	97.54	26.56	0.58	0.05
Return vel ave	11	-120.20	29.81	8	-128.71	25.47	17	-111.65	35.39	11	-117.81	30.47	0.83	0.02
Away jerk peak	11	9641.63	7.06	8	9185.53	5.40	17	7111.46	2.50	11	6591.53	3.56	0.46	0.06
Return jerk peak	11	124.09	103.87	8	192.54	182.61	17	98.27	101.71	11	103.87	120.74	0.31	0.09
Away jerk ave	11	4492.50	4.35	8	3218.91	1.68	17	2511.91	871.94	11	2878.13	2.37	0.89	0.02
Return jerk ave	11	4957.59	2.04	8	5299.70	3.19	17	3581.98	1.85	11	3746.53	2.14	0.52	0.06
Left rot														
Time	11	1.43	0.38	8	1.42	0.27	17	1.52	0.50	11	1.29	0.22	0.80	0.02
Peak	11	-65.84	8.22	8	-66.13	4.53	17	-64.81	8.76	11	-66.45	7.94	0.98	0.00
Away vel peak	11	-208.49	77.56	8	-210.49	45.55	17	-166.62	55.03	11	-194.65	62.31	0.87	0.02
Return vel peak	11	237.13	81.13	8	247.01	54.10	17	194.87	58.58	11	218.26	57.99	0.67	0.04
Away vel ave	11	-98.05	42.37	8	-92.71	20.50	17	-78.85	22.40	11	-97.58	34.03	0.64	0.04
Return vel ave	11	136.63	47.66	8	155.00	28.36	17	119.21	33.47	11	130.36	25.59	0.42	0.07
Away jerk peak	11	71.27	106.78	8	41.26	38.99	17	35.12	28.87	11	57.95	91.04	0.14	0.13
Return jerk peak	11	1.14	3.48	8	1.29	9.38	17	8817.83	2.23	11	8416.87	3.11	0.28	0.09
Away jerk ave	11	4497.55	4.31	8	3804.71	2.93	17	2501.31	1.33	11	3272.11	2.83	0.93	0.01
Return jerk ave	11	5477.53	2.59	8	6333.71	3.41	17	4013.36	1.89	11	3831.30	1.65	0.26	0.10

(M= mean, SD= standard deviation)

4.5.2 Unilateral Arm Task

4.5.2.1 Cervical Spinal Kinematics

Intragroup:

For the cervical spinal kinematics during the unilateral arm task, no effects were observed for within group assessment except for the thoracic group where an increase in flexion extension velocity average (t(16) = -2.263, *p* = 0.038) was found and within the control group an increase in flexion extension jerk average (t(10) = -3.291, *p* = 0.008) was seen, as shown in Table 4.10.

Table 4.10 Intragroup unilateral arm task CROM

	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	p-value	M	SD	p-value	M	SD	p-value	M	SD	*p*-value
NFE top value	2.73	8.20	0.23	-3.09	9.52	0.31	1.64	8.16	0.42	-4.21	5.18	0.06
NFE excursion range	-0.29	3.47	0.79	1.80	6.40	0.37	-1.29	5.37	0.34	0.13	4.99	0.94
NFE vel ave	-1.60	2.58	0.07	-0.56	3.20	0.58	-1.42	2.58	**0.038**	-1.16	3.49	0.38
NFE jerk ave	-196.48	197.99	**0.008**	-277.76	479.23	0.08	-203.59	496.60	0.11	-236.99	513.76	0.23
NLF top value	0.92	8.35	0.72	-1.71	4.20	0.21	1.32	6.63	0.42	-1.22	4.24	0.44
NLF excursion range	-0.16	2.24	0.82	0.55	2.87	0.54	-0.04	2.85	0.95	0.56	2.75	0.58
NLF velave	-0.93	1.62	0.08	-0.44	1.95	0.47	-.45	1.48	0.23	-0.41	2.12	0.60
NLF jerk ave	-55.65	112.10	0.13	-89.12	270.78	0.30	-87.00	210.16	0.11	-48.31	172.72	0.46
NROT top value	-0.09	13.49	0.98	0.16	7.06	0.94	-1.51	9.49	0.52	0.53	6.30	0.82
NROT excursion range	1.52	2.96	0.12	0.65	2.47	0.40	0.35	3.58	0.69	0.42	2.80	0.68
NROT vel ave	0.19	2.38	0.80	0.19	1.95	0.75	-0.30	2.00	0.55	-0.32	2.23	0.69
NROT jerk ave	-62.73	191.02	0.30	12.75	200.80	0.84	-81.22	260.14	0.22	-39.94	306.04	0.72

(M= mean, SD= standard deviation, NFE= neck flexion extension, NLF= neck lateral flexion, NROT= neck rotation)

Intergroup:

For the cervical kinematics during the unilateral arm task, there were no effects observed between the groups, as seen in Table 4.11.

Table 4.11 Intergroup unilateral arm task CROM

	Post Scores												ANCOVA	
	C-Spine			C+T-Spine			T-Spine			Control				
FLEX/EXT	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	***p*-value**	**Partial Eta Squared**
Top value	11	18.65	10.67	8	11.70	7.87	17	11.21	9.27	11	15.14	8.10	0.27	0.09
Range	11	32.14	13.10	8	27.02	6.18	17	31.99	13.01	11	30.71	12.54	0.55	0.05
Velocity	11	17.74	7.49	8	15.67	6.38	17	17.97	8.47	11	16.60	6.73	0.89	0.02
Jerk	11	1696.96	434.58	8	1726.84	586.19	17	1713.99	553.92	11	1367.10	470.21	0.66	0.04
LAT FLEX														
Top value	11	6.11	5.99	8	2.10	6.96	17	1.70	8.38	11	2.59	7.03	0.47	0.06
Range	11	16.12	5.20	8	13.89	3.17	17	17.21	5.91	11	16.68	5.94	0.86	0.02
Velocity	11	9.27	3.10	8	8.34	2.76	17	10.31	4.74	11	9.62	3.94	0.89	0.02
Jerk	11	1063.28	316.46	8	999.99	325.28	17	1180.90	388.93	11	843.67	297.27	0.73	0.03
ROT														
Top value	11	20.73	12.16	8	30.22	6.70	17	24.96	12.44	11	18.54	11.37	0.71	0.03
Range	11	8.98	1.73	8	9.85	3.74	17	11.99	4.23	11	8.81	3.31	0.13	0.13
Velocity	11	6.41	2.03	8	7.45	2.44	17	8.66	4.01	11	6.86	3.27	0.34	0.08
Jerk	11	910.98	272.06	8	946.56	311.57	17	1154.65	469.75	11	808.50	231.86	0.48	0.06

(M= mean, SD= standard deviation)

4.5.2.2 Upper Thoracic Spinal Kinematics

Intragroup:

For upper thoracic spinal kinematics during the unilateral arm task, there were no effects observed for the within group comparisons except for the combination group where there was increased flexion extension excursion range (t(7) = -2.434, *p* = 0.045), within the cervical group there was decreased flexion extension jerk average (t(10) = 2.367, *p* = 0.039), lateral flexion top value (t(10) = -2.707, *p* = 0.022) and increased rotation velocity average (t(10) = -2.223, *p* = 0.049), within the thoracic group there was increased lateral flexion velocity average (t(16) = -2.766, *p* = 0.014) and rotation top value (t(16) = 2.886, *p* = 0.011), as seen in Table 4.12.

Table 4.12 Intragroup unilateral arm task upper thoracic

	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	**SD**	***p*-value**	**M**	**SD**	***p*-value**	**M**	**SD**	***p*-value**	**M**	**SD**	***p*-value**
UTFE top value	0.10	1.82	0.86	-0.32	1.53	0.50	0.29	1.83	0.52	-0.14	2.11	0.86
UTFE excursion range	0.02	0.95	0.96	-0.06	1.06	0.85	0.13	0.92	0.57	-0.81	1.35	0.13
UTFE vel ave	-0.16	0.80	0.53	0.18	0.55	0.30	-0.106	1.05	0.69	-1.17	1.36	**0.045**
UTFE jerk ave	-55.48	440.56	0.69	141.61	198.40	**0.039**	-104.05	488.52	0.39	-638.42	817.55	0.06
UTLF top value	0.14	2.62	0.86	-1.42	1.74	**0.022**	0.30	1.63	0.46	-0.17	0.68	0.49
UTLF excursion range	0.65	1.37	0.15	0.66	1.27	0.12	0.02	1.37	0.95	-0.56	1.14	0.20
UTLF vel ave	-0.20	1.21	0.60	0.12	0.85	0.66	-0.51	0.76	**0.014**	-0.56	0.79	0.09
UTLF jerk ave	-71.97	122.30	0.08	31.78	99.81	0.32	-77.99	269.53	0.25	-0.50	330.92	0.99
UTROT top value	0 .63	1.70	0.25	-0.80	2.63	0.34	1.04	1.49	**0.011**	0.23	1.22	0.62
UTROT excursion range	-0.15	1.23	0.70	-1.51	2.75	0.10	-22.53	94.10	0.34	0.58	1.34	0.26
UTROT vel ave	-0.76	1.75	0.18	-0.99	1.48	**0.049**	-16.33	65.66	0.32	-0.12	1.17	0.78
UTROT jerk ave	-224.14	506.48	0.17	-78.53	497.14	0.61	-6539.34	26230.35	0.32	-21.14	369.82	0.88

(M= mean, SD= standard deviation, UTFE= upper thoracic flexion extension, UTLF= upper thoracic lateral flexion, UTROT= upper thoracic rotation)

Intergroup:

For the upper thoracic spinal kinematics during the unilateral arm task, there were no effects observed between the groups, as seen in Table 4.13.

Table 4.13 Intergroup unilateral arm task upper thoracic

	Post Scores												ANCOVA	
	C-Spine			C+T-Spine			T-Spine			Control				
FLEX/EXT	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	***p*-value**	**Partial Eta Squared**
Top value	11	-1.57	2.79	8	-1.53	1.50	17	-1.88	3.28	11	-2.14	2.73	0.63	0.04
Range	11	3.50	1.12	8	4.42	2.02	17	4.06	1.83	11	3.36	1.44	0.30	0.09
Velocity	11	3.12	0.87	8	4.67	3.86	17	4.09	2.07	11	3.27	2.01	0.07	0.16
Jerk	11	1389.84	755.94	8	1977.09	1.76	17	1797.47	1.04	11	1243.36	1.03	0.50	0.06
LAT FLEX														
Top value	11	-8.04	3.06	8	-7.19	3.47	17	-7.90	4.93	11	-7.54	3.75	0.56	0.05
Range	11	9.85	2.46	8	10.17	4.05	17	9.34	3.98	11	8.53	3.53	0.46	0.06
Velocity	11	6.19	1.78	8	6.17	1.77	17	5.83	2.58	11	5.10	2.79	0.98	0.01
Jerk	11	835.05	216.11	8	729.27	210.80	17	834.89	367.24	11	662.04	286.59	0.96	0.01
ROT														
Top value	11	11.60	4.35	8	6.31	4.59	17	-2.23	43.75	11	7.28	2.05	0.80	0.03
Range	11	13.26	4.54	8	10.65	1.58	17	33.92	93.65	11	10.33	2.33	0.66	0.04
Velocity	11	9.62	2.48	8	8.49	1.76	17	24.44	65.26	11	14.47	39.29	0.70	0.03
Jerk	11	1704.65	1.01	8	1359.29	830.43	17	8054.50	2.60	11	1275.41	462.58	0.69	0.04

(M= mean, SD= standard deviation)

4.5.2.3 Lower Thoracic Spinal Kinematics

Intragroup:

For the lower thoracic spinal kinematics during the unilateral arm task, there were no effects observed within the group except for the cervical group where there was decreased flexion extension top value (t(10) = -2.377, *p* = 0.039), within the thoracic group there was increased flexion extension velocity average (t(16) = -2.127, *p* = 0.049), lateral flexion velocity average i (t(16) = -3.201, *p* = 0.006) and lateral flexion jerk average (t(16) = -2.718, *p* = 0.015), as seen in Table 4.14.

Table 4.14 Intragroup unilateral arm task lower thoracic

	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
LTFE top value	0.30	1.90	0.62	-0.84	1.18	**0.039**	0.47	2.16	0.38	-0.38	1.29	0.43
LTFE excursion range	0.26	0.88	0.35	0.08	1.08	0.81	-0.25	1.21	0.42	-0.64	0.89	0.08
LTFE vel ave	-0.18	0.59	0.34	-0.20	0.34	0.08	-0.44	0.86	**0.049**	-0.41	0.70	0.14
LTFE jerk ave	-97.21	320.4 9	0.34	-69.91	207.65	0.29	-91.32	460.50	0.43	-31.15	195.98	0.67
LTLF top value	-0.25	0.98	0.42	-1.13	3.05	0.25	0.32	3.05	0.67	1.17	1.86	0.12
LTLF excursion range	0.45	0.95	0.15	-0.12	1.14	0.75	-0.21	1.02	0.41	-0.30	1.54	0.60
LTLF vel ave	-0.11	0.99	0.73	-0.12	0.84	0.65	-0.66	0.85	**0.006**	-0.76	1.24	0.13
LTLF jerk ave	4.33	166.6 1	0.93	10.48	404.62	0.93	-212.26	322.02	**0.015**	-232.27	338.58	0.09
LTROT top value	0.56	1.66	0.29	-1.10	2.23	0.13	-17.33	69.47	0.32	-1.73	2.91	0.14
LTROT excursion range	0.37	0.75	0.13	-0.65	2.03	0.31	-12.35	49.51	0.32	0.38	0.91	0.28
LTROT vel ave	-0.16	1.59	0.74	-0.02	1.34	0.96	-39.91	162.72	0.33	-00.48	1.75	0.47
LTROT jerk ave	-275.21	1186. 07	0.46	65.60	829.17	0.80	-17911.22	72878.9 6	0.33	-68.03	695.44	0.79

(M= mean, SD= standard deviation, LTFE= lower thoracic flexion extension, LTLF= lower thoracic lateral flexion, LTROT= lower thoracic rotation)

Intergroup:

For the lower thoracic spinal kinematics during the unilateral arm task, there were no effects observed between the group except for lower thoracic flexion extension jerk across the 4 treatment groups, after adjusting for the pre scores, (F(3, 40) = 2.892, *p* = 0.047). Post hoc analysis with a Bonferroni adjustment shows that the score for cervical and thoracic combination manipulation (adjusted mean = 1977.09) was significantly greater than for cervical manipulation alone (adjusted mean = 1389.84) (*p* = 0.033).

Table 4.15 Intergroup unilateral arm task lower thoracic

	Post Scores													
	C-Spine			C+T-Spine			T-Spine			Control			ANCOVA	
FLEX/EXT	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	***p*-value**	**Partial Eta Squared**
Top value	11	-9.63	3.05	8	-6.91	2.57	17	-8.64	3.53	11	-7.75	3.34	0.89	0.02
Range	11	5.59	1.62	8	5.58	2.09	17	5.30	1.50	11	3.69	0.93	0.45	0.06
Velocity	11	3.88	0.95	8	3.63	0.67	17	3.83	1.36	11	2.99	0.90	0.15	0.12
Jerk	11	1182.19	490.22	8	897.02	519.78	17	1215.46	626.06	11	947.82	402.16	**0.047**	0.18
LAT FLEX														
Top value	11	-3.99	4.19	8	-6.53	5.77	17	-5.12	5.18	11	-5.06	4.96	0.18	0.11
Range	11	6.52	2.70	8	7.26	4.36	17	6.72	2.16	11	6.44	3.06	0.15	0.12
Velocity	11	4.44	1.33	8	5.01	2.43	17	4.61	1.33	11	3.96	2.11	0.29	0.09
Jerk	11	1208.08	631.11	8	1016.29	337.84	17	1218.53	412.24	11	868.78	313.27	0.89	0.02
ROT														
Top value	11	1.59	5.23	8	2.34	3.99	17	8.16	26.52	11	0.14	3.60	0.07	0.16
Range	11	7.02	3.52	8	5.07	2.71	17	29.25	97.05	11	4.07	1.04	0.53	0.05
Velocity	11	6.32	2.29	8	5.37	2.30	17	50.91	183.05	11	4.89	1.62	0.56	0.05
Jerk	11	2701.28	1.65	8	1859.11	1.23	17	2.29	8.19	11	2201.46	1.21	0.39	0.07

(M= mean, SD= standard deviation)

4.5.3 Bilateral Arm Task

4.5.3.1 Cervical Spinal Kinematics

Intragroup:

For the cervical spinal kinematics during the bilateral arm task, there were no effects observed within the group except within the control group there was increased flexion extension jerk average ($t(10) = -2.888$, $p = 0.016$), within the cervical group there was decreased lateral flexion top value ($t(10) = -2.634$, $p = 0.025$) and increased rotation velocity average ($t(10) = -2.617$, $p = 0.026$), as seen in Table 4.16.

Table 4.16 Intragroup bilateral arm task CROM

	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
NFE top value	0.97	7.63	0.68	-2.95	8.33	0.27	-2.87	10.08	0.26	-0.68	8.32	0.82
NFE excursion range	-2.24	6.15	0.25	1.24	3.91	0.32	-4.12	12.02	0.18	2.04	5.65	0.34
NFE vel ave	-5.58	7.55	0.03	-0.11	5.40	0.95	-8.02	11.28	0.01	-1.65	5.81	0.45
NFE jerk ave	-444.61	510.62	0.016	-499.45	1282.88	0.23	-1975.25	3983.79	0.06	-552.37	1541.38	0.35
NLF top value	2.76	7.49	0.25	-0.96	1.21	0.025	0.78	3.79	0.41	1.34	3.85	0.36
NLF excursion range	-0.49	1.46	0.29	0.43	1.67	0.42	-0.62	3.11	0.43	-0.17	2.42	0.84
NLF velave	-.81	1.48	0.10	-0.35	1.25	0.38	-0.56	3.37	0.50	-0.60	2.36	0.50
NLF jerk ave	-519.84	1068.80	0.14	-117.37	465.00	0.42	-5.65	1954.45	0.99	-193.91	978.77	0.59
NROT top value	-0.65	8.87	0.81	-0.39	5.96	0.83	-0.42	8.22	0.84	0.86	6.12	0.70
NROT excursion range	-2.60	8.38	0.33	-0.67	1.91	0.27	1.56	6.99	0.37	4.67	19.02	0.51
NROT vel ave	-2.52	8.65	0.36	-1.01	1.28	0.026	0.54	7.12	0.76	3.67	16.86	0.56
NROT jerk ave	-1708.71	5467.33	0.32	-125.82	368.56	0.28	521.95	3746.19	0.57	2174.09	8360.14	0.49

(SD= standard deviation, NFE= neck flexion extension, NLF= neck lateral flexion, NROT= neck rotation)

Intergroup:

For the cervical spinal kinematics during bilateral arm task, there were no effects observed between the groups, as seen in Table 4.17.

Table 4.17 Intergroup bilateral arm task CROM

	Post Scores													
	C-Spine			C+T-Spine			T-Spine			Control			ANCOVA	
FLEX/EXT	n	M	SD	n	M	SD	n	M	SD	n	M	SD	*p*-value	Partial Eta Squared
Top value	11	33.52	17.60	8	23.61	14.71	17	35.07	17.35	11	33.39	20.24	0.15	0.12
Range	11	36.57	17.93	8	24.25	7.99	17	43.89	20.36	11	41.76	19.40	0.79	0.03
Velocity	11	30.14	23.16	8	22.61	8.86	17	34.32	20.37	11	33.89	15.77	0.42	0.07
Jerk	11	3014.75	1.94	8	2975.49	1.17	17	4745.86	4.99	11	2636.61	1.18	0.45	0.06
LAT FLEX														
Top value	11	-1.03	3.93	8	-0.84	2.49	17	-0.25	3.59	11	-1.10	2.25	0.26	0.10
Range	11	4.81	2.12	8	5.56	1.91	17	6.57	3.54	11	4.40	1.76	0.39	0.07
Velocity	11	5.16	1.93	8	5.58	1.58	17	6.41	4.17	11	4.85	1.67	0.81	0.02
Jerk	11	1552.67	592.01	8	1682.29	603.89	17	2102.63	2.04	11	1606.25	890.95	0.45	0.06
ROT														
Top value	11	0.86	4.33	8	1.02	6.11	17	2.52	7.38	11	-1.00	4.43	0.63	0.04
Range	11	5.64	1.88	8	7.10	3.40	17	7.56	4.87	11	6.99	7.76	0.55	0.05
Velocity	11	5.75	1.84	8	6.91	2.82	17	7.13	4.41	11	6.84	8.05	0.44	0.06
Jerk	11	1500.49	454.52	8	1889.78	935.46	17	2217.42	1.71	11	2767.31	5.28	0.52	0.05

(M= mean, SD= standard deviation)

4.5.3.2 Upper Thoracic Spinal Kinematics

Intragroup:

For the upper thoracic spinal kinematics during the bilateral arm task, there were no effects observed within the groups except within the thoracic group where there was increased flexion extension top value ($t(16) = 2.407$, $p = 0.029$), as seen in Table 4.18.

Table 4. 18 Intragroup bilateral arm task upper thoracic

	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
UTFE top value	0.78	3.29	0.45	-0.67	1.24	0.10	1.29	2.21	0.029	-0.51	2.79	0.62
UTFE excursion range	0.22	1.31	0.60	0.46	0.82	0.09	-0.07	2.61	0.92	0.67	2.732	0.51
UTFE vel ave	-0.06	1.9	0.85	0.40	1.27	0.32	-0.70	2.73	0.30	0.10	1.61	0.86
UTFE jerk ave	-76.37	429.91	0.57	162.84	737.45	0.48	-224.17	1167.16	0.44	322.58	868.58	0.33
UTLF top value	-0.10	1.94	0.86	0.65	1.76	0.25	-1.17	2.92	0.12	-0.45	0.66	0.10
UTLF excursion range	-0.46	1.33	0.28	0.04	1.28	0.93	-0.12	4.64	0.91	-0.36	1.37	0.48
UTLF vel ave	-0.50	1.02	0.14	-0.39	0.81	0.14	-1.04	3.50	0.24	-0.56	1.66	0.37
UTLF jerk ave	-98.27	211.07	0.15	-176.47	300.37	0.08	-260.33	2053.02	0.61	21.40	490.08	0.91
UTROT top value	11.24	58.42	0.54	-16.10	54.31	0.35	18.14	53.40	0.18	-21.38	63.96	0.38
UTROT excursion range	-12.11	148.78	0.79	-1.12	2.61	0.19	3.07	16.58	0.46	-25.66	69.67	0.33
UTROT vel ave	-31.39	191.21	0.60	-1.36	2.91	0.15	1.23	11.51	0.67	-20.45	54.69	0.33
UTROT jerk ave	-14252.65	85715.79	0.59	-963.45	2770.59	0.28	1077.45	7451.53	0.56	-13973.85	39329.71	0.35

(M= mean, SD= standard deviation, UTFE= upper thoracic flexion extension, UTLF= upper thoracic lateral flexion, UTROT= upper thoracic rotation)

Intergroup:

For upper thoracic spinal kinematics during the bilateral arm task, there were no effects observed between the group except for upper thoracic flexion extension range across the 4 treatment groups, after adjusting for the baseline scores, ($F(3, 40) = 3.127$, $p = 0.036$), as seen in Table 4.19. Post hoc analysis with a Bonferroni adjustment shows that the score for cervical and thoracic combination manipulation (adjusted mean = 5.58) was significantly greater than the control (adjusted mean = 3.69) (p=0.036).

Table 4.19 Intergroup bilateral arm task upper thoracic

	Post Scores													
	C-Spine			C+T-Spine			T-Spine			Control			ANCOVA	
FLEX/EXT	n	M	SD	n	M	SD	n	M	SD	n	M	SD	*p*-value	Partial Eta Squared
Top value	11	-1.84	3.07	8	-3.01	2.47	17	-3.78	2.72	11	-2.48	2.71	0.36	0.08
Range	11	5.64	2.07	8	6.74	3.57	17	6.63	4.12	11	4.85	2.36	**0.036**	0.19
Velocity	11	5.41	1.86	8	5.96	2.21	17	5.77	2.76	11	4.07	1.70	0.42	0.07
Jerk	11	1573.89	1.20	8	1113.77	418.08	17	1573.12	1.18	11	743.82	370.63	0.99	0.00
LAT FLEX														
Top value	11	-0.28	1.73	8	-0.19	2.54	17	1.45	3.68	11	0.94	3.01	0.26	0.10
Range	11	2.57	1.03	8	3.87	1.89	17	4.55	2.62	11	3.77	2.30	0.20	0.11
Velocity	11	3.12	1.33	8	4.01	1.85	17	4.65	3.31	11	3.94	2.41	0.19	0.11
Jerk	11	1118.16	491.18	8	979.60	289.19	17	1637.52	1.59	11	821.73	352.40	0.14	0.13
ROT														
Top value	11	17.06	54.20	8	21.33	64.26	17	0.72	4.04	11	9.14	37.66	0.75	0.03
Range	11	5.25	3.55	8	30.84	68.90	17	5.78	2.23	11	39.36	229.26	0.68	0.04
Velocity	11	5.66	3.54	8	25.23	54.30	17	6.22	3.51	11	55.61	172.46	0.38	0.07
Jerk	11	2234.69	3.13	8	1.53	3.95	17	2327.46	1.96	11	2.43	7.73	0.32	0.08

(M= mean, SD= standard deviation)

4.5.3.3 Lower Thoracic Spinal Kinematics

Intragroup:

For the lower thoracic spinal kinematics during the bilateral arm task, there were no effects observed within the group except for the combination group where flexion extension velocity average increased (t(7) = -2.692, p = 0.031), within the cervical group where flexion extension jerk average increased (t(10) = -2.783, p = 0.019), lateral flexion velocity average increased (t(10) = -2.617, p = 0.026), lateral flexion jerk average increased (t(10) = -4.404, p = 0.001), rotation top value decreased (t(10) = -2.233, p = 0.049) and rotation jerk average increased (t(10) = -2.339, p = 0.041), as seen in Table 4.20.

Table 4.20 Intragroup bilateral arm task lower thoracic

	Control (n=11)			C-Spine (n=11)			T-Spine (n=17)			C+T-Spine (n=8)		
	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value	M	SD	*p*-value
LTFE top value	0.98	3.58	0.38	2.84	13.87	0.51	2.34	7.80	0.23	-2.15	3.71	0.15
LTFE excursion range	0.25	0.81	0.34	0.47	1.17	0.21	0.29	4.45	0.79	-1.19	1.58	0.07
LTFE vel ave	-0.18	0.79	0.48	0.12	1.01	0.70	-0.42	2.34	0.47	-1.78	1.87	**0.031**
LTFE jerk ave	-65.18	209.75	0.33	-199.89	238.19	**0.019**	339.75	1526.88	0.37	-228.75	305.94	0.07
LTLF top value	0.04	2.13	0.95	-0.58	2.05	00.37	0.27	2.24	0.63	0.32	0.75	0.26
LTLF excursion range	-0.06	1.27	0.88	-0.26	0.51	0.13	0.29	1.46	0.42	0.11	0.84	0.72
LTLF vel ave	-0.28	1.05	0.40	-0.40	0.51	**0.026**	0.01	0.89	0.97	-0.63	0.94	0.10
LTLF jerk ave	-114.38	185.88	0.07	-203.75	153.43	**0.001**	52.78	593.42	0.72	-282.91	450.15	0.12
LTROT top value	5.20	16.70	0.33	-1.85	2.76	**0.049**	-21.40	59.22	0.16	-31.61	63.18	0.20
LTROT excursion range	-30.62	102.18	0.34	0.05	1.33	0.90	15.15	153.81	0.69	85.52	163.24	0.18
LTROT vel ave	-35.17	111.86	0.32	-0.59	1.69	0.28	22.73	112.27	0.42	98.60	189.97	0.19
LTROT jerk ave	-15948.32	50740.18	0.32	-552.77	783.68	**0.041**	12997.10	53977.83	0.34	54214.37	1.02	0.18

(M= mean, SD= standard deviation, LTFE= lower thoracic flexion extension, LTLF= lower thoracic lateral flexion, LTROT= lower thoracic rotation)

Intergroup:

For lower thoracic spinal kinematics during the bilateral arm task, there were no effects observed within the group except for lower thoracic flexion extension jerk across the 4 treatment groups, after adjusting for the pre scores, ($F(3, 40) = 2.902$, $p = 0.047$), as seen in Table 4.21. Post hoc analysis with a Bonferroni adjustment shows that the score for cervical and thoracic manipulation (adjusted mean = 1046.33) was significantly greater than the control group (adjusted mean = 645.63) (p=0.049).

Table 4.21 Intragroup bilateral arm task lower thoracic

	Post Scores													
	C-Spine			**C+T-Spine**			**T-Spine**			**Control**			**ANCOVA**	
FLEX/EXT	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	**n**	**M**	**SD**	***p*-value**	**Partial Eta Squared**
Top value	11	-12.03	12.86	8	-11.19	10.82	17	-9.32	8.29	11	-7.67	4.17	0.90	0.01
Range	11	8.05	3.60	8	10.86	4.41	17	8.03	3.51	11	6.23	3.12	0.12	0.13
Velocity	11	6.08	2.02	8	8.88	3.09	17	6.27	2.95	11	5.16	2.61	0.10	0.14
Jerk	11	915.91	352.35	8	1046.39	329.93	17	987.14	323.66	11	645.63	225.27	**0.047**	0.18
LAT FLEX														
Top value	11	0.40	2.56	8	0.62	1.82	17	-0.52	1.76	11	1.08	1.28	0.27	0.09
Range	11	2.63	1.01	8	3.28	1.71	17	2.96	1.02	11	2.48	1.13	0.78	0.03
Velocity	11	3.01	0.67	8	3.73	1.77	17	3.04	0.91	11	2.80	1.35	0.28	0.09
Jerk	11	1121.32	388.22	8	1183.32	723.19	17	1099.82	519.08	11	880.22	412,19	0.45	0.06
ROT														
Top value	11	0.81	2.28	8	1.66	1.67	17	10.36	43.11	11	-21.29	54.79	0.17	0.12
Range	11	2.57	1.03	8	5.13	3.09	17	27.27	98.72	11	35.58	101.23	0.68	0.04
Velocity	11	4.19	2.01	8	6.35	3.85	17	16.43	48.21	11	39.39	111.44	0.55	0.05
Jerk	11	1960.33	1.42	8	1996.04	1.30	17	6030.20	1.64	11	1.77	5.05	0.50	0.06

(M= mean, SD= standard deviation)

4.6 SUMMARY OF THE SUBJECTIVE AND OBJECTIVE MEASURES

With regard to the subjective measures of pain intensity, there was a decrease in pain intensity within each of the four groups as well as across the four groups. The significant difference across the groups was ($F(3, 47) = 0.41$, $p = 0.27$). This result suggests that all groups resulted in decreased pain intensity.

The objective measures of spinal kinematics showed results of a number of significant differences found within the groups, which were not significant within for the study. When examining the comparison across the four groups, three significant differences were found across the groups, namely unilateral arm task lower thoracic flexion extension jerk ($F(3, 40) = 2.892$, $p = 0.047$), bilateral arm task upper thoracic flexion extension range ($F(3, 40) = 3.127$, $p = 0.036$) and the bilateral arm task lower thoracic flexion extension jerk ($F(3, 40) = 2.902$, $p = 0.047$). These significant differences were not significant within the study.

CHAPTER 5

DISCUSSION

5.1 INTRODUCTION

This chapter contains a discussion of the key results that were observed within Chapter 4. This discussion examines the results of Chapter 4 and how the current literature correlates. This chapter also examines a possible explanation for the observed data. The results observed concerning the demographics of the participants, pain, and the different groups, the control group, cervical manipulation, thoracic manipulation and the combination of cervical and thoracic manipulation are discussed.

5.2 DEMOGRAPHIC CHARACTERISTICS

The age range within this study was restricted to 18–50 years of age, which means that those under 18 years of age and those over 50 years of age were excluded. When considering a study such as this, it is important that there are restrictions with regard to age as elderly individuals may have decreased muscle strength that could affect the movement of the functional tasks because individuals will not be able to lift the relevant objects. This can also apply with individuals under the age of 18 years of age.

In this study the mean age was 29.6 years for males and females across all four groups. In the control group it was 29.09, cervical group 28.81, thoracic group 29.82 and the cervical and thoracic combination group 30.75. In studies made by other researchers that were referred to in earlier chapters, it showed that for males the peak age for neck pain was 45–49 years of age and for females the peak age was 50–54 years of age (Hoy *et al.* 2010). Another study found that the prevalence of neck pain increased to 70–74 years of age (Kazeminasab *et al.* 2022). These ages for neck pain are substantially higher than those of participants participating in this study. Future studies that assess neck pain may examine an increased age range but ensure that adequate history and examinations are conducted so there are no conditions present that are associated with older individuals.

Studies have indicated that there may be variations in the intensity of neck discomfort among various age groups and it is not always clear how age and the intensity of neck discomfort are related. However, the research shows what has typically been discovered. When examining the prevalence, middle aged and older persons are more likely than younger people to experience neck pain. The age range of 45–64 is frequently where the highest frequency is seen (Hoy *et al.* 2010; Kazeminasab *et al.* 2022). The severity of the pain experienced can affect anyone at any age but some research indicates that older individuals may be more susceptible to persistent or severe neck pain. However, this can change based on personal circumstances and the reason behind the neck pain. Younger people, from teenagers to young adults, may have neck pain because of bad posture, excessive use of technology, or sports-related injuries. Adults in their middle years frequently complain of neck pain that is brought on by stress at work, extended desk time, or the beginning of degenerative diseases (Khired 2022). Younger people typically get over neck pain faster and chronic neck pain may be more common in older individuals. Studies have indicated that women experience more severe neck discomfort in all age categories, but especially in the middle and advanced age (Kazeminasab *et al.* 2022). Different age groups also experience different degrees of pain depending on the nature of their work. These are all broad patterns, and individual experiences can differ somewhat regardless of the aforementioned factors.

Variances in neck pain between the genders is evident. Studies have consistently demonstrated that women are more likely to experience neck pain than men and that this pain is also generally more severe. Females experience longer episodes of chronic neck pain, which can be due to hormonal factors, changes in the oestrogen levels, workplace factors, or stress related. A difference in biomechanics can result in females experiencing pain differently due to body composition and muscle strength. Studies have indicated that women have a lower pain threshold which causes them to feel pain more frequently than that of men and that women recover more slowly than men (Vincent and Tracey 2008; Osborne and Davis 2022; Zheng *et al.* 2022).

5.3 SUBJECTIVE MEASURES: PAIN

It is difficult to accurately assess and determine the subjective measure of pain because it depends on individuals' perceptions. They may feel that their pain has decreased or increased, but this could be due to a variety of factors, including their activities for the remainder of the day, whether they exercise, or whether they were injured during that time. In this study pain was assessed before the treatment and again 24 hours post treatment; the results show that there were no significant differences across all four of the groups. This adds to the knowledge about pain and how it is perceived by the participants because one of the groups was the control group which could suggest that there may have been an error or there may have been a placebo effect.

Within this study, the data show that there were significant differences with the pain intensity experienced by the participants in all four groups. The data does correlate with those studies which show a decrease in pain intensity with CSM alone (Mayana *et al*. 2017. Martinez-Segura *et al*. 2006). When examining the TSM alone in this study, some decrease in the pain intensity that was experienced by the participants was evident. This was also observed in the studies by Cleland *et al.* (2005); Casanova-Mendez *et al.* (2014) and Lau *et al.* (2010). The data are the same for the group that received both cervical and TSM. Many other studies on the combination of spinal manipulation also saw a decrease in pain intensity post treatment. Lastly, the control group also showed a decrease in pain intensity. The studies that had control groups and which were utilised as comparison also reported a decrease in pain intensity (Cleland et al. 2005; Casanova-Mendez et al. 2014; Lau et al. 2010), but this could be due to a placebo effect experienced by the participants.

Within this study, there were 47 participants but a larger sample size could be utilised in future studies to increase the variability as well as give more accurate data and true representation of the findings. Some research may examine different ways to assess pain experience so that there is a more accurate and a less subjective measure, eliminating possible errors and placebo effects within control groups, which could sway the data.

5.4 OBJECTIVE MEASURES: SPINAL KINEMATICS (VELOCITY, DISPLACEMENT, AND JERK)

Since the objective measures were not normally distributed, non-parametric statistical tests were used to analyse the data. The study's objective measures examined various aspects of spinal kinematics, including displacement, velocity, and jerk. Every group was measured for each of these characteristics, and the movements used to measure them were CROM, neck flexion/extension, neck lateral flexion, and neck rotation. Additionally, there were two functional tasks: a bilateral standing task and a seated single arm task.

5.5 INTRAGROUP ANALYSIS

The groups were all assessed through CROM, which included flexion/extension, lateral flexion and rotation. Through each one of these movements the participants were assessed on the time it took to accomplish the task, the peak (how far they were able to move), the velocity used through the movements, and the jerk that occurred through the movements.

The objective measurements evaluated the jerk, displacement (peak), velocity, and spinal kinematics. Velocity measures the speed at which a movement happens, displacement measures the amount or distance that a person may move. The jerk refers to abrupt, quick motions that are not smooth and this measure determines if the participant is still experiencing jerky movement or whether there are smoother movements. There were also marginally significant differences ($p<0.05$) between each group; these were observed in the cervical group for unilateral and bilateral arm tasks and in the control group for CROM. More research is necessary to understand how this finding impacts motor control and its relationship to SMT. Previous studies have shown improvements in participants' CROM and functionality and this was observed in all the groups that received the spinal manipulation intervention (Mayana *et al.* 2017; Martinez-Segura *et al.* 2006; Dunning *et al.* 2012; Masaracchio *et al.* 2019) compared to control groups. These studies had significant differences with their results compared to this study which had insignificant differences. These studies also had larger sample sizes compared to this study, which could have had an impact on positive data that have been shown.

5.6 CONCLUSION

All groups including the control group improved during the trial. It is likely that a significant Hawthorne effect was in operation during this trial, which is when participants are aware that they are being observed and so they alter their behaviour (McCambridge *et al.* 2014).

In particular, the variations that were observed in the control group may indicate a placebo effect or that the control utilised results in a treatment effect. It is difficult to develop adequate controls for studies utilising manual therapy due to the nature of the interventions. Upon review of the groups, significant changes were observed in the unilateral and bilateral arm tasks related to the average velocity and average jerk of upper thoracic flexion/extension. Further investigation is warranted to investigate if these changes were subject to chance or were important real observations. A larger sample size is warranted with an investigation that utilises as many statistical comparisons as within this study. The motion capture system requires an expert in utilising it to ensure correct and accurate data are recorded.

This study, and previous studies, have similar results that have been noted regarding the change in pain intensity (Mayana *et al.* 2017; Lau *et al.* 2010), but there is a disparity with the results of spinal kinematics, the CROM, and functionality within the cervical spine and thoracic spine. More studies are needed into NSNP and assessing the kinematics, considering increasing the sample size, and considering having someone who is familiar with the system used to ensure greater accuracy. Positive views are evident in previous studies and how such studies are researching more into a condition that impacts so many individuals worldwide.

CHAPTER 6

CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

6.1 CONCLUSION

The aim of this study was to determine the relative effectiveness of cervical and thoracic spinal manipulation applied alone and in a combination. The groups were compared to a control to determine effect on pain intensity, disability, and cervical and thoracic kinematic outcomes (angular displacement, peak and mean velocity and jerk) during CROM and two upper extremity functional limb tasks in individuals with NSNP.

The results of this study demonstrated a significant change in pre post testing in all groups including the control but not when comparing between the group changes. Thus, we accept the null hypothesis that there are no significant differences attributable to treatment.

Therefore, spinal manipulation can be used by manual therapists to help patients that have chronic NSNP to help improve their pain with immediate effects, but we cannot say that spinal manipulation will help patients with improvements in their spinal kinematics as there is not enough of a significant difference that can support that theory. More studies and research will need to be conducted with spinal manipulation effects on spinal kinematics in patients with chronic NSNP.

6.2 LIMITATIONS

In this study, the following limitations are recognised:

1. The spinal manipulation that was utilised could not be standardised or verified according to the velocity and the amplitude of the thrust, even though each manipulation was performed by the same research assistant.
2. For each of the movements that were performed, there was a demonstration done by the researcher, as well as practise for each of the participants. However, there was no control over how the participants performed during the actual recording; there may have been some hesitancy or they may have become more accustomed to the movements in the post treatment recordings.

3. The varying duration of the chronic NSNP may have had an influence on the results.
4. The technology used was a new type of technology, which was very temperamental. This may have resulted in issues not being seen by the operator. The technology should have been operated by an expert.
5. As this study examined the immediate effects of spinal manipulation on pain and spinal kinematics, only one course of treatment was given to the participants. Future studies may want to examine more treatments.
6. The single arm task utilised the right arm of the participant due to the setup of the lab; this may or may not be the dominant arm of the participant which could affect the movement. Future studies should consider using each participant’s dominant arm.

6.3 RECOMMENDATIONS

The following recommendations are made for future studies:

1. The duration of the chronic neck pain should be restricted to a certain time frame to help decrease the variation in pain which could affect the results.
2. Future studies should consider recording the side and the level manipulated for each participant and see if that has any effect.
3. Multiple treatments should be given to the groups that received the intervention and the change after each treatment for immediate and long-term changes should be monitored.
4. When using the motion capture system, there should be an expert of the system present to ensure that all data are recorded accurately and correctly every time.

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APPENDICES

Appendix A: Letter of permission

To : Dr D. Varatharajullu

Clinical Director, Department of Chiropractic

From : Mr D. Twiss

Registered student: M. Tech Chiropractic (student number: 21959321)

RE : Request to utilise DUT Chiropractic Clinic for research purposes

Date : 20 November 2021

I would like to request to utilise the DUT Chiropractic Clinic to collect data for my M. Tech research project titled: The relative effectiveness of spinal manipulation of cervical, thoracic and a combination of the two on pain, cervical and thoracic kinematics in non-specific neck pain participants residing in KwaZulu-Natal.

I would be requiring a treatment room and access to the Optitrack cameras. I will source my own patients. However, should there be patients who are wanting to enrol in the study from the clinic patient base I request that the option is open for the patient to join the study should they meet the required inclusion criteria.

The study aims and objectives pertaining to using the clinic detailed below:

To compare the effectiveness of cervical spine manipulation, thoracic spine manipulation and a combination of the two in participants with non-specific neck pain, both in objective measures and subjective measures

Objective measures:

- Cervical spine range of motion (ROM)

- Kinematics for the cervical and thoracic spine (angular displacement, velocity and acceleration) during two functional tasks

Subjective measure:

- Pain

I envisage utilising the facility from March 2022 to August 2022.

Should you require any further information from me please do not hesitate to contact me on

083 304 8163/dbtwiss@gmail.com

Yours sincerely,

Dale Twiss

Appendix B: Request for permission to conduct research

20 November 2021

Mr D. Twiss

B. Tech Chiropractic

Registered student

M Tech: Chiropractic, DUT

Student number: 21959321

Request for Permission to Conduct Research

Dear Director: Research and Postgraduate Support.

My name is Dale Twiss, a M. Tech Chiropractic student at the Durban University of Technology. The research I wish to conduct for my masters thesis involves 'The relative effectiveness of spinal manipulation of cervical, thoracic and a combination of the two on pain, cervical and thoracic kinematics in non-specific neck pain participants residing in KwaZulu-Natal'.

I am hereby seeking your consent to advertise my study to the students and staff of DUT.

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent forms to be used in the research process, as well as a copy of the approval letter which I received from the Institutional Research Ethics Committee (IREC) (Still to be approved and attached)

If you require any further information, please do not hesitate to contact me 083 304 8163 or dbtwiss@gmail.com. Thank you for your time and consideration in this matter.

Your sincerely,

Dale Twiss

B. Tech

Durban University of Technology

Appendix C: Ethical clearance certificate

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

6 September 2022

Mr D B Twiss
P.O Box 7200
Palm Court
Roodepoort
Johannesburg

Dear Mr Twiss

A four way comparison of cervical and thoracic spinal manipulation on pain and spinal kinematics in non-specific neck pain
Ethical Clearance number IREC 178/22

The DUT-Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

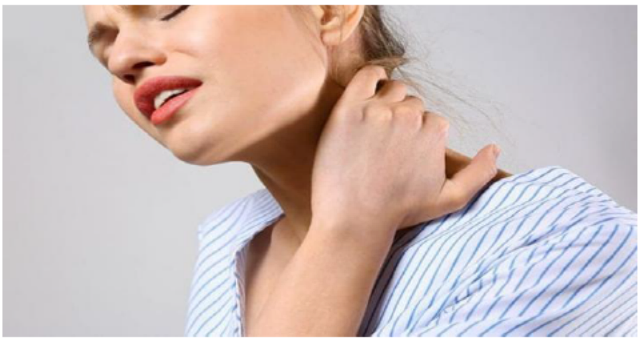
Yours Sincerely

Prof J K Adam
Chairperson: DUT-IREC

Appendix D: Advertisement

Neck Pain??

Let's Have A Look



Would you like to be part of an interesting research study?

Research being conducted at the Durban University of Technology Chiropractic Clinic

Contact :

Dale Twiss - 083 304 8163

Appendix E: Request to place advertisement

To : Whom it may concern

From : Mr D. Twiss

Registered student: M. Tech Chiropractic (student number: 21959321)

RE : Requesting to place advertisement regarding participants for research study

Date :

I would like to request permission to place an advertisement advertising my master's study at your establishment. The study is titled: The relative effectiveness of spinal manipulation of cervical, thoracic and a combination of the two on pain, cervical and thoracic kinematics in non-specific neck pain participants residing in KwaZulu-Natal.

The study aims and objectives pertaining to using the clinic detailed below:

To compare the effectiveness of cervical spine manipulation, thoracic spine manipulation and a combination of the two in participants with non-specific neck pain, both in objective measures and subjective measures

Objective measures:

- Cervical spine range of motion (ROM)
- Kinematics for the cervical and thoracic spine (angular displacement, velocity and acceleration) during two functional tasks

Subjective measure:

- Pain

Permission granted/denied:

Name:____________________ Signature: ________________________

Position:____________________ Date: ____________________________

Appendix F: Letter of consent

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, _(name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: __,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

________________________	____________	_______	_______________
Full Name of Participant	**Date**	**Time**	**Signature/Right Thumbprint**

I, ________________(name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

________________________	_____	_______________
Full Name of Researcher	**Date**	**Signature**
________________________	_____	_______________
Full Name of Witness (If applicable)	**Date**	**Signature**
________________________	_____	_______________
Full Name of Legal Guardian (If applicable)	**Date**	**Signature**

Appendix G: COVID-19 consent

Department of Chiropractic Faculty of Health Sciences Ritson Campus

Durban University of Technology

11 Ritson Road, Berea, Durban 4001

P O Box 1334, Durban, 4000, South Africa Tel: (031)373 2205

www.dut.ac.za

CONSENT FOR CHIROPRACTIC TREATMENT DURING THE COVID-19 PANDEMIC

I,_________________, knowingly and willingly consent for myself or for a minor_________ ______, under my care, to receive elective Chiropractic or emergency Chiropractic treatment from the Durban University of Technology Chiropractic Day clinic during the COVID-19 pandemic.

I understand the COVID-19 virus has a long incubation period during which carriers of the virus may not show symptoms but still be highly contagious.

Chiropractic procedures/treatment take place with the patient in very close proximity to the practitioner. This potentially exposes the patient and the practitioner to the COVID-19 virus.

I understand that due to the frequency of other Chiropractic patients, the characteristics of the virus, and the characteristics of Chiropractic practice, that I have an elevated risk of contracting the virus simply by being in the Chiropractic clinic.____(Initial)

I confirm that I am not presenting with ANY of the following symptoms of COVID-19 listed below:

- Fever
- Shortness of Breath
- Dry Cough
- Runny Nose
- Sore throat

High risk patients relating to the severity of COVID-19 are persons of the age of 60 and persons who have pre-existing medical conditions such as: asthma; chronic lung conditions; hypertension; autoimmune diseases; organ transplants; cancer; immunocompromised; obesity (BMI over 40); more than 27 weeks pregnant; and liver or kidney conditions.

a.) I confirm that I do not fall into any of these high risk categories ____(Initial) or

b.) I confirm that I do fall into these high health risk categories and I am aware of the increased risk of severe infection due to my age/pre-existing medical conditions should I contract Covid-19_____(Initial)

I am aware of the risks involved with the spread of COVID-19 and the risks it may hold to my health and the health of others I come into contact with. I accept those risks and hereby indemnify and hold the Durban University of Technology Chiropractic Day Clinic and its students and staff blameless should I contract the disease at the clinic premises or from the clinic staff and/or students.

______________________________ ____________________

Patient's signature Date

PRACTICAL GUIDELINES TO THECONSULTATION

1.1 I,____have read and understand the practical guidelines as set out hereunder and confirm that I will comply thereto and prepare accordingly.

1.1.1 I will sign all consent forms at home and bring the forms to the Chiropractic Day Clinic at the time of my appointment, failing which I will not be treated. I may also sign same electronically and email same to the clinic.

1.1.2 Patients will be contacted and screened the day before consultations, and requested to take appropriate action if they are presenting with any risk symptoms or history.

1.1.3 Patients will be prohibited from entering the campus/clinic if the patient hasn’t complied with proper control measures.

.

1.1.4 Patients will not be allowed in the waiting room and will be requested to wait in their cars until called by the reception staff to enter the clinic.

1.1.5 All patients will be sprayed with hand sanitizer upon entry.

1.1.6 All patients must wear a face mask at all times once on campus.

1.1.7 Patients are to requested to ensure that they arrive on time for their appointment otherwise their appointment may need to rescheduled.

1.1.8 On arrival, patients will again be screened for risk factors including the taking of temperature.

1.1.9 Between consultations, the necessary hygiene/cleaning protocols will be done by the students/staff and this may cause a delay and prolong waiting periods.

1.1.10 Patients are requested to avoid touching anything inside the clinic.

1.1.11 Patients are requested to remove any jewellery and leave the same at home as it can be a carrier of infection droplets.

1.1.12 Friends and family members will be requested to wait in the car and will not be permitted into the clinic except in the case of patients who require assistance or a minor.

1.1.13 Patients are requested to pay for their appointments using a card. If this is not possible then please ensure that you have the correct denomination of cash available as we will not be able to issue change.

1.1.14 Patients are requested to please bring their own towel, gown and shorts to avoid having to use clinic attire.

_________________________ _________________________

Appendix H: Declaration for entry into the Chiropractic Day Clinic

Department of Chiropractic Faculty of Health Sciences Ritson Campus

Durban University of Technology

11 Ritson Road, Berea, Durban 4001

P O Box 1334, Durban, 4000, South Africa Tel: (031)373 2205

www.dut.ac.za

Declaration for entry into the Chiropractic Day Clinic

Name and Surname	
File No	
Contact number	
Reason for entry	Appointment
Body temperature reading at time of entry	

TICK AS APPLICABLE	**YES**	**NO**
Have you been in contact in the last 14 days with someone who is confirmed to have COVID-19?		
Have you been for a COVID-19 test in the last 14 days?		
Have you received test results for COVID-19 in the last 14 days?		
What was the outcome: ___________________________	N/A	
Do you have any results pending for COVID-19 testing?		

Are you currently suffering with any of the following symptoms or have you had any of these symptoms within the past 14 days?		
• Cough		
• Fever		
• Sore throat		
• Shortness of breath (or difficulty of breathing)		
• Fatigue, weakness or tiredness		
• Aches and pains or headaches		
• Loss of smell		
• Loss of taste		
• Redness of eyes		
• Nausea		
• Vomiting		
• Diarrhoea		

Declaration

I hereby declare that the information I have disclosed is correct at the time of completion. To the best of my knowledge I have not had direct contact with any person who has tested positive for COVID-19 symptoms in the past 14 days, nor have I presented with any of the above COVID-19 symptoms within the past 14 days.

____________________ ____________________

Signature Date

Appendix I: COVID guidelines

Department of Chiropractic Faculty of Health Sciences Ritson Campus

Durban University of Technology

11 Ritson Road, Berea, Durban 4001

P O Box 1334, Durban, 4000, South Africa Tel: (031)373 2205

www.dut.ac.za

Dear patient,

Given the current situation with the COVID-19 Virus around the world we have implemented some measures toensure the safety of all our patients, staff and students.

With this in mind please take note of the following protocols that have been implemented in our clinic:

1. Patients will be contacted and screened the day before consultations, and requested to take appropriateaction if they are presenting with any risk symptoms or history.
2. Access to campus will be strictly controlled. Upon arrival at gate 6 you will be required to present your ID as well as confirmation of your appointment which will be sent to you either via email, WhatsApp orSMS.
3. Please note that it is essential that you arrive **on time for your appointment** as we cannot admit morethan one patient at a time to the clinic and should you arrive late, your appointment may have to be rescheduled.
4. Upon arrival you will need to please telephone the clinic reception on 031 3732205 **from the parking area** to advise them that you have arrived for your appointment. Once you have done this **please wait in your vehicle** until you are notified via telephone to enter the building. You will once again be screened and your temperature will be checked upon entry and you will be required to sign a consent to treatment as well as a declaration for entry into the Chiropractic clinic. Please bring your own pen with you in orderto complete/sign any relevant documentation.
5. All patients, staff and students will be required to wear masks at all times. **Any person not wearing a mask will strictly not be permitted access to the campus and/or clinic**. Should you need more information on the AHPCSA's guidelines for good practice hygiene, please consult www.ahpcsa.co.za
6. Patients will be required to sanitise their hands in the reception prior to treatment.

7. Please leave as many accessory items at home or in the car as you are able to. This includeswatches/jewellery etc. the less there is on you, the less chance there is of contamination.
8. Please bring your own shorts/gowns or wear loose comfy clothing that you do not need to change into theclinic attire.
9. Please note that for health and security reasons we will not be retaining cash on our premises so it wouldbe preferable for you to make payment by card. If you choose to pay with cash, please ensure that you have the correct denominations available as **it will not be possible for us to give change**.
10. Please note that all friends and family will be asked to wait in the car.
11. Appointment times will be made longer due to the time taken to disinfect all handles/machines andtreatment surfaces. Please keep this is mind when making your appointment.
12. Patients are requested to avoid touching anything inside the clinic.
13. If you are experiencing **any signs and symptoms of COVID-19 please reschedule your appointment** (cough, fever (above 38 degrees), sore throat, tiredness, exposure to anyone with suspected or diagnosed with COVID-19 in the last 14 days or if you have worked or attended a clinic facility treating COVID-19patient/s).

Please note that under South African law any person who intentionally exposes another person to COVID-19, may be prosecuted for an offence, including assault, attempted murder or murder.

14. Patients who are at **high risk** of contracting severe COVID-19***(see table below)** are advised to only book an appointment in the event of an emergency. Otherwise you are urged to rather stay at home in theinterest of your own health and safety.

RISK FACTORS FOR SEVERE COVID-19

Risk Factor	Detail	Definition
Age	People 60 years and older withcomorbidities	Aged 60 years or older with one or more disorders or conditions
People of all ages with the following underlying medical conditions, particularly if not well controlled:		
Cardiovascular disease	Moderate/Severe Hypertension	Moderate hypertension: Systolic BP 160-179mmHg and/or systolic BP ≥180mmHg. Severe hypertension: systolic BP≥180mmHg and/or diastolic BP≥110mmHg.
	Congestive cardiac failure or otherserious cardiovascular disease	Confirmed clinical diagnosis of congestive cardiac failure or otherserious cardiovascular disease
	Cerebrovascular disease, including stroke and transient ischemic attack	Confirmed clinical diagnosis of cerebrovascular disease.
Respiratory Disease	Pulmonary Tuberculosis – untreatedor in early treatment	People who have not completed theintensive phase or first two monthsof treatment in line with the National Department of Health Standard Treatment Guidelines.
	Moderate to severe asthma	Asthma which requires treatment with high dose inhaled corticosteroids, plus a second controller (and/or systemic corticosteroids) to prevent it from becoming 'uncontrolled' or which remains 'uncontrolled' despite this therapy.
	Chronic Obstructive PulmonaryDisease (COPD)	Confirmed clinical diagnosis ofCOPD
	Other severe chronic lung pathology,including cystic fibrosis and bronchiectasis	Confirmed clinical diagnosis – irrespective of severity.
Kidney Disease	Chronic Kidney Disease	eGFR< 45
Pregnancy	Third trimester pregnancy	Estimated to be further than week 27 of pregnancy
Immunosuppression	Poorly controlled type II DiabetesMellitus	HBAIc ≥7.5% within last 6 months
	Cancer undergoing active treatment	Currently undergoing chemotherapy and/or radiotherapy
	Human Immunodeficiency Virus with advanced immunosuppression	HIV positive persons with CD4 count <200 cells/mm³ who are ART-naïve or who initiated ARTwithin the last three months.
	Chronic immunosuppressant use	Chronic use of corticosteroids of >20mg prednisone per day or equivalent, methotrexate, biologicals or other immunosuppresants.
	Transplant	On chronic immunosuppressants.
Metabolic Syndrome	Severe Obesity	Body mass index (BMI) of 40 andhigher.

Please feel free to contact us if you have any queries. Stay safe.

Appendix J: Central sensitisation check list

Central Sensitisation Inventory: Part A

Name:________________________Date: __________________

Please circle the best response to the right of each statement.

1	I feel tired and unrefreshed when I wake from sleeping.	Never	Rarely	Sometimes	Often	Always
2	My muscles feel stiff and achy.	Never	Rarely	Sometimes	Often	Always
3	I have anxiety attacks.	Never	Rarely	Sometimes	Often	Always
4	I grind or clench my teeth.	Never	Rarely	Sometimes	Often	Always
5	I have problems with diarrhea and/or constipation.	Never	Rarely	Sometimes	Often	Always
6	I need help in performing my daily activities.	Never	Rarely	Sometimes	Often	Always
7	I am sensitive to bright lights.	Never	Rarely	Sometimes	Often	Always
8	I get tired very easily when I am physically active.	Never	Rarely	Sometimes	Often	Always
9	I feel pain all over my body.	Never	Rarely	Sometimes	Often	Always
10	I have headaches.	Never	Rarely	Sometimes	Often	Always
11	I feel discomfort in my bladder and/or burning when I urinate.	Never	Rarely	Sometimes	Often	Always
12	I do not sleep well.	Never	Rarely	Sometimes	Often	Always
13	I have difficulty concentrating.	Never	Rarely	Sometimes	Often	Always
14	I have skin problems such as dryness, itchiness, or rashes.	Never	Rarely	Sometimes	Often	Always
15	Stress makes my physical symptoms get worse.	Never	Rarely	Sometimes	Often	Always
16	I feel sad or depressed.	Never	Rarely	Sometimes	Often	Always
17	I have low energy.	Never	Rarely	Sometimes	Often	Always
18	I have muscle tension in my neck and shoulders.	Never	Rarely	Sometimes	Often	Always
19	I have pain in my jaw.	Never	Rarely	Sometimes	Often	Always
20	Certain smells, such as perfumes, make me feel dizzy and nauseated.	Never	Rarely	Sometimes	Often	Always
21	I have to urinate frequently.	Never	Rarely	Sometimes	Often	Always
22	My legs feel uncomfortable and restless when I am trying to go to sleep at night.	Never	Rarely	Sometimes	Often	Always
23	I have difficulty remembering things.	Never	Rarely	Sometimes	Often	Always
24	I suffered trauma as a child.	Never	Rarely	Sometimes	Often	Always
25	I have pain in my pelvic area.	Never	Rarely	Sometimes	Often	Always
					Total=	

Central Sensitization Inventory: Part B

Name: ____

Date: ____

Have you been diagnosed by a doctor with any of the following disorders?

Please check the box to the right for each diagnosis and write the year of the diagnosis.

NO YES Year Diagnosed

1	Restless Leg Syndrome			
2	Chronic Fatigue Syndrome			
3	Fibromyalgia			
4	Temporomandibular Joint Disorder (TMJ)			
5	Migraine or tension headaches			
6	Irritable Bowel Syndrome			
7	Multiple Chemical Sensitivities			
8	Neck Injury (including whiplash)			
9	Anxiety or Panic Attacks			
10	Depression			

Appendix K: Tampa scale for kinesiophobia

Tampa Scale for Kinesiophobia

(Miller, Kori and Todd 1991)

1 = strongly disagree

2 = disagree

3 = agree

4 = strongly agree

1. I'm afraid that I might injury myself if I exercise	1	2	3	4
2. If I were to try to overcome it, my pain would increase	1	2	3	4
3. My body is telling me I have something dangerously wrong	1	2	3	4
4. My pain would probably be relieved if I were to exercise	1	2	3	4
5. People aren't taking my medical condition seriously enough	1	2	3	4
6. My accident has put my body at risk for the rest of my life	1	2	3	4
7. Pain always means I have injured my body	1	2	3	4
8. Just because something aggravates my pain does not mean it is dangerous	1	2	3	4
9. I am afraid that I might injure myself accidentally	1	2	3	4
10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening	1	2	3	4
11. I wouldn't have this much pain if there weren't something potentially dangerous going on in my body	1	2	3	4
12. Although my condition is painful, I would be better off if I were physically active	1	2	3	4
13. Pain lets me know when to stop exercising so that I don't injure myself	1	2	3	4
14. It's really not safe for a person with a condition like mine to be physically active	1	2	3	4
15. I can't do all the things normal people do because it's too easy for me to get injured	1	2	3	4
16. Even though something is causing me a lot of pain, I don't think it's actually dangerous	1	2	3	4
17. No one should have to exercise when he/she is in pain	1	2	3	4

Scoring Information Tampa Scale for Kinesiophobia

(Miller et al 1991)

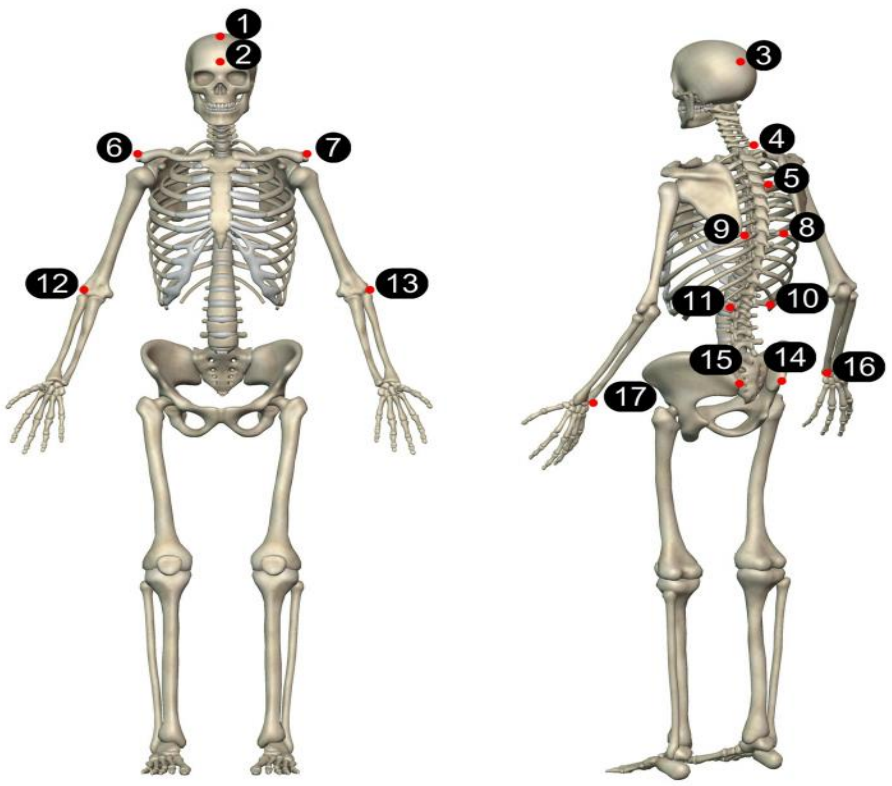
A TOTAL SCORE IS CALCULATED AFTER INVERSION OF THE INDIVIDUAL SCORES OF ITEMS 4, 8, 12 AND 16.

APPENDIX L: Marker placement diagram

Spine & upper-body analysis

BODY MARKERS	AUXILIARY MARKERS	FLOOR DEFINITION	INITIAL POSE
17 *17 markers fixed on the skin.*	0 *No auxiliary markers needed.*	Not Required *The floor plane definition resulting from a good calibration is enough.*	Required *Anatomical position: Start the capture standing still and upright (back straight) with both arms on each side of the body.*

Marker placement



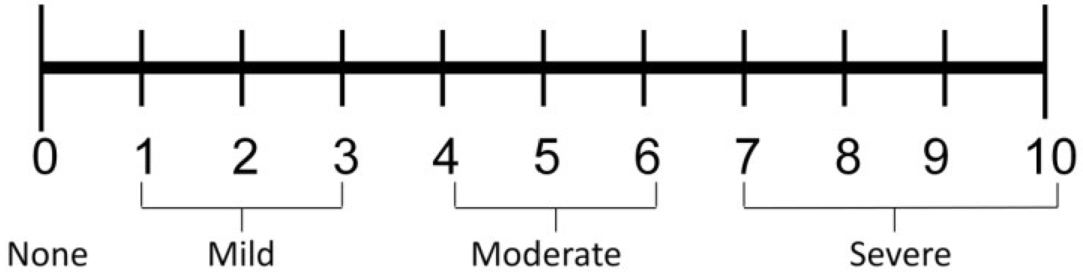
- 1 -

	MARKER NAME	ANATOMICAL POSITION
1	Head (top)	Centered on top of the head (top of the cap, helmet or head band).
2	Head (front)	Centered on the forehead (front of the cap, helmet or head band).
3	Head (back)	Centered on the back of the head (back of the cap, helmet or head band).
4	C7	C7 vertebra (most prominent protrusion when bending down the head).
5	T3	T3 vertebra.
6	Right shoulder	Acromion of the right scapula.
7	Left shoulder	Acromion of the left scapula.
8	T7 (Right)	On the back, around 4cm to the right of the T7 vertebra.
9	T7 (Left)	On the back, around 4cm to the left of the T7 vertebra.
10	L1 (Right)	On the lower back, around 4cm to the right of the L1 vertebra.
11	L1 (Left)	On the lower back, around 4cm to the left of the L1 vertebra.
12	Right elbow	Lateral epicondyle of the right humerus.
13	Left elbow	Lateral epicondyle of the left humerus.
14	Right PSIS	Protuberance of the right posterior superior iliac spine.
15	Left PSIS	Protuberance of the left posterior superior iliac spine.
16	Right wrist	On the right ulnar styloid process.
17	Left wrist	On the left ulnar styloid process.

Appendix M: Numerical pain rating scale

Patient Instructions (adopted from (McCaffery, Beebe et al. 1989):

"Please indicate the intensity of current, best, and worst pain levels over the past 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)"



Appendix N: Telephonic questions check list

Telephonic question:

- How old are you?
- Have you had neck pain for more than three months?
- Have you had treatment for your neck in the last three weeks?
- What is your pain from 0-10?
- Have you had any head trauma?
- Do you have any known neurological or orthopaedic disorders?
- Have you had any surgery to the brain or spine?
- Do you have any tempromandibular disorders?
- Do you suffer from rheumatic disease?
- Are you able to come in to the Durban University of Technology Chiropractic Clinic?

Appendix O: Letter of information

LETTER OF INFORMATION

Dear Sir/Madam

Thank you for taking the time to respond to the advert for this research study. This letter aims to provide you with the necessary details for you to make an informed decision about partaking in this research project. Please read through it carefully and should you require clarification please ask.

Title of the Research Study: The relative effectiveness of spinal manipulation of cervical, thoracic and a combination of the two on pain, cervical and thoracic kinematics in non-specific neck pain participants residing in KwaZulu-Natal

Principal researcher: Mr D. Twiss B. Tech: Chiropractic

Supervisors: Dr L. O'Connor M. Tech: Chiropractic
Prof H. Pollard PhD:

Brief Introduction and Purpose of the Study:

This study is investigating the effect that a type of treatment for neck pain, called spinal manipulation, has on spinal motion, pain and disability in people with neck pain. Investigating this study involves having four groups, three of which will receive the intervention of manipulation of the cervical spine, thoracic spine or a combination of the two, the fourth group will be a control group with no intervention. The study will look at the effect the intervention will have on individuals with neck pain and will contribute to the literature in terms of how spinal manipulation comes about a therapeutic effect.

Outline of the procedure:

The participants that volunteer for the study need to be between the ages of 18 and 50 with neck pain for three or more months, this neck pain will be diagnosed by the researcher. The participants will be assessed while performing two function tasks and cervical range of motion. All participants must have had no spinal surgery, severe trauma, sensory or vestibular deficits, bony abnormalities, deformities of the trunk, be suffering from rheumatic disease or experience problems with their temporomandibular joint.

Once one has met the relevant criteria they will receive the various forms that will need to be completed prior to starting. These forms look at your health status and pain. Once the forms are complete the participant will change into appropriate attire to ensure there is minimal interference. The reflective markers will then be placed onto the participant, once all reflectors are placed the participant will be placed in position where the range of motion and functional tasks can be performed. There will be two functional tasks performed which would have been taught to the participant. After the assessment has taken place the participant will either receive cervical manipulation, thoracic manipulation, a combination of the two or no intervention, this will depend on the allocation of the group, there is a 75% chance of receiving a manipulation. After the intervention has been received the participant will then be assessed again with range of motion and the two functional tasks. The researcher/research assistant will telephone you in one week to ask about the neck pain and then your participation will be complete.

Risks or Discomforts to the Participant:

The procedures used in this study are commonly utilized. Following the cervical spinal manipulation, thoracic spinal manipulation and combination of the two, you may experience some mild discomfort which may last 24 hours. This can be managed by having a shower and letting the warm water run over the area.

Benefits:

The results of this study will contribute to our understanding of how spinal manipulation brings about improved movement and decreased pain. Participants will receive either cervical spinal manipulation, thoracic spinal manipulation or a combination of the two, during the study or after the study, depending which group you are allocated to.

Reason/s why the Participants May Be Withdrawn from the study:

Should you become ill during the study, if you develop pain within the arm or the trunk or if you are non-compliant with the treatment schedule you will be withdrawn from the study. You are also free to withdraw from the study at any time, without any adverse consequence for you.

Remuneration:

There is no monetary remuneration for you partaking in this study. However, all treatments administered will be free of charge.

Costs of the Study:

There is no cost to you for partaking in this study, except your travelling cost to the DUT chiropractic clinic.

Confidentiality:

All your personal information will be kept confidential. When reporting the results of this study coding will be used to ensure that your name is not associated with any of the reported research results.

Research-related Injury:

Should you sustain any injury while being enrolled in this study please advise the researcher immediately.

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher on 083 304 8163/dbtwiss@gmail.com or the supervisor Dr O'Connor on 031 373 2923/lauraw@dut.ac.za. Alternatively the Institutional Research Ethics Administrator can be contacted 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof Moyo on 031 373 2575 or moyos@dut.ac.za

Appendix P: Case history form

CHIROPRACTIC PROGRAMME

CHIROPRACTIC DAY CLINIC

CASE HISTORY

Patient:	Date:
File#:	Age:
Sex:	Occupation:
Student:	Signature:

FOR CLINICIANS USE ONLY:

Initial visit

Clinician:	Signature:

Case History:

Examination:

Previous:	Current:

X-Ray Studies:

Previous:	Current:

Clinical Path. lab:

Previous:	Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL:
Reason for Conditional:
Signature: Date:

Conditions met in Visit No:	Signed into PTT:	Date:

Case Summary signed off:	Date:

<u>Student's Case History:</u>

1. **Source of History:**

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

3. Present Illness:

	Complaint 1(principle complaint)	Complaint 2 (additional or secondary complaint)
Location Onset : Initial: Recent: Cause: Duration Frequency Pain (Character) Progression Aggravating Factors Relieving Factors Associated S & S Previous Occurrences Past Treatment Outcome:		

4. Other Complaints:

5. Past Medical History:

General Health Status

Childhood Illnesses

Adult Illnesses

Psychiatric Illnesses

Accidents/Injuries

Surgery

Hospitalizations

6. Current health status and life-style:

Allergies

Immunizations

Screening Tests incl. x-rays

Environmental Hazards (Home, School, Work)

Exercise and Leisure

Sleep Patterns

Diet

Current Medication

    Analgesics/week:

    Other (please list):

Tobacco

Alcohol

Social Drugs

7. Immediate Family Medical History:

Age of all family members

Health of all family members

Cause of Death of any family members

	Noted	Family member		Noted	Family member
Alcoholism			Headaches		
Anaemia			Heart Disease		
Arthritis			Kidney Disease		
CA			Mental Illness		
DM			Stroke		
Drug Addiction			Thyroid Disease		
Epilepsy			TB		
Other (list)					

8. Psychosocial history:

Home Situation and daily life

Important experiences

Religious Beliefs

9. Review of Systems (please highlight with an asterisk those areas that are a problem for the patient and require further investigation)

General

Skin

Head

Eyes

Ears

Nose/Sinuses

Mouth/Throat

Neck

Breasts

Respiratory

Cardiac

Gastro-intestinal

Urinary

Genital

Vascular

Musculoskeletal

Neurologic

Haematological

Endocrine

Psychiatric

APPENDIX Q: Cervical spine regional

CHIROPRACTIC PROGRAMME

REGIONAL EXAMINATION – CERVICAL SPINE

Patient: .... File No: ....

Date: .... Student: ....

Clinician: .... Sign: ....

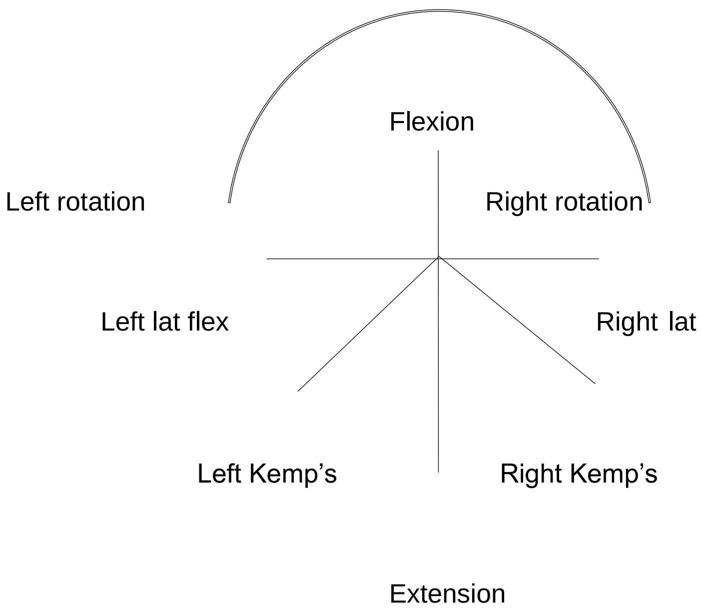
OBSERVATION:

Posture
Swellings
Scars, discolouration
Hair line
Body and soft tissue contours

Shoulder position
Left:
Right:
Shoulder dominance (hand):
Facial expression:

RANGE OF MOTION:

Extension (70º):
L/R Rotation (70º):
L/R Lat flex (45º):
flex
Flexion (45º):



PALPATION:

Lymph nodes
Thyroid Gland
Trachea

MYOFASCIAL ASSESSMENT

Tenderness		Right	Left
Trigger Points:	SCM		
	Scalenii		
	Post Cervicals		
	Trapezius		
	Lev scapular		

ORTHOPAEDIC EXAMINATION:

	Right	Left		Right	Left
Adson's test			Halstead's test		
Brachial plexus test			Hyper-abduction test		
Cervical compression			Kemp's test		
Cervical distraction			Lateral compression		
Costoclavicular test			Lhermitte's sign		
Dizziness rotation test			Shoulder abduction test		
Doorbell sign			Shoulder compression test		
Eden's test					

NEUROLOGICAL EXAMINATION:

Dermatones	**Left**	**Right**	**Myotomes**	**Left**	**Right**	**Reflexes**	**Left**	**Right**
C2			C1			C5		
C3			C2			C6		
C4			C3			C7		
C5			C4					
C6			C5					
C7			C6					
C8			C7					
T1			C8					
			T1					

Cerebellar tests:	Left	Right
Dysdiadochokinesis		

VASCULAR:	**Left**	**Right**		**Left**	**Right**
Blood pressure			Subclavian arts.		
Carotid arts.			Wallenberg’s test		

MOTION PALPATION & JOINT PLAY:

Left: Motion Palpation:

Joint Play:

Right: Motion Palpation:

Joint Play:

<u>BASIC EXAM: SHOULDER</u>:

Case History:

ROM: Active:

Passive:

RIM:

Orthopaedic:

Neuro:

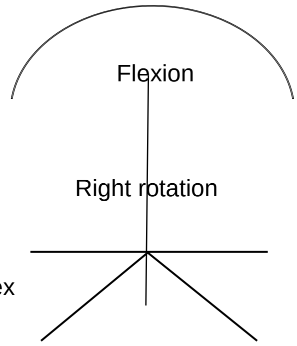
Vascular:

Kemp's right

<u>BASIC EXAM: THORACIC SPINE:</u>

Case History:

ROM:



Flexion

Left rotation

Right rotation

Left lat flex

Right lat flex

Kemp's left

Extension

Motion Palpation: Motion Palp:	
Orthopaedic:	
Neuro:	
Vascular:	
Observ/Palpation:	
Joint Play:	

Appendix R: Thoracic spine regional

THORACIC SPINE REGIONAL EXAMINATION

Patient:_______________________________________File:___________________

Date:________________________

Student:_________________________________Signature: ___________________

Clinician: _______________________________Signature:____________________

<u>STANDING:</u>

Posture (incl. L/S & C/S)	Scars
Muscle tone	Chest deformity
Skyline view – Scoliosis	(pigeon, funnel, barrel)

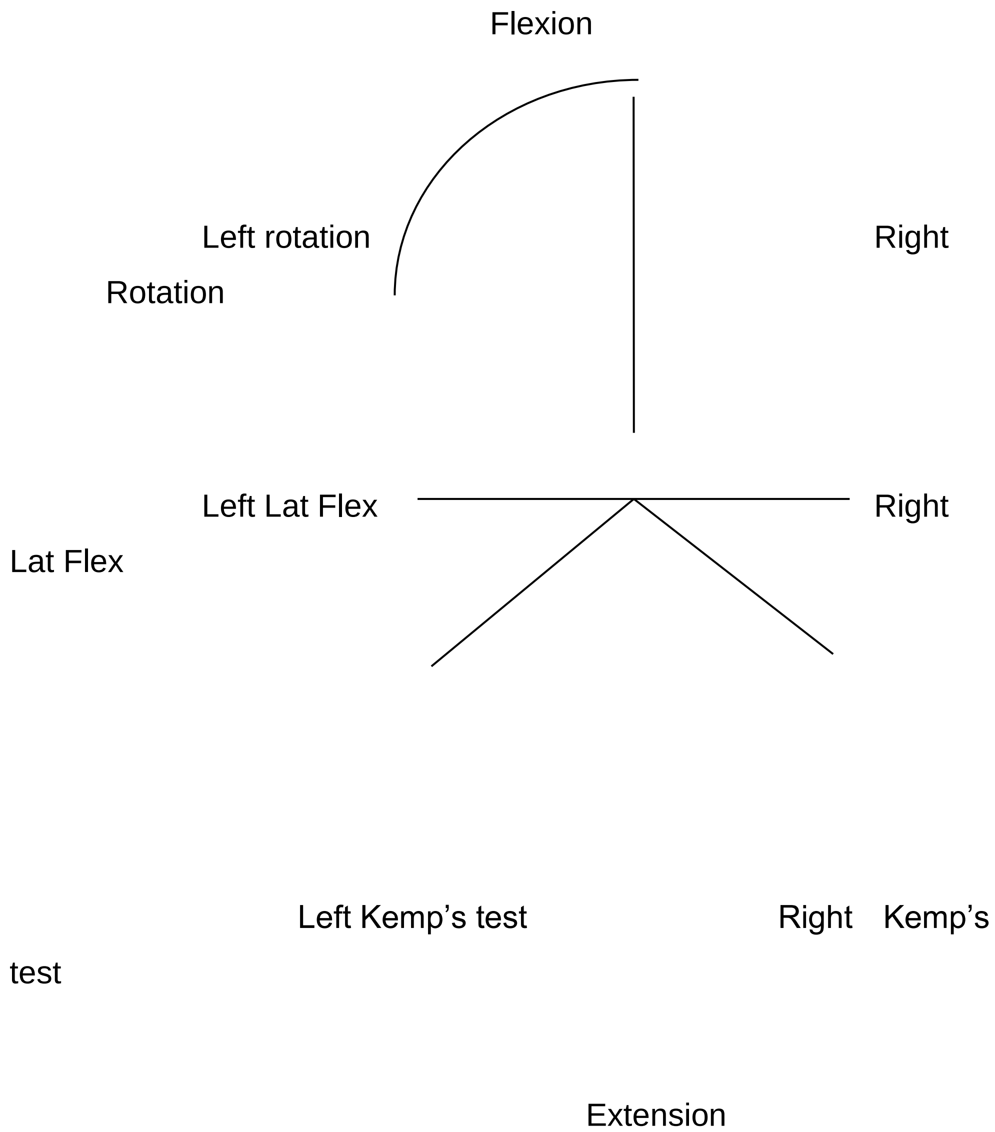
Spinous Percussion

Breathing (quality, rate, rhythm, effort)

Deep Inspiration

<u>RANGE OF MOTION:</u>

Forward Flexion	20 – 45 degrees (15cm from floor)
Extention	25 – 45 degrees
L/R Rotation	35 – 50 degrees
L/R Lat Flex	20 – 40 degrees



RESISTED ISOMETRIC MOVEMENTS: (in neutral)

Forward Flexion — Extension

L/R Rotation — L/R Lateral Flexion

SEATED:

Palpate Auxillary Lymph Nodes

Palpate Ant/Post Chest Wall

Costo vertebral Expansion (3 – 7cm diff. at 4th intercostal space)

Slump Test (Dural Stretch Test): LOCAL PAIN (T/S) DISTAL PAIN (L/S) DISTAL PAIN (LEG)

SUPINE:

Rib Motion (Costo Chondral joints)

Soto Hall Test (#, Sprains)

SLR

Palpate abdomen

PRONE:

Passive Scapular Approximation

Facet Joint Challenge

Vertebral Pressure (P-A central unilateral, transverse)

Active myofascial trigger points:

	Latent	Active	Radiation Pattern		Latent	Active	Radiation Pattern
Rhomboid Major				Rhomboid Minor			
Lower Trapezius				Spinalis Thoracic			
Serratus Posterior				Serratus Superior			
Pectoralis Major				Pectoralis Minor			
Quadratus Lumborum							

COMMENTS:____

NEUROLOGICAL EXAMINATION:

DERMATOMES												
	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	T 11	T 12
Left												
Right												

Basic LOWER LIMB neuro:

Myotomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Dermatomes	T11	T12	L1	L2	L3	L4	L5	S1	S2	S3
Reflexes	Patella – Left					Achilles – Left				
	Patella - Right					Achilles – Right				

MOTION PALPATION:

			Right	Left
Thoracic Spine				
Ribs	Calliper (Costo-transverse joints)			
	Bucket Handle	Opening		
		Closing		
Lumbar Spine				
Cervical Spine				

BASIC	History	ROM	Neuro/Ortho
LUMBAR			
CERVICAL			

Appendix S: Training certificate

Zertifikat

Certificado

Certificat

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

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Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/05/08
CID : rO6ILLMee8

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

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Zertifikat

Certificado

Certificat

Certificate

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du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/05/09
CID: AbXKdVnieG

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

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TRREE

Zertifikat Certificat Certificado Certificate

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Certificat de formation - Training Certificate

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Informed Consent

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/05/09
CID : hUQDalCSvh

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

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TRREE

Zertifikat Certificat Certificado Certificate

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du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/05/09
CID : GX4QeYqIEK

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

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