The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mechanical mid-back pain
At the Durban University of Technology Chiropractic Day Clinic

By

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Master's Degree of Technology: Chiropractic in Health Sciences at the

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2017

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DEDICATIONS

I would like to dedicate this dissertation to:

My Lord, God and Saviour, for being my guiding light and providing me with strength and resilience throughout my journey of life and academic endeavour.

My parents (Paula and Calvin Petersen) and siblings (Gizela, Chemon and Caville Petersen), you all have struggled with me though this. Thank you so much for being my unwavering base of support and encouragement. Mama, thank you especially for never faltering in your kindness and belief in me, even when I was unwilling to receive it.

My Vovo, I wish you could have been here to see the conclusion of this chapter of my life. Thank you for always reminding me that although life may be difficult, a strong spirit will endure.

Dr. Korporaal, thank you for your relentless dedication to your students and for believing in me when I did not believe in myself. There are no words fitting enough to express my gratitude.

ACKNOWLEDGEMENTS

I would like to thank the following people:

Dr. Kretzmann, my supervisor, thank you for your patience, support and knowledge. I could not have completed this dissertation without your guidance and encouragement. Thank you for believing in me.

Dr. Korporaal, thank you for your guiding hand and faith in my abilities. Your role in my academic career has been profound and appreciated.

Glenda Matthews, thank you for your efficiency and all your work on the statistics for this study.

Tio Mandinho and Aunty Erica, most people are blessed with only one set of parents, but I have been fortunate enough to be blessed with two. Thank you for all the life changing things you have done for me.

Tio Mico and Aunty Tracey (The cool, younger and funkier uncle and aunt), thank you for all your powerful words that have reached me in my darkest times and for all the love, support and laughter that you have given so freely.

Sharne Jean-Pierre, thank you for being my guinea pig and for your enduring and unique friendship. It’s not often that you get to choose another sibling.

DEFINITIONS

Arthrokinematics

Refers to the specific movements that occur within a joint (MacConaill and Basmajian, 1977). These are movements that occur independently from global motion.

Biomechanics

The practical application of mechanical laws on living structures and tissues (Bergmann and Peterson, 2011).

Closed kinematic chain

This describes the arrangement of a system of several adjacent joints that work together during motion. A closed kinematic chain describes a system that is composed of joints wherein one link in the system has a relative effect on all other links in the system (Peterson and Bergmann, 2002)

Degrees of freedom

These are independent co-ordinates in a system of various co-ordinates that are necessary to determine an object's position in space. The spine has six degrees of freedom because it is capable of rotation about three axes and translation along three axes (Gatterman, 2005).

Functional spinal unit

Is found in the spine and may be defined as the union of two adjacent vertebrae, the intervertebral disc between them and their interconnecting tissues (Oda, Abumi, Lu, Shono and Kaneda, 1996).

Joint dysfunction

Functional changes, without structural changes, in the in joint mechanics that alter the quality and range of motion that a joint is capable of. These functional joint changes can manifest as changes in the pattern of joint movement or decreased or increased joint motion (Peterson and Bergmann, 2002).

Kyphosis

An abnormal increase in the convex curvature of the thoracic spine (Peterson and Bergmann, 2002).

Manipulation

A manual procedure performed on a joint via a directed and controlled thrust, with the intention of moving a joint past its range of physiological motion but not exceeding its anatomical range of motion (Gatterman, 2005).

Mid-back pain (mbp)

Pain occurring between the cervical and lumbar spine (Moore and Dalley, 2006), produced by dysfunction of the surrounding musculature (Irwin, 2015), innervation (Manchikanti, Singh, Falco, Cash and Pampati, 2012) and/ or joints (Cleland, Glynn, Whitman and Eberhart, 2007) within the thoracic spine. The boundaries for mid-back pain are between the T3 to T9 vertebrae and the shoulder blades (scapulae) (Irwin, 2015).

Myofascial Trigger Point

A tender localized point in a taut band of skeletal muscle, with increased pain and intensity on compression of this point (Travell, Simons and Simons, 1983).

Myofascial trigger point therapy

The fingers are used to apply pressure to the myofascial trigger point. The pressure is increased over a period of 30 to 60 seconds or until there is a decrease in tenderness (Travell et al. 1983). This method of treatment is referred to as ischaemic compression. The pressure may be modified to include massage and amplify the local state of tissue hypoxia (i.e. deprivation of oxygen/ blood) (Travell et al., 1983).

Presenteeism

This refers to individual being present at work but in a decreased productive capacity (Dagenais, Caro and Haldeman, 2008).

Prevalence

This is an estimation of the proportion of a population that may have a specific disease or condition at any given time. Therefore, a high prevalence suggests that a random individual selected from a population may be more likely to have the specific disease or condition (Leach, 2004).

Spinal Manipulation

For the purpose of this study, spinal manipulation will refer to the manipulation of the facet joints in the spine. The area of the spine i.e. cervical, thoracic or lumbar, will be specified in text.

Abstract

Mid-back pain (mbp) is defined as pain occurring within the limits of the third thoracic (T3) and ninth thoracic (T9) vertebrae, caused by the dysfunction of the musculoskeletal structures in the thoracic spine. It can present as pain and/ burning between the shoulder blades with reduced thoracic spine mobility and increased muscle tension. Congenital disorders such as scoliosis and Scheuermann's disease, or acquired disorders such as thoracic facet and costovertebral joint dysfunction may cause mbp. The thoracic facet and costovertebral joints are similar in anatomy and share a mutually dependent biomechanical relationship. There were a handful of controlled studies that highlighted the effectiveness of thoracic facet manipulation on mbp, but there were none on the effects of costovertebral manipulation on mbp.

Objectives

The aim of this study was to investigate the immediate effects of the combination of thoracic facet and costovertebral joint manipulation on mbp in terms of pain perception, pressure pain thresholds (PPT) and thoracic spine range of motion (ROM).

Design

A prospective single-blind randomised comparative clinical trial.

Setting

This study was conducted in a university setting at the Durban University of Technology Chiropractic Day Clinic

Participants

Fifty participants were recruited via responses to advertisements placed around the Durban University of Technology (DUT) campuses and individuals presenting at the Chiropractic Day Clinic (CDC).

Intervention

The participants were divided into two groups of twenty-five. Group A received the thoracic facet joint manipulations and Group B received a combination of the thoracic facet and costovertebral joint manipulations.

Outcome Measures

All subjective and objective measurements were taken before and after the application of the manipulations. Pain perception i.e. subjective measurement) was measured by the Numerical Pain Rating Scale (NPRS), pressure pain thresholds (PPT) (i.e. objective measurement) were measured by the Wagner's FDK Force Gage Algometer and thoracic spine range of motion (ROM) i.e. objective measurement was measured by the Saunders Digital Inclinometer.

Results

The data was analyzed using the latest version of SPSS and a *p*-value = 0.05 was used to determine statistical significance. Descriptive statistics in the form of univariate analysis described the data in terms of measures of central tendency and measures of dispersion. Data that was distributed normally was analyzed using the t-test and ANOVA. Data that was distributed abnormally was analyzed using the non-parametric Wilcoxon ranked and Mann Whitney tests. Nominal and ordinal data was analyzed using the Chi squared test.

The results of the intra-group analysis indicated a statistically significant decrease in pain perception ($p \leq 0.000$), increase in PPT ($p \leq 0.05$) and decrease in thoracic spine ROM ($p \leq 0.000$). However, the results for the inter-group analysis indicate there was no statistically significant difference in pain perception ($p = 0.386$), PPT ($p > 0.05$) and thoracic spine ROM ($p > 0.05$) between Group A and Group B.

Conclusions

These results showed that the combination of thoracic facet and costovertebral joint manipulation was as effective as thoracic facet joint manipulation alone, in the treatment of mbp. These findings suggested that manipulation of the costovertebral joints may not be necessary for the effective treatment of mbp.

List of Acronyms

CDC	**-**	Chiropractic Day Clinic
DUT	**-**	Durban University of Technology
EEG	**-**	Electroencephalogram
FSU	**-**	Functional Spinal Unit
IFC	**-**	Interferential Current
Mbp	**-**	Mechanical mid-back pain
MRI	**-**	Magnetic Resonance Imaging
NPRS	**-**	Numerical Pain Rating Scale
PPT	**-**	Pressure Pain Threshold
ROM	**-**	Range of motion
T and number e.g. (T3)	**-**	A representation of the thoracic vertebral level

List of Figures

Table of Contents

Chapter One
Introduction

1.1 Introduction

The mid-back is defined as the region between the cervical (i.e. neck) and lumbar spine (i.e. lower back) (Irwin, 2015 and Moore and Dalley, 2006) (Figure 1.1). It is considered a transitional zone and its mobility varies between regions (Phillip, Brismee and Cock 2007).The mid-back consists of the thoracic spine (T3 to T9) and ribcage (ribs 3 to 9) (Irwin, 2015) (Figure 1.1). Mid-back pain (mbp) may be produced by the dysfunction of the surrounding musculature (Falla, Gizzi, Tschapek, Erlenwein and Petzke, 2014), nerves (Manchikanti et al., 2012) and/ joints (Cleland et al., 2007) within the thoracic spine. Causes include congenital anomalies such as block vertebrae (Livingston and Emans, 2014), Scheurmann's disease (Palazzo, Sailhan and Revel, 2014) and hyperkyphosis (Katzman, Vittinghoff, Kado, Ensrud, Lane and Shipp, 2016). Acquired anomalies such as Pott's disease (Tuli, 2013), poor posture (Knox, Orchowski, Scher, Owens, Burks and Belmont, 2014) and facet joint dysfunction (Briggs, Smith and Straker, 2009a and Knox, 2014) may also cause mbp. However, musculoskeletal; disorders of a mechanical nature, such as thoracic facet joint dysfunction and muscular strain are a likely and common cause of mid-back pain (Benjamin, 2007).

This particular type of mid-back pain may present as a deep constant or intermittent ache/ burning, either unilaterally or centrally in the mid-back (Chadwick and Silvano, 2015; Mahmoud, Hussein, Girgis, Kamal and Nafady, 2014) and may occasionally refer to the chest (Crothers, French, Herbert and Walker, 2016), shoulder (Dunning, Mourad, Giovannico, Maselli, Perreault and Fernandez-de-las-Penas, 2015) or neck (Langenfeld, Humphreys, Bie, Swanenburg, 2015). These painful symptoms may be exacerbated by specific actions and movements such as; deep inspiration, coughing, sneezing and truncal rotation (Scaringer and Ketner, 1999).

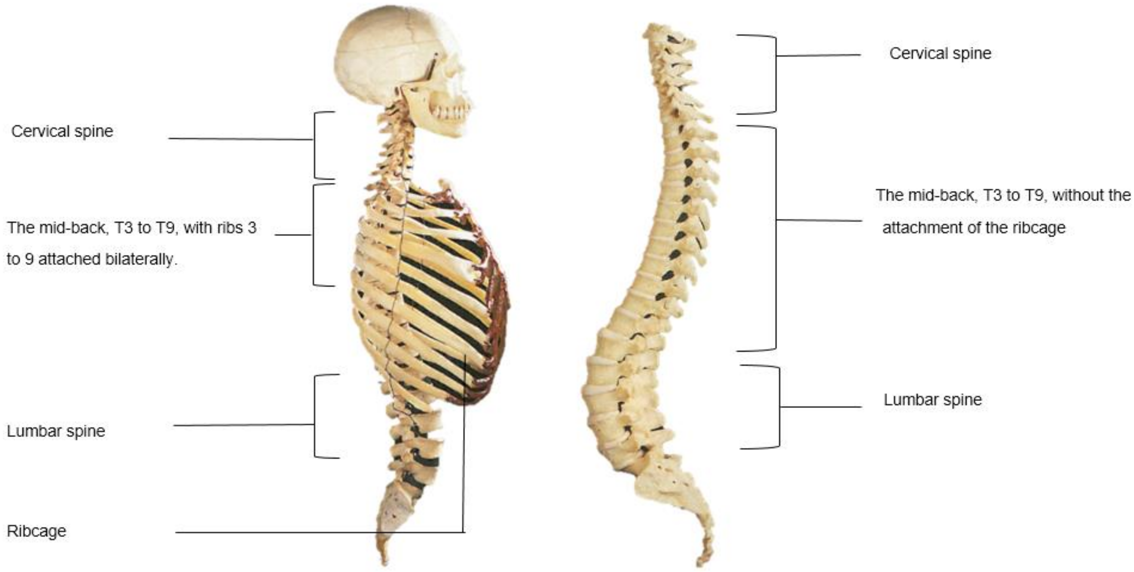
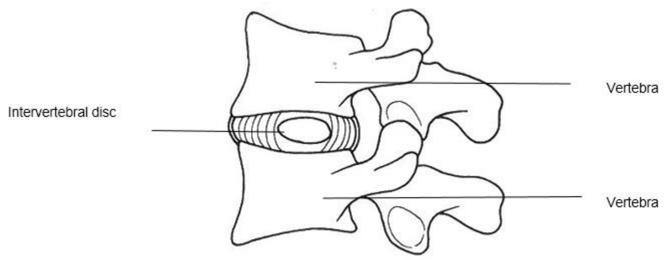


Figure 1.1: Illustrates the region of the mid-back, situated between the cervical and lumbar spine, with and without the attachment of the ribcage (Abrahams, Marks and Hutchings, 2003).

Mbp occurs in various populations, age groups and genders (Briggs, Smith and Straker, 2009b). Johannes, Le, Zhou, Johnston, Dworkin's (2010) survey of the general American population, showed that 11% of the sample population complained of low back pain, whereas, 14% complained of mbp. These findings indicated that within Johannes' (2010) study sample, mbp was more common than low back pain. Similarly, Manchikanti, Boswell, Singh, Pampati, Damron and Beyer's (2004) findings highlighted the prevalence of mbp. The study investigated the prevalence of facet joint pain in the spine and found facet joint pain in the thoracic spine had a prevalence of 42% - 78% within the study's sample population. Briggs' (2009b) systematic review of the literature on mbp suggested that the general population may have a prevalence of 12% - 31, 2% in the period of a lifetime. Similarly, mbp caused by facet joint dysfunction is a common complaint in practice, as was observed in Benjamin's (2007) findings. Several therapies may be used in the treatment of mbp such as, massage (Hamm, 2006), myofascial trigger point therapy (Irwin, 2015), nerve blocks (Manchikanti et al., 2012) and spinal manipulation (Irwin, 2015). Spinal manipulation may be instrumental in clinical practice for the treatment of mbp (Gatterman, 2005 and Leach, 2004). It helps control pain (Skyba, Radhakrishnan, Rohlwing, Wright and Sluka, 2003), relax muscle spasm secondary to joint dysfunction (Lelic, Niazi, Holt, Jochumsen, Dremstrup, Yielder, Murphy, Drewes and Haavik, 2016) and encourages movement of restricted spinal segments (Vieira-pellenz, Olivia-Pascual-Vaca, Rodriguez-Blanco, Heredia-Rizo and Ricard, 2014). To achieve these positive effects, manipulation may be applied in different styles such as the manipulation of only the thoracic spine (Dimopoulos, 2002; Fryer, Carub and McIver, 2004; Pillay, 2001), the manipulation of extra-spinal components (i.e. structures other than the spine) such as the ribcage, or a combination of the two (Gavin, 1999). The findings of previous studies have highlighted the effectiveness of spinal manipulation in the short and long term treatment of mbp (Irwin, 2015 and Pillay, 2001). There are also studies that have shown an immediate, statistically significant improvement in range of motion and pain perception following thoracic spine manipulation (Fryer, 2004; Gavin, 1999).

However, there was a paucity in the literature on the effects of the combination of thoracic facet and costovertebral joint manipulation for the treatment of mbp. It may be of relevance to consider the addition of costovertebral manipulation in mbp treatment because the costovertebral joint is an integral component of the functional spinal unit (FSU) in the thoracic spine. The FSU is composed of two adjacent vertebrae, the intervertebral disc between them and their connecting tissues (Bergmann and Peterson, 2011) (Figure 1.2). Research has highlighted the mutually dependent relationship shared by the articular components i.e. thoracic facet and costovertebral joints of the thoracic FSU (Bergmann and Peterson, 2011; Fruth, 2006; Phillip et al., 2007). Movement and the degree of movement, in either of these joints has a direct effect on the motion of the other, and the range of motion (ROM) in the thoracic spine. The thoracic facet and costovertebral joints are responsible for the movement of the thoracic spine and ribcage during truncal movement, which cannot occur without both joints moving relative to one another (Bergmann and Peterson, 2011; Fruth, 2006).



Figure, 1.2: Illustrates the functional spinal unit, formed by two adjacent vertebrae and the intervertebral disc between them (Bergmann and Peterson, 2011:286).

There is compelling evidence that is suggestive of the intimate connection between the thoracic spine, ribcage and its joints (i.e. thoracic facet and costovertebral) (Bergmann and Peterson, 2011; Oda et al., 1996 and Phillip et al., 2007). However, there was a paucity in the literature on the combination of the manipulation of these joints for the treatment of mbp.

Therefore the aim of this study was to investigate the effectiveness of the combination of thoracic facet and costovertebral joint manipulation compared to thoracic facet joint manipulation only, for the treatment of mbp.

1.2 Aim and Objectives

Aim

To investigate the immediate effect of thoracic facet manipulation compared to thoracic facet and costovertebral joint manipulation, in terms of subjective and objective measures, on mbp.

Objectives

Objective One:

To determine the effect of thoracic facet manipulation on mbp using subjective (NPRS) and objective (Wagner Algometer i.e. referred to as the Algometer and Saunders Digital Inclinometer i.e. referred to as the Inclinometer measurements.

Objective Two:

To determine the effectiveness of a combination of thoracic facet and costovertebral joint manipulation on mbp using subjective (NPRS) and objective (Algometer and Inclinometer) measurements.

Objective Three:

To compare the two groups for statistical variances.

1.3 Rationale

Mbp is common in the general population (Briggs, 2009b; Wong and Fielding, 2011). It may be caused by the dysfunction of joints such as the thoracic facet and/ costovertebral joints (Benjamin, 2007). These joints are responsible for mobilising the thoracic spine and ribcage during movement of the trunk (Bergmann and Peterson, 2011). The relationship between the thoracic facet and costovertebral joints is a mutually dependent one. Therefore, dysfunction of one of these joints may affect the function and movement of the other. Thus, perpetuating joint dysfunction and increasing the risk of mbp (Chadwick and Silvano, 2015), muscular spasm (Pickar and Kang, 2006) and decreased spinal mobility (Campbell and Snodgrass, 2010; Wei-Dong, Hua-qun and Hai-song, 2013). Studies have indicated that the negative effects of mbp, caused by joint dysfunction, have been effectively treated with spinal manipulation (Irwin, 2015; Schiller, 1999 and Vieira-Pellenz et al., 2014). However, these studies applied manipulation to only the thoracic facet joints and none had used a combination of thoracic facet and costovertebral joint manipulation for the treatment of mbp. Therefore, the null hypothesis was that the combination of thoracic facet and costovertebral joint manipulation, therefore addressing both articular components (joints) in the kinematic chain, may yield a more favourable outcome for the treatment of mbp.

1.4 Limitations of this study

This was a pilot study and not a fully powered clinical trial. However, there have been previous pilot studies with smaller sample sizes that yielded statistically significant data. Such as, Irwin's (2015) study on mid-back pain, with a sample size of only thirty participants. Whereas the sample size for this study is larger, with fifty participants.

This study was conducted in a university setting which resulted in a heavy saturation of tertiary student participants. This ultimately has resulted in the sample taking the shape of a certain demographic. However, other studies conducted in a university setting have had a similarly uneven distribution of occupation within their sample sizes (Pillay, 2001, Tsolakis, 2001)

This study also relied heavily on the abilities of the researcher and research assistant, thus it was not entirely blinded.

1.5 The Benefits of this Study

There is a prevalence of mbp in the general population that may be caused by thoracic facet and costovertebral joint dysfunction (Benjamin, 2007; Briggs, 2009b; Wong and Fielding, 2011). Mbp may present with muscle spasm and decreased spinal mobility (Aiken and Vaugh, 2013; Lelic et al., 2016; Roquelaure, Bodin, Ha, Le Marec, Fouquet, Ramond-Roquin, Goldberg, Descatha, Petit and Imbernon, 2014).The literature suggested that thoracic facet joint dysfunction was effectively treated with spinal manipulation and relieved the symptoms of mbp (Shiller, 1999; Pillay, 2001; Dimopoulos, 2002). The thoracic facets form part of the articulations in the thoracic FSU (Bergmann and Peterson, 2011) and work in tandem with the costovertebral joints for the movement of the thoracic spine and ribcage (Bergmann and Peterson, 2011; Lee, 1993 and Oda et al., 1996;). The thoracic facet and costovertebral joints share a mutually dependent relationship in terms of biomechanics and kinetics and so too are similar in anatomical nature (Gatterman, 2005; Moore and Dalley, 2006; Phillip et al., 2007). However, there were no studies that investigated the effect of costovertebral joint manipulation or the combination of thoracic facet and costovertebral joint manipulation on mbp.

Therefore the researcher proposed that the combination of thoracic facet and costovertebral manipulation may amplify the positive effects of spinal manipulation and effectively treat mbp. These effects included decreased pain and muscle spasm and increased spinal mobility (Irwin, 2015 and Tsolakis, 2001), therefore helping to improve an individual's quality of life and make daily activities and tasks easier to perform (Tomey, 1992). The findings of this study may provide practitioners with new information for the treatment of mbp.

Chapter Two

Literature Review

2.1 Prevalence and Incidence of Mid-back Pain

Several studies have suggested that back pain is common in the general population (Briggs, 2009a; Wong and Fielding, 2011). This was highlighted in a study (Wong and Fielding, 2011) conducted in Hong Kong, on the prevalence and characteristics of chronic pain. The sample included 5 001 randomly selected participants from the general population, which were 18 years of age and older (Wong and Fielding, 2011). The participants completed the Choice Pain Grade Questionnaire via telephonic interviews. The results of this study indicated that 28.5% of the sample complained of back pain (Wong and Fielding, 2011). Similar results were obtained in an earlier study conducted in America, in the form of a cross-sectional survey. This study investigated the prevalence of chronic pain in the American adult population. The participants were recruited through Knowledge Networks Incorporated (i.e. a survey research company), using probabilistic sampling. The sample included 27 035 participants which were 18 years old and older. The results of this study indicated that lower back pain accounted for 11% and mbp accounted for approximately 14% of the chronic pain complaints in the sample of 27 035 participants (Johannes, 2010).

Mbp occurs between the vertebral levels of T3 and T9 (Irwin, 2015). Research has suggested that mbp may be common in the general population. Briggs (2009b) conducted a study in Australia, which reported on the prevalence and associated factors of mbp in the working population. The data was obtained in the form of fifty-two published studies on mbp, from nine electronic databases. The studies that were included ranged from the time of each databases' inception to January 2008. The results of Briggs' (2009a) study suggested that the prevalence of mbp varied according to occupation, which was higher in medical professionals, manual labourers and performing artists. The results indicated an overall prevalence of 23% - 28.8% over a two-year period and 3.7% - 77% over a lifetime period. Thus indicating that mbp was common in the working population. A cohort study was conducted in Canada, on the incidence of mbp after traffic collisions. The study was conducted over the periods of 1 December 1997 to 30 November 1999. Of the 8 634 traffic collision cases reported, 2 075 fulfilled the criteria for the study. The individuals from the 2 015 cases included, were recruited for this study and had presented to a registered health care professional seeking treatment for traffic collision related injuries. The data was collected from an initial questionnaire and follow up interviews at the third, sixth, ninth and twelfth months. The results indicated that there was an overall average incidence of 11% for cases of mbp, from the sample of 2 075 participants. The results of this study suggested that mbp may be evident after traffic collisions (Johansson, Boyle, Stochkendahl, Carroll and Cassidy, 2015).

Mbp is also a common complaint from patients presenting at teaching clinics which is highlighted in Benjamin's (2007) study. Benjamin's (2007) study was conducted at the DUT CDC and highlighted the prevalence of mbp. This study was in the form of a retrospective, quantitative, clinical survey. The DUT CDC patient files included in the study were drawn from the periods of 13 January 1995 to 30 November 2005. These files were selected through a random sampling process of 24 487 electronic files. Of the 24 487 files, 7 111 were randomly selected and from the sample of 7 111 files, 249 were of thoracic spine cases. This finding indicated an overall prevalence of 3.5% of thoracic spine over a ten-year period. The analysis of the results suggested a statistically significant increase in the prevalence of thoracic spine cases from 2.85% in the first five years (1996 to 2000) to 4.33% ($p < 0.001$) in the last five years (2001 to 2005). Benjamin's (2007) results also highlighted that mbp accounted for 41.4% of the primary complaints and thoracic facet syndrome accounted for 71% of the primary diagnoses. These findings suggested that thoracic facet joint dysfunction was a common cause of mbp in the thoracic cases seen at the DUT CDC over a ten-year period (Benjamin, 2007).

Manchikanti's et al. (2004) study investigated the prevalence of facet joint pain in chronic spinal pain in the American population. This study was conducted in a private clinic setting with a sample of five hundred patients that presented with chronic non-specific (i.e. not of neurological origin) back pain. Lidocaine (i.e. a substance that blocks the transmission of pain signals) was injected into the thoracic facets of these patients. Those who responded favourably, received Bupivacaine (i.e. a nerve block) injections of the facets, three to four weeks after the initial Lidocaine injections (Manchikanti et al., 2004). The results indicated that 14% of the patients had mbp. Of those patients, 74% experienced pain relief after the Lidocaine injections and 42% after the Bupivacaine injections (Manchikanti et al., 2004). These findings indicated that the thoracic facets were generators of mbp and responded favourably to the Lidocaine and Bupivacaine blocks, which reduced mbp. Therefore, the results of this study suggested that the thoracic facet joints were a prevalent cause of pain in 42% of the mbp patients. No further statistical data was available for this study (Manchikanti et al., 2004).

These studies have highlighted the prevalence of mbp in the general population and that the thoracic facet joints may be primary generators of it (Benjamin, 2007; Johannes et al., 2010; Manchikanti et al., 2004) indicate that occurs across age, gender and occupation.

2.2 Related Anatomy and Function

2.2.1 The Thoracic Spine

The thoracic spine consists of 12 thoracic vertebrae (Moore and Dalley, 2006). Its curvature is kyphotic in nature of approximately 20° to 50° (Bergmann and Peterson, 2011). A typical thoracic vertebra consists of a vertebral body, pedicles, and processes (i.e. spinous and transverse) for articulations (i.e. costovertebral joint) and the attachment of muscles and ligaments (transverse and radiate) (Figure 2.1) (Moore and Dalley, 2006). The facets are largely responsible for the protection of the intervertebral disc from shear forces, support of the spinal column and controlling the patterns of motion of the spine (Bergmann and Peterson, 2011). The spinous processes of the thoracic vertebrae are long and project inferiorly, often overlapping the vertebra below it (Figure 2.4). They aid in protecting the spinal cord by projecting over the laminae of the adjacent vertebrae, this prohibits the entrance of foreign objects into the vertebral canal (Moore and Dalley, 2006). Each thoracic vertebral segment (Figure 2.4) has adjacent articulations (i.e. joints) superiorly and inferiorly. The superior and inferior facets are formed by the superior and inferior articular processes of the thoracic vertebrae and arise from their laminae; the superior articulating facets of the superior articular processes are positioned posteriorly and slightly laterally (Figure 2.4). Whereas, the inferior articular facets of the inferior articular processes, are positioned anteriorly and slightly medially (Figure 2.4). The orientation of these facet joints bilaterally creates a central axis of rotation, this allows for a meagre amount of rotary movement between adjacent vertebrae, which is kept in check by the attachment of the rib cage (Moore and Dalley, 2006). The facet joints are innervated by the medial branch of the posterior dorsal ramus at the level which the facet joint occurs and a branch of the posterior dorsal ramus from the level above the facet joint (Gatterman, 2005).

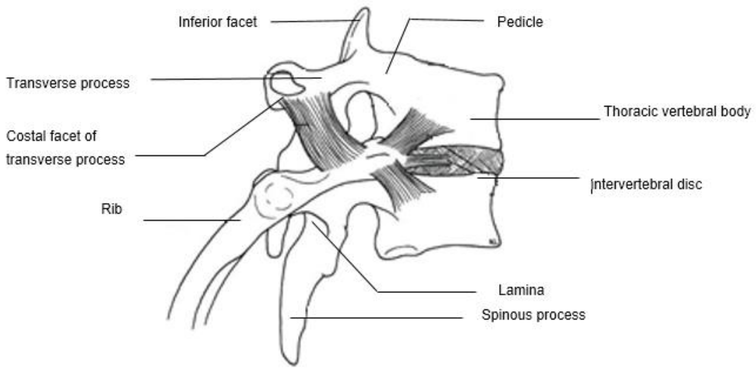


Figure. 2.1 illustrates a typical thoracic spinal segment. This modified illustration depicts the typical anatomy and attachments of the thoracic vertebrae (Peterson and Bergmann, 2002: 228).

2.2.2 Ribcage and Costovertebral Joint

The ribcage attaches anteriorly to sternum by way of the costal cartilages, forming the costosternal and costochondral joints (Figure 2.2) and posteriorly to the thoracic spine by way of the costovertebral and costotransverse joints (Figure 2.3) (Tortora and Derrickson, 2007). The ribcage attachments are reinforced by ligaments from the sternum i.e. radiate sternocostal ligaments and between the ribs i.e. intercostal ligaments (Peterson and Bergmann, 2002). T2 to T9 vertebrae and ribs 3 to 9 are typical. The thoracic vertebral bodies of T2 to T9 possess two pairs of bilateral costal facets (i.e. superior and inferior) on thoracic vertebral body (Figure 2.4). The superior costal facets are situated on the superior posterolateral portion and the inferior costal facets occur on the inferior posterolateral (Figure 2.4). The union of these facets creates a single facet that allows the attachment of a rib head and forms the costovertebral joint (Moore and Dalley, 2006) (Figure 2.3). The rib is further attached to the thoracic vertebra by way of the costotransverse joint, which is created by the articulation of the tubercle of the rib and the costal facet on the transverse process of the thoracic vertebra (Moore and Dalley, 2006) (Figure 2.1). The thoracic facet and costovertebral joints are diarthroses and planar synovial in nature, which allows them to move in a gliding motion (Tortora and Derrickson, 2007). The costovertebral joints are innervated by an articular branch of the ventral ramus or articular branches from the somatic branch of the ventral ramus of that thoracic vertebral level. Whereas, the costotransverse joints are innervated by the dorsal ramus of the spinal nerve, articular branches from the dorsal ramus and medial branch (Haldeman, 2005).

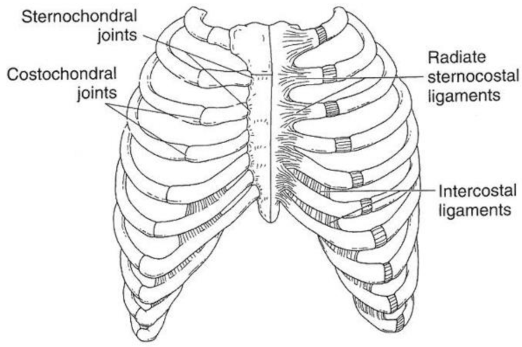


Figure. 2.2 An illustration of the ribcage with the attachment of the sternum via the sternocostal and costochondral joints (Peterson and Bergmann, 2002: 233).

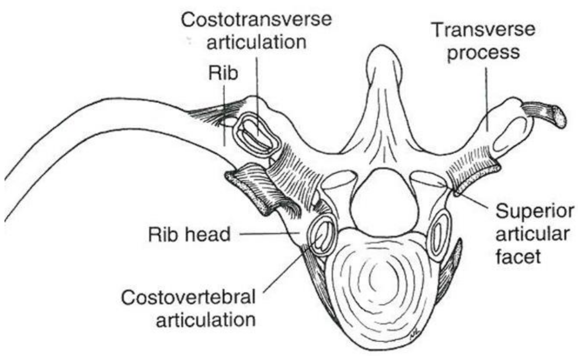


Figure. 2.3 The figure illustrates the attachment of the rib to the vertebral body via the costovertebral and costotransverse joints. (Peterson and Bergmann, 2002: 233)

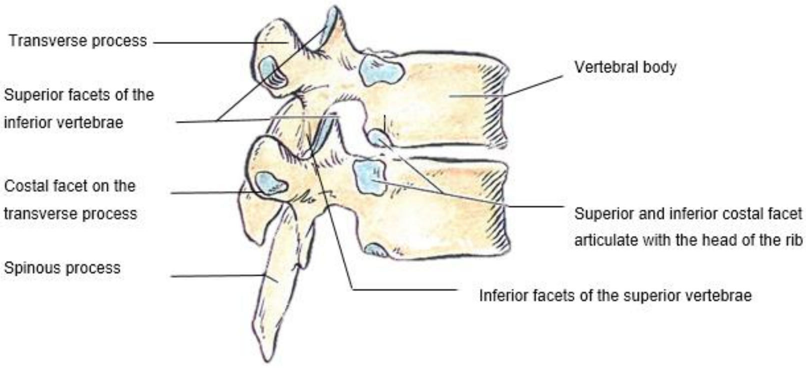


Figure. 2.4 illustrates the typical thoracic vertebrae and its facets forming joints (Moore and Dalley, 2006: 489).

2.2.3 Primary Functions of the Ribcage

The primary functions of the ribcage are to support and stabilize the thoracic spine and protect the vital organs of the thorax (Gatterman, 2005). It also and aids in respiration and provides support for the attachment of the upper limbs and the musculature (Gatterman, 2005; Moore and Dalley, 2006).

Oda's et al. (1996) study, demonstrated the role of the costovertebral joints and the ribcage in stabilizing the thoracic spine. The cadaveric thoracic-rib complexes of 8 canine skeletons were used. Stage one involved the resection of the posterior elements of the thoracic spine (i.e. bilateral facet joints and the posterior thoracic ligaments). Stage two involved the resection of the bilateral seventh ribs and the costovertebral ligaments. Stage three involved the resection of the entire ribcage with the sternum. The results showed that the complete resection of the ribcage exhibited the greatest increase in thoracic ROM. Thoracic flexion and extension motion had a difference of 6.1°, lateral flexion had a difference of 3.7° and right rotation had a difference of 3.4°. These results were statistically significant and suggested that the ribcage plays an important role in thoracic spine stability (Oda et al., 1996). Similarly, Watkins, Watkins III, Willliams, Ahlbrand, Garcia, Karamanian, Sharp, Vo and Hedman's (2005) study produced comparable results to those obtained from Oda's et al. (1996) study. In this study (Watkins et al., 2005) cadaveric thoracic rib complexes of 10 human skeletons were used. These complexes were subjected to axial compression, rotation, lateral flexion, flexion, extension. The first stage involved testing all complexes with the sternum and ribcage intact, stage two involved the fracturing of the sternum and manubriosternal joint and stage three involved the complete removal of the ribcage. The results showed that the ribcage increased the thoracic spinal stability by 40% in flexion and extension (*p*-value = 0.012), 35% in lateral flexion (*p*-value = 0.008), 31% in rotation (*p*-value = 0.008). These findings suggested that the attachment of the ribcage to the thoracic spine significantly increased its stability (Watkins et al., 2005).

The results of these studies highlight the importance of the relationship between the thoracic spine and ribcage. The costovertebral joints facilitate the attachment of the ribcage to the thoracic spine, which increases the stability of the thoracic spine. Therefore, it may be proposed that the integrity of the costovertebral joints play a role in the stability of the thoracic spine and dysfunction of these joints may result in the development of mbp as a consequence of spinal instability.

2.3 Biomechanics and Kinetics of the Thoracic Spine and Ribcage

The term biomechanics encompasses the application of mechanical laws such as, the effect of compressive forces on a water-balloon between two bricks, on living structures. An example of mechanical laws on living structures is the effect of compressive forces on an intervertebral disc between two vertebral bodies. When considering the human body, it refers to the relationships and interactions between the skeletal, articular and muscular structures. During movement, these structures are subjected to the forces acting upon them, these forces, in turn, alter the motion of these structures. This interaction is referred to as kinetics (Bergmann and Peterson, 2011). Consider the example of the intervertebral disc between two vertebral bodies. In a stationary state, there are only the compressive forces of gravity and the weight of the levels above acting on the disc. However, during movement such as rotating the trunk and spine, the intervertebral disc is now also subjected to a torsional force (Lee, 1993).

A functional spinal unit (FSU) is created by two adjacent vertebrae, the intervertebral disc between them and interconnecting tissues (Kim, Shin, Arbatin, Park, Chung and McAfee, 2008) (Figure 2.1). A vertebral segment moves within six degrees of freedom (Phillip et al., 2007). This refers to the degrees of motion that a rigid body is capable of i.e. flexion, extension, right and left rotations, abduction, adduction (i.e. lateral flexion) and medial and lateral rotation (Phillip et al., 2007). Bergmann and Peterson (2011), suggested that based on the works of Panjabi (1992), the thoracic spine is capable of specific degrees of motion depending on the region of the thoracic spine that the movement is occurring at, and the type of movement occurring. During flexion (i.e. forward bending) of the thoracic spine there is an average of approximately 6° of movement at each spinal segment, 4° in the upper thoracic spine, 6° in the mid-thoracic spine and 12° in the lower thoracic spine. However, thoracic spine extension i.e. pulling shoulders backward and pushing the chest out is far more limited and the degree to which it occurs is the same throughout the thoracic spine. This may be due to the facets impacting on one another during extension. Lateral flexion produces approximately 7° of movement, which may increase lower in the thoracic spine to approximately 9° (Bergmann and Peterson, 2011). A similar degree of rotation is present in the thoracic spine, this is approximately 8° to 9° and unlike extensions, decreases considerably in the lower thoracic spine (Bergmann and Peterson, 2011). Bergmann and Peterson (2011), suggest that this decrease may be due to the alteration of the orientation of the facets from the lower thoracic spine to those in the lumbar spine.

The movements of the ribcage and thoracic spine result in the occurrence of biomechanical coupling (Phillip et al., 2007). This was best described by Panjabi (1992) who said that it may be likened to the two degrees of motion that occur simultaneously when tightening and/ or loosening a screw i.e. rotation of the screw (tightening or loosening) causes it to translate inward or outward. Translation implies that a body is moving in the same direction as a fixed point and rotation implies that a body spins or has an angular position about an axis (Panjabi, 1992). The global kinematics spine occur as follows; flexion and extension, and right and left rotation are movements that occur along and about the coronal axis, respectively. Abduction and adduction are movements that rotate about the sagittal axis and medial and lateral rotation are movements that occur about a vertical or a longitudinal axis. Arthrokinematics refers to the movement of a joint independent of the global kinematics of the spine during motion (MacConaill and Basmajian, 1977).

The biomechanics and kinetics of the thoracic spine and ribs/ ribcage will be discussed further with illustrative aids:

Lee's (1993) study proposed a clinical model of the in vivo (i.e. in its' natural environment) biomechanics of the thoracic spine, with the FSU and 3 Cm of the bilateral ribs intact. Based on the work of Panjabi, Brand and White (1976), Lee (1993) suggested that flexion

(Figure 2.5) of the thoracic spine occurs with anterior rotation in the sagittal plane and x-axis, anterior translation along the z-axis and minimal distraction along the y-axis (Figure 2.6). Globally, the rib cage flattens superiorly and inferiorly, increasing the sternal angle and allowing for forward flexion of the thoracic spine (Bergmann and Peterson, 2011). Arthrokinematically i.e specific movements of the joints, the inferior facets of the superior vertebral body flex over and separate from the superior facets of the inferior vertebral body (Fruth, 2006), gliding in a superoanterior direction (Lee, 1993). This allows the vertebral motion segment to rotate around the x-axis facilitating forward flexion (Moore and Dalley, 2006). Concomitantly, there is the coupled rotation of the superior aspect of the rib heads anteriorly (Figure 2.7). The ribs rotate anteriorly and superiorly at the costovertebral joint (Fruth, 2006) (Figure 2.7). This costovertebral rotation occurs about the coronal plane and along the neck of the rib, with the anterior aspect moving inferiorly and the posterior aspect moving superiorly. This movement along the neck of the rib causes the tubercle of the rib to glide superiorly at the costotransverse joint, further supporting the anterior rotation occurring at the neck of the rib and thus the forward flexion of the FSU. Truncal forward flexion is limited by the attachment of the posterior ligamentous and muscular structures (Lee, 1993).

The findings of Fruth (2006), Lee (1993) and Panjabi et al. (1976) indicated that during flexion of the thoracic spine, movement occurs at both the thoracic facet and costovertebral joints. These are two integral components which have the capacity to produce pain, should there be mechanical discord in either (Gatterman, 2005). The mechanical dysfunction of either the thoracic facet or the costovertebral joint may cause mbp and affect the range and quality of motion in the thoracic spine. Similarly, the co-dependent behaviour of these joints observed during flexion, was also observed during extension (Figure 2.8 – 2.10), lateral flexion (Figure 2.11 – 2.13) and rotation (Figure 2.14 – 2.16) of the thoracic spine.

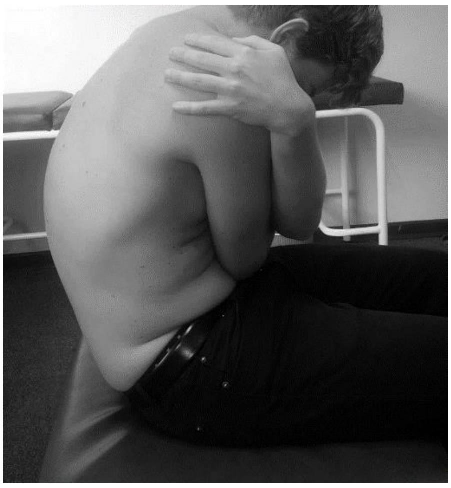


Figure. 2.5 Thoracic spine flexion (Petersen, 2017).

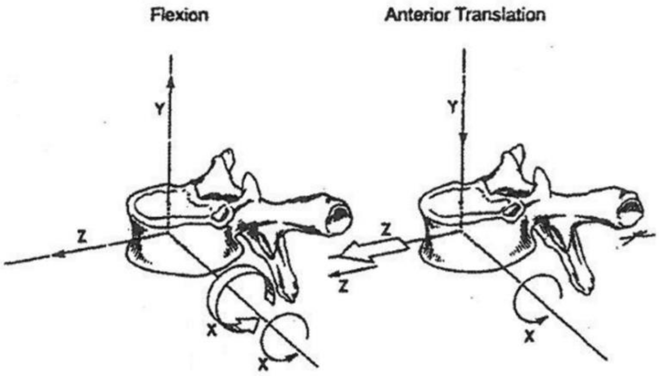


Figure. 2.6 Illustrates the movement at the axes of the thoracic vertebra during flexion. Anterior rotation around the x-axis, forward translation along the z-axis and distraction along the y-axis (Lee, 1993).

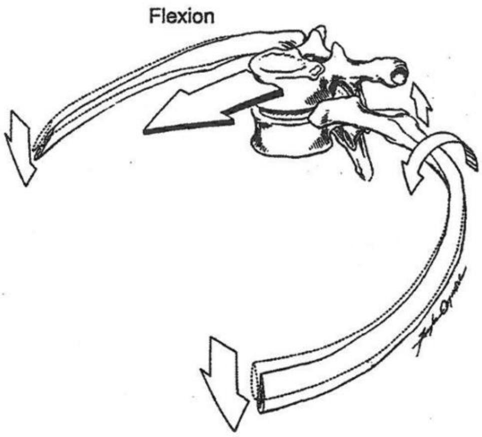


Figure. 2.7 Illustrates the simultaneous movement of the rib and thoracic vertebra during flexion. The rib rotates in a superoanterior direction as a result of the forward translation of the thoracic vertebra (Lee, 1993)

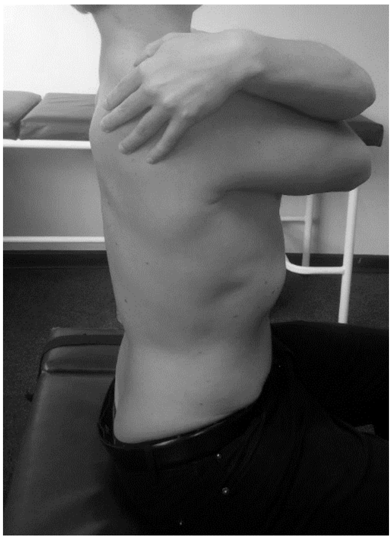


Figure. 2.8 Thoracic spine extension (Petersen, 2017).

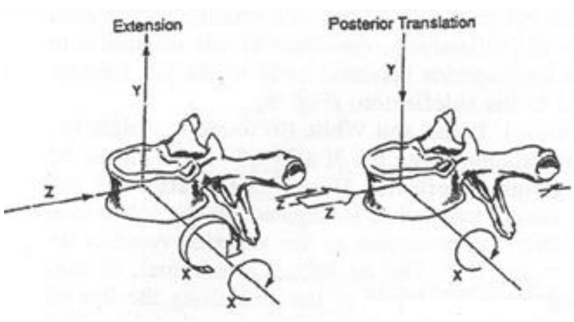


Figure. 2.9 An illustration of the movement at the axes of the thoracic vertebra during extension. Posterior rotation around the x-axis, posterior translation along the z-axis and compression along the y-axis (Lee, 1993).

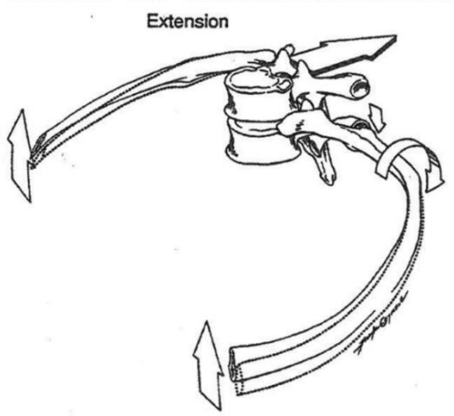


Figure. 2.10 An illustration of the simultaneous movement of the rib and thoracic vertebra during extension. The rib rotates in an inferoposterior direction as a result of the posterior translation of the thoracic vertebra (Lee, 1993).

Figure. 2. 11 Thoracic spine lateral flexion (Petersen, 2017).

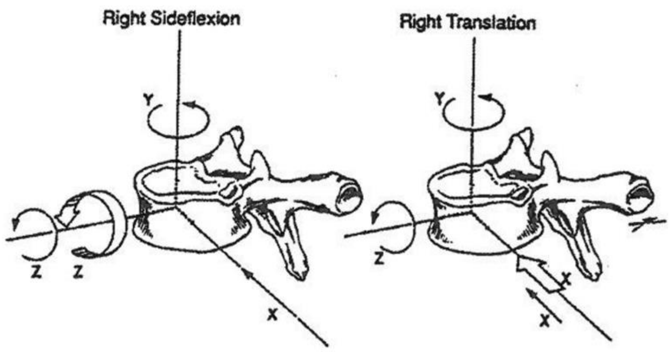


Figure. 2.12 An illustration of the movement at the axes of the thoracic vertebra during right lateral flexion. Right translation along the x-axis, right rotation about the z-axis and left rotation about the y-axis (Lee, 1993).

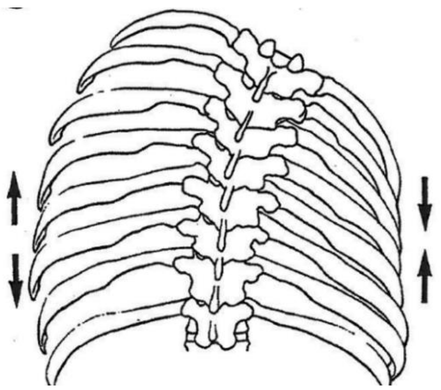


Figure. 2.13 An illustration of the movement of the ribs during truncal right lateral flexion. The ipsilateral ribs approximate and the contralateral ribs separate (Lee, 1993).

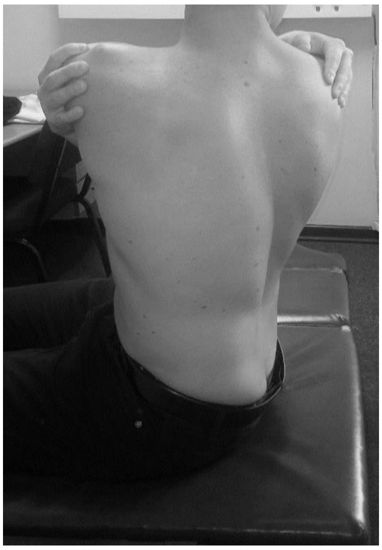


Figure. 2. 14 Thoracic spine rotation (Petersen, 2017).

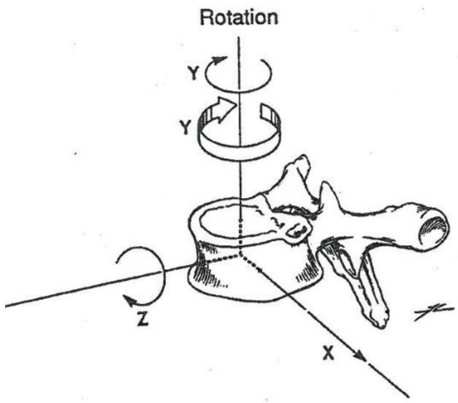


Figure. 2.15 An illustration of the movement at the axes of the thoracic vertebra during rotation. Contralateral translation along the x-axis, contralateral rotation about the z-axis and ipsilateral rotation about the y-axis (Lee, 1993).

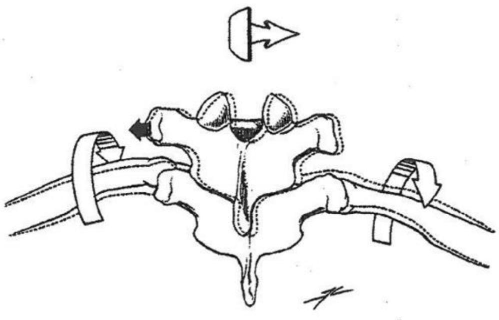


Figure. 2.16 An illustration of the simultaneous movement of the rib and thoracic vertebra during rotation. The rib rotates in an anterior direction as a result of the ipsilateral rotation of the thoracic vertebra (Lee, 1993).

The literature (Lee, 1993; Oda et al., 1996; Phillip et al., 2007) strongly supports that the biomechanics and kinematics of the thoracic spine are influenced by the attachment of the rib cage. Studies indicated that the biomechanics and kinematics of the thoracic facet and costovertebral joints are mutually dependent. Global movement of the thoracic spine involves local movement of both the facet and costovertebral joints for the execution of harmonious and smooth motion. The articulations of the ribs at any given thoracic vertebral level directly influence on the biomechanics of that vertebral level. And the attachment of the rib cage influences the global biomechanics of the thoracic spine. Thus, it stands to reason that should dysfunction occur in either joint, it is likely to influence the unaffected joint between them and if untreated, a perpetual cycle of joint malposition, decreased mobility and pain may ensue (Bergmann and Peterson, 2011).

These studies highlight the biomechanical relationship between the thoracic spine and ribcage. Previous studies (Bergmann and Peterson, 2011; Lee, 1993 and Oda et al., 1996) suggest that the thoracic facet and costovertebral joints are responsible for the movement of the thoracic spine and ribcage during motion and are mutually dependent on each other to allow for motion to occur. Lee (1993) and Oda et al. (1996) demonstrated that movement in either joint (i.e. thoracic facet or costovertebral) would have a direct effect on the motion occurring in the other forming a closed kinematic chain between the thoracic facet and costovertebral joints. Therefore, the researcher proposed that if there is dysfunction of either the thoracic facet or costovertebral joints, aberrant motion may ensue in the unaffected joint. Joint dysfunction is a cause of mid-back pain, therefore, the mechanical correction of the affected joints, using manipulation, may reduce pain and improve range and quality motion in the thoracic spine.

2.4 Aetiology of Mid-back Pain

2.4.1 Causative Factors

Mbp of musculoskeletal origin may be generated by pathology, structural anomalies and dysfunction of the structures in and surrounding the thoracic spine. Pathological causes may include osteoporosis (David, Patricia, Schweickert, William, Jensen, 2002), rheumatoid arthritis (Chadwick and Silvano, 2015), cancer (Downie, Williams, Henscke, Hancock, Ostelo, de Wet, Macaskill, Irwig, van Tulder, Koes, Maher, 2013), pulmonary disease (HajGhanbari, Holsti, Road, Reid, 2012), rib or vertebral fracture (David et al., 2002), spinal stenosis (Manchikanti et al., 2012), ankylosing spondylitis (Van Tubergen, Ramiro, van Heijde, Dougados, Mielants and Landewe, 2012) and intervertebral disk herniation (Fruth, 2006). Some congenital anomalies such as, Scheuermann's disease (Wood, Melikian and Villamil, 2012), hyperkyphosis (Ettinger, Black, Palermo, Nevitt, Melnikoff, Cummings SR, 1994), scoliosis (Smith, Shaffrey, Berven, Glassman, Hamill, Horton, Ondra, Schwab, Shainline, Fu and Bridwell, 2009), butterfly vertebrae (Patinharayil, Han, Marthya, Meethall, Surendran and Rudrappa, 2008) may also contribute to the development of mbp. Dysfunctional causes may include active myofascial trigger points (Irwin, 2015), herniated intervertebral discs and facet and costovertebral joint dysfunction (Fruth, 2006).

Horton (2002) suggested that due to their innervation, the thoracic facet and costovertebral joints may cause mbp, should dysfunction occur in either. A study demonstrating the presence of mechanoreceptors in the facet joints showed that mechanical loading and inflammation can trigger a nociceptive cycle of afferent input and reflex hyper tonus and pain (Erwin, Jackson, Homonko, 2000). Erwin et al. (2000) suggested that the presence of similar nociceptive neurons in and around the costovertebral joints may produce a pain cycle like that produced by the thoracic facets (Erwin et al., 2000). Manchikanti, Singh, Falco, Cash, Pampati and Fellows' (2010) study was conducted in the United States of America and investigated the effectiveness of thoracic medial branch blocks in the treatment of mbp after a one year follow up. One hundred participants were selected by random allocation from patients that presented at a pain focused practice, with non-specific mbp of greater than six months' duration. The diagnosis of thoracic facet joint pain was confirmed by local anesthetic blocks (Manchikanti et al., 2010). The participants were divided into two groups of fifty each. One group received bupivacaine nerve blocks and the other received bupivacaine and non-particulate betamethasone nerve block. The group that received the bupivacaine nerve blocks showed an 80% improvement when assessed through the Oswestry Disability Score Test and the group that received the combined nerve blocks showed an 84% improvement. Overall, pain relief was noted in 90% of the participants in both groups. This study further supports the evidence (Gatterman, 2005 and Horton, 2002) that the thoracic facet joints play an important role in mbp. Therefore, the treatment of dysfunctional thoracic facet joints, with spinal manipulation, may result in the modulation of pain and the improvement or resolution of mbp.

2.4.2 Risk Factors

The risk of mbp increases with age, gender and occupation (Briggs, 2009a). Studies on mbp have all indicated a similar age prevalence for mbp. Schiller's (1999) study on mid-back pain indicated that approximately 47% of the study sample was between the ages of 16 to 24 years old and 30% were between the ages of 25 and 34 years old. Similarly, Dimopoulos' (2002) study indicated that 45% of the sample were between the ages of 18 and 24 years old and 40% were between the ages of 25 and 34 years old. The findings in Wong and Fielding's (2011) study correlated with these results. Wong and Fielding's (2011) study was conducted in Hong Kong, in the form of a survey of chronic pain in the general population (sample of 5001 participants). The results of this study suggested that 25% of the sample were between the ages of 18 to 29 years of age and 27.8% had chronic back pain. These studies show that mbp is common in the adult working population.

Studies have also suggested that mbp may be prevalent in women (Benjamin, 2007 and Roquelaure et al. (2014). Benjamin's (2007) study was conducted in South Africa in a teaching chiropractic clinic. The study was in the form of a retrospective survey of the thoracic cases seen over a 10-year period (1995 to 2005) (Benjamin, 2011). Benjamin (2011) found that between 1995 and 2000, 52% of the study sample were women that presented with mbp and this percentage increased to 79%, between 2001 and 2005. These findings indicated that mbp was prevalent in women that presented to the DUT CDC between the periods of 1995 to 2005. In a similar study conducted in Denmark, a correlation was found between spinal pain and the female gender. The findings of this study were obtained in the form of a survey of the form of a survey of the general Danish population. The results suggested that in the study sample, women were 20% more likely than men, to report and experience mbp (Leboeuf-Yde, Nielsen, Kyvik, Fejer, Hartvigsen, 2009). These studies suggested that mbp may be more common in women than in men.

Studies have indicated that poor posture may increase the risk of and perpetuate of mbp. This increase in risk may be attributed to periods of sustained abnormal posture and as a result abnormal, excessive strain of the thoracic spine (Maffulli and Bruns, 2000). Therefore, causing alterations in the thoracic spine biomechanics and kinematics, which may pre-dispose to muscle imbalances (i.e. some muscles may become weaker) (Kebaetse, McClure, Pratt, 1999). Adirim and Cheng (2003) study highlighted that overuse and repetitive activities such as, carrying a handbag on the same side, may also be a risk factor for mbp. This study overviewed injuries that young athletes are susceptible to and found that overuse and repetitive actions, especially repetitive thoracic rotation may cause injury to the thoracic spine (Adirim and Cheng, 2003). Thus pre-disposing to the development of mbp.

2.5 The Presentation of Thoracic Facet and Costovertebral Joint Dysfunction

The pain produced by thoracic facet dysfunction may be localized or can refer to pain to other areas of the mid-back (Aiken and Vaugh, 2013). Dysfunction of the facet and costovertebral joints may present similarly, with ipsilateral or central pain occurring in the mid-thoracic spine and interscapular regions (Dimopoulos, 2002; Fruth, 2006; Young, Gill, Wainner and Flynn, 2008). The joint dysfunction and pain exhibited in mbp may be because of noxious afferent input from the articular receptors that are stimulated with joint dysfunction (Cleland et al., 2007). Costovertebral joint dysfunction may or may not accompany dysfunction of the facet joints (Gatterman, 1995).

A study by Young et al. (2008) investigated the pain referral patterns of the costovertebral joints of eight asymptomatic male participants. A non-irritant contrast was injected into the 21 costovertebral joints. The injections were administered to either the costovertebral joints of T2, T4 and T6 on the right or T3, T5 and T7 on the left. The participants reported a unilateral local deep, dull aching and pressure sensation and one of the participants that received the T5 costovertebral injections reported a local sharp, burning pressure (Young et al., 2008). The participants that received the T2 costovertebral injections experienced referral pain to the thoracic vertebral segment above and below the segment administered with the contrast (Young et al., 2008). Fruth (2006) suggested that in some cases pain referral into the chest and shoulder may be produced by dysfunction of the costovertebral joints (Fruth, 2006).

Swiss practitioners (Arroyo, Jolliet and Junod, 1992) reviewed 5 cases of costovertebral dysfunction that presented with atypical chest pain. Vertebral palpation and rib mobilization of the dysfunctional segments produced localized pain and reproduced the presenting symptoms (Arroyo et al., 1992). Fruth (2006) reviewed a case of mbp caused by costovertebral dysfunction and found that the patient reported an increase in pain with deep breathing, coughing and sneezing (Fruth, 2006). In a case review by Austin and Benesky (2002), a swimmer with mbp showed aggravation of pain with trunk rotation and deep inhalation. In another review of mbp, Chadwick and Silvano. (2015) observed the effect of costovertebral manipulation on a rheumatoid patient and noted that the pain was made worse with coughing and trunk extension and rotation. The examination of the patient also produced pain with palpation of the affected thoracic vertebral segments (Chadwick and Silvano, 2015).

2.6 The Neurophysiology and Effects of Spinal Manipulation

Pickar (2002) suggested that spinal manipulation may mechanically overload the manipulated vertebral segment and interfere and alter the signals transmitted by the surrounding tissues that are sensitive to mechanical, chemical and nociceptive stimulation (Pickar, 2002). This alteration in sensory afferent input may cause changes in neural interactions by affecting reflex activity or central neural integration in the motor, nociceptive or autonomic neurons (Pickar, 2002). During manipulation of the facet joints, there is an initial cohesion of the articular surfaces preventing their separation, until the point at which the tension created within the joint is enough to result in a decrease in the joint pressure (McFadden and Taylor, 1990). This effect was observed in Maigne and Guillon’s (2000) study. This intra-articular event may be accompanied by an audible 'crack or pop', and is referred to as a 'cavitation'. This auditory manifestation is caused by the change in sub-atmospheric pressure within the joint space, because of the release of intra-articular gases (Leach, Lantz and Phillip, 1994).

As per the works of Gatterman (2005) the theory of intervertebral encroachment, suggested that the encroachment of the neural contents of the intervertebral foramen may interfere with the neural impulses transmitted to the central nervous system. Thus, symptoms of increased (i.e. pain, muscular hypertonicity) or decreased neural activity (i.e. muscle weakness) may be produced (Gatterman, 2005). A clinical trial undertake by Floman, Liram and Gilai (1997), investigated the effects of spinal manipulation on the H-reflex (i.e the reflex reaction of muscles after their nerves have been electrically stimulated) changes in participants with a unilateral disc herniation. Twenty-four participants with herniation of the L5 – S1 intervertebral discs were recruited for this study. The H-reflex was recorded bilaterally before and after the spinal manipulation. These recordings were obtained from electrodes attached to the medial aspect of the gastro-soleus muscle, induced by the excitation of the tibial nerve fibers within the popliteal fossa. All the participants received a single L5/S1 lumbar spine manipulation. The results showed that the post-manipulation measurements of the H-reflex had increased and were statistically significant *(p* = 0.0037)*.* These findings suggested that spinal manipulation was effective in increasing the H-reflex in participants with unilateral disc herniation of L5/S1 intervertebral disc. The results of this study indicated that spinal manipulation was effective in the treatment of radicular symptoms caused by intervertebral disc herniation (Floman et al., 1997).

Gatterman's (2005) theory of altered somatic afferent input suggested that aberrant input from non-neural structures i.e. facet joint, muscle and joint capsule, may mimic the symptoms of those produced by the encroachment of neural contents (Gatterman, 2005). The joint capsule is composed of two layers, the outer fibrous layer and the inner synovial membrane, both of which are innervated by the medial branches of the dorsal ramus nerve (Moore and Dalley, 2006). Thus, it has the potential to generator pain.

A study conducted in Denmark, investigated the effects of spinal manipulation on the sensorimotor integration in the prefrontal cortex. Nineteen participants with spinal joint dysfunction and pain were placed in a supine position and attached to an Electroencephalogram (EEG). The study consisted of three sessions, the first session involved thorough screening of the participants, the second session involved manual manipulation of the lumbar spine and sacroiliac joints and the third session involved a sham treatment mimicking chiropractic manipulation, by assisting the participant or asking the participant to perform movements of the body and spine. The data used for interpretation were the Amplitude analysis of N30 and brain source localization obtained from the EEG readings. The results for the Amplitude analysis of N30 showed that there was a statistically significant difference between the group that received the sham treatment *(p* = 0.4) and the group that received the spinal manipulation *(p* = 0.02). These results were similar for the brain source localisation measurements, which showed a statistically significant difference between the group that received the sham treatment *(p* = 0.2) and the group that received the spinal manipulation *(p* = 0.03). These findings suggested that spinal manipulation had a direct effect on the somatosensory processing, specifically within the prefrontal cortex (Lelic et al., 2016). Lelic's et al. (2016) study supported the theory of altered somatic afferent input and suggested that spinal manipulation had an effect on the signals transmitted by the sensory-somatic receptors in the spine to the central nervous system (Gatterman, 2005). The theories of Gatterman (2005) and the research findings in Lelic's et al. (2016) study suggest that the effects of spinal manipulation would cause modulation of pain at a spinal cord level, which effectually may alter the interpretation of pain in the Central nervous system. Therefore, the sensory input of manipulation at both a spinal and extra-spinal i.e costovertebral joints level may amplify the effects of spinal manipulation alone.

Manipulation aids in increasing the mobility of restricted joints (Gatterman, 2005). Bergmann and Peterson (2011) suggested that mbp caused by joint dysfunction may result in local pain, altered spinal alignment and hypertonicity of the local musculature. The soft tissue changes that may be caused by joint dysfunction, further alter or perpetuate aberrant articular biomechanics by causing soft tissue fibrosis, decrease spinal flexibility and increasing the likelihood of joint instability (Panjabi, 2003). Manipulation is able to increase mobility via its effect on various mechanism, such as increasing joints spaces. Theories are suggested that the separation of articular surfaces may release entrapped synovial segments/ folds (Schekelle, 1994), break down adhesions that may be limiting joint motion (Indahl, Kaigle, Reikeras, Holm, 1997) or increase tension on the joint capsule which may inhibit muscular spasm (Bogduk and Jull, 1985). A randomized clinical trial conducted by Cramer, Tuck Jr, Knudsen, Fonda, Schliesser, Fournier and Patel (2000) in America, sought to observe the effect of chiropractic spinal manipulation on the joint spacing of the lumbar facet joints. Sixteen participants were randomly allocated into four groups of four each. Magnetic Resonance Imaging (MRI) scans of the lumbar facet joints were taken before and after the lumbar spine manipulation. The scans were examined by three radiologists, who were blinded to the group randomization and whether the scans were before or after the manipulation. The results showed that there was an increase of 0.7mm in the lumbar facet joint spaces after lumbar spine manipulation. Thus, due to the increase in the facet joint spaces after chiropractic manipulation, it is suggested that manipulation of facet joints may increase spinal mobility (Cramer et al., 2000). Campbell and Snodgrass (2010) investigated the immediate mechanical effects of manipulation on the mid-back which revealed a slight decrease in '" stiffness" post-manipulation, as opposed to the pre-manipulation "stiffness" measured. In this study 24 asymptomatic participants were recruited and the "stiffness" of the manipulable thoracic vertebral segment and two segments above and below were measured prior to and after manipulation. The mechanical effects and improvement in stiffness were associated with the specific vertebral segment manipulated (Campbell and Snodgrass, 2010). Campbell and Snodgrass (2010) found that the change in PA stiffness ranged from 0.11 – 6.33 N/ mm (Newtons per millimeter) and suggested that the changes would be detectable by manual therapists. These results suggested that the change in stiffness of the spinal segments was significant enough that it would be detectable by manually palpating the treated segments. Campbell and Snodgrass (2010) proposed that the positive mechanical effects of manipulation may be amplified in participants with more severe thoracic restrictions.

Maigne and Guillon (2000) conducted a study that investigated the effect of lumbar spine manipulation on intervertebral movements and intra-discal pressure. The study involved the application of two different lumbar spine manipulations on two unembalmed cadavers. Cadaver one had a pressure sensor inserted into the intervertebral disc between L3 and L4 vertebrae, which were fitted with a two monoaxial (measures acceleration in the vertical axis) and one biaxial accelerometer (measures acceleration in the horizontal axis) (Maigne and Guillon, 2000). Cadaver two had a pressure sensor inserted into the intervertebral discs between L1 to L5 vertebrae, L4 and L5 were fitted with a two monoaxial (measures acceleration in the vertical axis), and one biaxial accelerometer (measures acceleration in the horizontal axis). A total of four lumbar spine manipulations were performed on each cadaver, two in flexion and two in extensions. The results of this study showed that there was an initial increase in intra-discal; pressure (mean value, 0.5 ± 0.17 bar) followed by a decrease in intra-discal pressure (mean value, 0.65 ± 0.2bar). The results also showed that there was movement of the vertebral endplates relative to the initial increase (approximation of endplates by 1.1mm) and decrease of intradiscal pressure (Maigne and Guillon, 2000). Therefore, the assumption can be made that should an intervertebral disc become entrapped and symptomatic, manipulation may liberate this entrapped potion of the disc and relieve its symptoms.

Vincenzino, Collins, Benson and Wright (1998) proposed that the abrupt stretching of the musculoskeletal structures of that surrounding a restricted vertebral segment, may reduce pain by activating the "diffuse descending pain inhibitory system" and increase the pain PPT by encouraging the presynaptic inhibition of the skin (Vernon, Dhami, Howley and Annett, 1986). The presence of nociceptors within the spine predispose it to pain caused by dysfunction or irritation of its structures (Gatterman, 2005). These receptors are specialized to detect mechanical, chemical and thermal changes (Haldeman, 2005). Thus, changes in stimuli may be interpreted by the central nervous system as pain, depending on their degree of stimulation (Haldeman, 2005). Gatterman (2005) proposed is that manipulation on affected spinal segments, and by extension, the spinal structures responsible for the aberrant input, will help 'normalize' the aberrant afferent input to the central nervous system.

Fryer et al. (2004) conducted a study on 96 asymptomatic participants to investigate the immediate effect of manipulation and mobilizations on the PPT in the mid-back. The participants were screened for palpatory tenderness of thoracic vertebral segments and the PPT were taken prior to manipulation. Participants were divided into three groups, receiving manipulation, mobilization or a sham laser application. There was a significant improvement in the group that received the mobilizations and the manipulation group was statistically significant with $p = 0.04$ (Fryer et al., 2004). A similar Spanish study investigated the effect of a cervico-thoracic manipulation on the PPT of C5 and C6. Thirty asymptomatic participants were recruited for this study and divided into three groups of ten: Group A received the C7-T1 manipulation on the right-hand side, Group B received the C7-T1 manipulation on the left-hand side, and Group C received a sham manual procedure. The results of this study showed that Group A and B ($p < 0.05$) had a statistically significant difference in PPT compared Group C ($p > 0.8$) (Fernandez-de-las-Penas, Alonso-Blanco, Cleland, Rodriguez-Blanco, Alburquerque-Sendin, 2008).These studies suggested that spinal manipulation was effective in increasing the PPT within the spine.

Gatterman (2005) suggested that manipulation may have an effect on muscular hypertonicity. Mechanoreceptors present in the spine, are specialized to detect stimuli that cause physical or mechanical changes in the facets, muscles, ligaments, capsules and skin. They are divided into two categories; muscle spindles and Pacinian corpuscles. Muscle spindles are slow adapting receptors and signal the amount and speed of muscle stretch required. Lengthening of a muscle stretches its intra-fusal fibers, whereas contraction of a muscle shortens them (Haldeman, 2005. The Pacinian corpuscles are rapidly adapting receptors and signal the onset and resolution of a mechanical stimulus.

A descriptive study collected the Electromyographic (EMG) data from 16 participants from two different chiropractic clinics. This study investigated effect of spinal manipulation on the paraspinal muscle activity. They were chosen from patients presenting to these clinics with low back pain and divided into two groups of eight each: Group One received the activator treatment and Group Two received the manual manipulative treatment. The practitioners palpated each participant for the paraspinal muscles with the most tension, and placed Electromyographic (EMG) electrodes over those areas. The lumbar spine manipulations were performed by either using the activator gun method or manual manipulation. Sixteen paraspinal muscles were monitored in the total of eight participants in the manual manipulation group. The results indicated that thirteen of the sixteen monitored sites had a decrease in EMG activity by $\geq$ 25%. However, some participants showed an initial increase, followed by a decrease in paraspinal muscle activity. These results suggested that spinal manipulation causes an immediate decrease in paraspinal muscle activity in some participants with low back pain (DeVotch 2005; Pickar 2002 and Wilder, 2005). Thus highlighting that spinal manipulation may affect the transmission of information from the mechanoreceptors to the central nervous system, but also, aid in muscle relaxation. No further statistical data was provided for this study.

In conclusion, spinal manipulative therapy may be able to alter pain perception by way of the following mechanisms:

- Altering sensory pain input at a spinal cord level
- Activation of descending pain inhibitory pathways
- Increasing range of motion and decreasing joint stiffness
- Reducing muscle tension in the surrounding musculature

2.7 Manipulation and Studies on the Effectiveness of Thoracic Facet and Costovertebral Joint Manipulation

Chiropractic manipulation is a mechanically oriented treatment that has a direct effect on the biomechanics of the joint to which it is applied (Hessel, Herzog, Conway, McEwen, 1990). One of the core principles of chiropractic is to provide gentle methods of treatment to aid the natural ability of the body to repair injury, heal disease and encourage good overall health (Haldeman, 2005). Spinal manipulation is the application of a controlled, specific, high-velocity thrust through a joint with aberrant motion with the intention of moving the joint beyond its point of resistance to its neutral anatomical limit (Leach et al., 1994). There is an initial gradual pre-loading force applied through the joint, followed by a swift thrust with a greater force (Hessel et al., 1990). The force is applied in a direction that is continuous with the orientation of a restricted joint, with the intention of aiding in the correction of aberrant vertebral motion (Bereznick, Ross and McGill, 2002).

In a retrospective chiropractic survey conducted in Spain, Wenban (2003) investigated whether the chiropractic care delivered in a practice, was supported by sound evidence. The data was collected from 180 patient files from a chiropractic clinic in Spain. These were reviewed by the researcher and the clinic chiropractor. The chiropractor delivering the treatments in this study was blinded to the purpose of the study, thus reducing bias in the study. The patient complaints were paired with the chiropractor's chosen course of treatment and then compared to the supporting literature. The literature used was sourced from local Spanish medical libraries and electronic databases (Medline and Mantis) from the periods 1966 to 1998. Fourteen clinical trials were used in the study and fitted the criteria. These clinical trials were critically appraised and given a score out of 100. If the score was equal to ≥ 50, the trial was considered to be of good quality. If the score was < 50, the trial was considered to be of poor quality. The treatment interventions used were categorised according to the level of supporting evidence. Category 1: interventions with one or more good quality clinical trials and Category 2: interventions with experimental evidence. The results of this study indicated that 68% of the interventions used in the 180 patients, were supported by good quality clinical trials. The results of this study suggested that chiropractic treatment (i.e. including spinal manipulation) may provide a significantly high level evidence of evidence based treatment in practice (Wenban, 2003). There was good blinding in this study, with the chiropractor unaware of the intent of the study. However, to further reduce bias, the selection and appraisal of the clinical trials used, could have been done by a blinded third party.

Manipulation is applied to a manipulable lesion, which is a restricted joint with decreased mobility, slight incongruence of the articulating surfaces and may be accompanied by pain (Leach et al., 1994). In the spine these manipulable joints are referred to as the facet joints (Moore and Dalley, 2006). The most affirming evidence of the effectiveness of manipulation on the mid-back are from studies conducted on symptomatic participants. Wei-dong et al. (2013) conducted a study in China on the effectiveness of Tuina (i.e. Eastern form of manipulation) and electroacupuncture (i.e. acupuncture with and electrical current through the needles) on thoracic facet joint dysfunction. Eighty participants between the ages of 16 and 70 years old were randomly selected. There were no statistically significant differences in age and gender of the participants, which made the results comparable. The participants were divided into two groups by the randomisation of the SPSS 16.0 version software; a manipulation group and an electroacupuncture group and received 5 to 7 treatments each. The results indicated that the manipulation group had a 92.5% recovery and the electroacupuncture group had a 47.5% recovery. The difference in results between the groups was statistically significant with $p \leq 0.001$. The results of this study also reflected a statistically significant decrease in pain perception according to the Visual Analogue Pain Rating Scale (VAS), with $p \leq 0.001$. The results of this study indicated that manipulation (i.e. Tuina) was more effective than electroacupuncture in the treatment of mbp caused by thoracic facet joint dysfunction (Wei-dong et al., 2013). However, there was no indication of blinding in this study, which may have reduced bias. These findings correlated with Schiller's (1999) study, which was conducted at the DUT in South Africa. Schiller (1999) investigated the effectiveness of thoracic facet manipulation compared to a placebo procedure (i.e. non-functional ultrasound) on for the treatment of mbp. Thirty-six participants were selected using randomised sampling and were divided into two groups that either received thoracic facet manipulation or the placebo procedure. The study was conducted over a period of two weeks, with a total of six treatments given to each group. The results for the manipulation group indicated that there was a statistically significant difference in the subjective measurements, with regards to disability and pain perception and intensity ($p < 0.000$), between the final and first treatments. The same was observed in the results for the objective measurements in the manipulation Group, with regards to the PPT ($p = 0.000$) and thoracic spine ROM ($p < 0.05$). The inter-group results for the objective measurements study also indicated a statistically significant difference between the manipulation group and the placebo group. The manipulation Group had a greater improvement disability ($p = 0.047$) and thoracic spine ROM in left and right lateral flexion ($p < 0.05$) and right rotation (p – 0.304), by the last treatment (Schiller, 1999). The results of Schiller's (1999) study suggested that thoracic facet manipulation was more effective than the placebo procedure in the short-term management of mbp. The inclusion of a placebo group and blinding of the study participants reduced bias. However, the researcher was not blinded at all and performed the screening, interventions and data capture for this study. To further reduce bias, it may have been beneficial for the screening and data capture to have been done by a third party. The sample size for this study was small and although the results did show statistical significance, the findings of this study are more insightful than conclusive.

Another study conducted at the DUT in South Africa (Pillay, 2001) compared the effectiveness of thoracic facet manipulation and passive thoracic spinal mobilisations. Forty participants were divided into two groups of twenty: group one received five treatments of thoracic facet manipulation and group two received five treatments of passive thoracic spinal mobilisations. This study was conducted over a period of two weeks. By the final treatment, the results indicated that according to the McGill Numerical Pain Questionnaire (p = 0.000) and NPRS (p = 0.000), the manipulation group had a statistically significant difference in pain perception (Pillay, 2001). Similarly, the inter-group results indicated that according to the McGill Pain Questionnaire (p = 0.008), there was a statistically significant difference in pain perception between the groups. There was no statistical significance between the two groups for the Algometry measurements (Pillay, 2001). Pillay's (2001) findings do indicate that the manipulation group showed a statistically significant improvement when compared to the mobilisations group. However, there was no control group and the researcher was not blinded to the screening of the participants nor during data capture. Similar to Schiller's (1999) study, this may have resulted in bias. Pillay's (2001) results were in contrast with those obtained by Dimopoulous (2002). A year later, Dimopoulos (2002) conducted a randomized controlled clinical trial, conducted at the DUT in South Africa. This study compared the effectiveness of thoracic facet manipulation and passive oscillatory mobilisations for the treatment of mbp. Forty participants were selected through randomised sampling and divided into two groups of twenty each and received four treatments over a period of two weeks (Dimopoulos, 2002). By the fifth treatment, the results for the intra-group analysis indicated a statistically significant difference in pain perception (p = 0.000), PPT (p = 0.000) and ROM ($p \leq 0.001$) in the manipulation group. However, the results for the inter-group analysis indicated no statistical significance between the two groups. This suggested that spinal manipulation and passive oscillatory mobilisations were equally effective in the treatment of mbp. The difference between Pillay's (2001) study and Dimopoulos' (2002) may be because of the difference in pain ratings between the two groups at the outset between the two groups because Pillay's (2001) study had participants in the mobilisation group with more severe symptoms compared to the manipulation group (Dimopoulos, 2002; Pillay, 2001). However, both studies indicated that spinal manipulation was effective in the treatment of mbp.

Tsolakis (2001) conducted a comparative study at the DUT in South Africa. This study compared thoracic facet manipulation and interferential current therapy (IFC) for the treatment of mbp. Sixty participants were selected through randomised sampling and were divided into two groups which received thoracic facet manipulation or IFC over the thoracic spine. The participants received a minimum of three and a maximum of six treatments, over a period of one to two weeks. The results of Tsolakis' (2001) study indicated that there was a statistically significant difference in disability ($p = 0.000$) and pain perception ($p < 0.000$) in the manipulation group. Similarly, the PPT ($p = 0.031$) and ROM ($p < 0.05$) measurements also showed statistical significance. These results indicated that thoracic facet manipulation was effective in the treatment of mbp. However, there was no statistical significance between the two groups with regards to the pain perception, PPT and ROM measurements. The lack of a control group and researcher blinding may have affected bias in this study. The results of Tsolakis' (2001) study may have been influenced by the lack of consistency between the groups such as, the variable number of treatments and the different treatment periods between the participants.

These studies provide useful insight into the effectiveness of spinal manipulation as a treatment for mbp (Pillay, 2001; Schiller, 1999 and Tsolakis, 2001). They highlight the role of the thoracic facets as pain generator in mbp (Dimopoulous, 2002; Pillay, 2001 and Tsolakis, 2001). Although the findings of these studies show statistical significance, the small sample sizes and the potential for bias, provide informative but inconclusive evidence.

As discussed, the literature provides good pilot study evidence for the effectiveness of manipulation of the thoracic facet joints in the treatment of mbp, but there are few studies concerned with the role of the costovertebral joints in mbp (Fruth, 2006 and Oda et al., 1996). In Fruth (2006) case study of mbp, the patient presented with pain of 4 months' duration and decreased functionality due to pain. After seven treatments of rib mobilisations and trigger point therapy over 4 weeks, the patient reported relief of pain and could perform daily functional tasks without pain (Fruth, 2006). In an older case study of swimmers with mbp, both thoracic facet and costovertebral joint dysfunction were reported as major contributors of pain. It was noted that the swimmers reported a significant decrease in mbp within 48 hours of thoracic facet and/ costovertebral joint manipulation (Thomas, 1988). Thomas (1988) suggested that approximately 19% of the swimmers who had mbp was attributed to costovertebral joint dysfunction.

Chadwick and Silvano (2015), reported on the case study of a rheumatoid patient with unilateral mbp. The patient was diagnosed with costovertebral dysfunction of the sixth and seventh ribs. The treatment included manipulation of the restricted costovertebral joints which were manipulated over four treatment sessions within a seven-day period. The patient reported relief of mbp by the third and fourth treatment sessions, which was successfully sustained over time (Chadwick and Silvano, 2015). In an earlier case study on mbp in which a patient presented with pain of 4 months' duration reported that it was aggravated by deep breathing, coughing and sneezing and accompanied by decreased functionality. Seven treatments of rib mobilizations and trigger point therapy were done over a period of 4 weeks. The NPRS at the end of the seventh treatment was 0 – 1/ 10 (at rest) and 1 – 2/ 10 (with activity), compared to NPRS at the initial consult 7.5/ 10 (at rest) and 9/ 10 (with activity). The patient reported a decrease in mbp and could resume daily and recreational activities after treatment (Fruth, 2006). The findings of Chadwick (2015), Fruth (2006) and Thomas (1988) are informative and insightful, providing a useful perspective into the effects of costovertebral manipulation in the treatment of mbp. However, these are case studies, with inadequate sample sizes and therefore, do not provide comparable and conclusive data.

Similarly, Irwin (2015) conducted a randomized clinical trial that compared the effectiveness of costovertebral manipulation and trigger point therapy of the rhomboid muscles on mbp. Randomized allocation was used to divide thirty participants with mbp into three groups of ten: group one received the costovertebral manipulations, group two received ischemic compression of the myofascial trigger points in the rhomboid muscles, and group three received a combination of the two treatments. This study was conducted over a period of four weeks, with two weekly treatments per group. The intragroup analysis indicated that per the NPRS ($p = 0.000$), McGill Pain Rating Questionnaire ($p = 0.000$) and Algometry measurements ($p = 0.000$), the manipulation group had a statistically significant improvement. The results of this study suggested that costovertebral joint manipulation was effective in the treatment of mbp (Irwin, 2015). The division of participants into three groups provides comparable information on the effectiveness of ischaemic trigger point therapy, costovertebral manipulation and the combination of the two, in the treatment of mbp. However, the sample size was small and provided insightful, rather than conclusive evidence. Similar to previous studies the researcher was not blinded to the screening and data capture of the participants, which may have influenced bias in this study.

Due to the limited randomized, placebo controlled and blinded studies, the literature is not conclusive as to the efficacy of costovertebral manipulation relating to the mid-back (Irwin, 2015). Only a single study on the effect of coupling thoracic facet and costovertebral joint manipulation was found (Gavin, 1999). Gavin’s (1999) comparative study recruited seventy-eight asymptomatic participants through randomised sampling. This study investigated the immediate effects of coupling thoracic facet and costovertebral manipulation on the active ROM in flexion and lateral flexion in the thoracic spine. The participants were divided into three groups and the active ROM was measured between the levels of T3 to T8. group one did not receive any intervention, group two received thoracic spine mobilisations between T3 to T8, and group three received thoracic facet and costovertebral joint manipulations between the vertebral levels of T3 to T8. The results indicated a significant difference in group three with an increase of 0.8° in active flexion, 2.5° in active right lateral flexion and 1.9° in active left lateral flexion. The intergroup analysis indicated that the combined manipulation group had a significant improvement in active thoracic lateral flexion (Gavin, 1999). These results suggested that the combination of thoracic facet and costovertebral manipulation effectively increased active ROM in flexion and lateral flexion in the thoracic spine.

These studies highlighted that thoracic facet and costovertebral manipulation effectively decreased pain (Fruth, 2006 and Pillay, 2001), increased PPT (Schiller, 1999) and increased spinal mobility (Gavin, 1999). However, no evidence has been found that suggested the manipulation of either the thoracic facet or the costovertebral joint independently, would improve the function of the other.

2.8 Gap in the Literature

A thorough review of the literature yielded studies that mentioned the use of thoracic facet and costovertebral joint manipulation on conditions such as, neck (Cleland et al., 2007), and shoulder (Dunning et al, 2015) pain. Several studies have investigated the effect of thoracic facet manipulation on mbp and compared its effectiveness to other treatments such as IFC (Tsolakis, 2001), placebo procedures (non-functional ultrasound) (Schiller, 1999), spinal mobilisations (Dimopoulos, 2002 and Pillay, 2001) and myofascial trigger point therapy (Irwin, 2015).

However, there appeared to be no studies comparing the effectiveness of the combination of thoracic facet and costovertebral joint manipulation in participants presenting with mbp. The researcher hypothesized that because of the anatomical similarities and mutually dependent biomechanics and kinetics of the thoracic facet and costovertebral joints, dysfunction in either may affect the global wellbeing and functionality of the mid-back. Thus, overlooking costovertebral dysfunction may lead to the perpetuation of mbp. Therefore this study investigated whether it was more effective to employ thoracic facet manipulation only or the combination of thoracic facet and costovertebral joint manipulation for the treatment of mbp.

Chapter Three
Research Methodology

3.1 Study Design

This study is a prospective single-blind randomised comparative clinical trial

3.1.1 Sample Size

Fifty participants aged between 18 – 45 years of age were recruited for this study. The sample size was determined using the G-Power version with an 80% power, effect size of 0.25 and a 95% probability, which resulted in a minimum number of 50 participants being required for the study. The effect size is the difference between Groups A and B, pre-manipulation and post-manipulation, for NPRS, inclinometer and algometer measurements. It was established based on published similar studies. The sample size was established .as per email communication with the statistician at DUT, D Singh on the 11th November 2015.

3.1.2. Sample Population

The participants for this study included individuals presenting to the Durban University of Technology (DUT) Chiropractic Day Clinic (CDC) with mbp, and individuals who responded to the advertisements (Appendix A) placed around the DUT campus and central and surrounding Durban areas. No bias was placed on gender and the age limit was set at 45 years of age, to exclude individuals with moderate to severe joint degeneration due to the aging process (Musumeci, Szychlinska and Mobasheri, 2015).

3.2 Study Procedure

3.2.1 Recruitment Method

Prior to the commencement of this study, formal approval was obtained from the IREC ethics committee (Appendix A), clinic director permission (Appendix B) and gatekeeper permission (Appendix C). Once all permissions were obtained, this study was registered on the National Human Research Electronic Application System (Appendix D)

The participants were selected from individuals presenting to the DUT CDC with mbp, and from individuals who responded to the advertisements (Appendix E) placed around the DUT campus and Durban areas. All potential participants were interviewed by the researcher as a preliminary screening for this study. The potential participants that responded to the advertisements (Appendix E) were contacted telephonically, and those that inquired about the study in person, were interviewed at the time (Table 3.1). The following are the questions that were asked during the telephonic/ physical interview:

Table 3.1 Questions asked at the telephonic/ physical interview

Questions	**Yes**	**No**
• Are you between the ages of 18 and 45 years of age?	x	
• Do you have mid-back pain or pain in-between your shoulder blades?	x	
• Have you experienced tingling, numbness, burning, pins and needles or weakness in your arms or hands?		x
• Do you have a recent history of cancer and or tuberculosis?		x
• Do you have neck or low back pain?		x
• Have you experienced any falls, trauma or injuries to the back?		x

Table 3.1 lists the questions asked in the telephonic/ physical interview. Individuals who answered per the crosses in the required columns passed the preliminary selection round for inclusion in this study. Following the interview, the selected individuals were asked to attend a consultation with the researcher at the DUT CDC.

3.2.2 Procedure

The following is a step-by-step account of the events occurring from the initial consultation at the DUT CDC to the conclusion of the participants' involvement in this study:

- Fifty squares of paper marked with a group allocation (i.e. Group A or Group B), twenty-five squares were marked A, and twenty-five squares were marked B were placed in an envelope and kept in the clinic reception area.

- At the initial consultation, each individual was asked to complete and sign a DUT CDC patient information sheet (Appendix F) and read and sign a research letter of informed consent (Appendix G).

- The DUT CDC receptionist was asked to pick a square of paper from the envelope as each participant arrived for the consultation. The patient was allocated the group marked on the selected square. The randomization of the participants for this study was done by the DUT CDC receptionist, who was blind to the group selected for each participant and the allocated treatment for each group. Similarly, the research assistant and all participants were blinded to the group allocation in this study.

- The researcher accompanied the participant to the clinic room to conduct the consultation. The following assessments/ examinations were conducted:

    - Full case history (Appendix H)

    - Senior physical examination (Appendix I)

    - Thoracic regional examination (Appendix J)

    - SOAPE note (Appendix K)

- The researcher described how the NPRS (Appendix L) worked and its purpose the participant. The participant was asked to read the explanatory insert and circle the number most representative of the pain they were experiencing.

- A registered chiropractic master's student was trained as a research assistant and motion palpated the participant (in the prone position) for thoracic vertebral and costovertebral restrictions.

- With the participant, still in the prone position, the research assistant explained to the participant that she would be pressing into areas of the restricted levels with an instrument, and for the participant to prompt with the response "now" when pain was felt. This was done using the Algometer (Figure 3.1) (Appendix M).

- The research assistant then asked the participant to sit upright and explained that she would be measuring the angles of movement in the participants' spine. The researcher performed the movements of thoracic flexion, extension, right and left lateral flexion and rotation for the participant to see. The participant was asked to mimic those movements when prompted by the assistant.

- The Inclinometer (Appendix N) was attached to a 1 meter narrow wooden plank (Figure 3.2). The plank was positioned per the movement being measured. To measure thoracic flexion and extension the plank was placed over the T1 spinous process in a vertical position with the Inclinometer (Appendix N) on its base. The participant was instructed to bend forward to induce flexion, to push out their 'chest' and extend their spine to induce truncal extension. When measuring right and left lateral flexion, the plank was placed over the T1 spinous process in a horizontal position with the Inclinometer (Appendix N) on its base. The participant was instructed to lean their trunk to the left or right to induce thoracic lateral flexion. When measuring right and left rotation, the plank was placed over the T6 spinous process in a horizontal position with the Inclinometer (Appendix N) on its side. The participant was instructed to turn their trunk to the left or the right-hand side to induce thoracic rotation.

- Once all measurements were taken by the research assistant, the researcher performed the respective intervention/s assigned to the participant per their group allocation:

    - Group A received thoracic facet manipulations (Appendix O) of the restricted segments between T3 to T9, in the prone position.
    - Group B received thoracic facet (Appendix O) and costovertebral manipulations (Appendix P) of the restricted segments between T3 to T9 and ribs 3 to 9 (costovertebral joints), in the prone position.

- Immediately after the manipulations, the participant was asked to complete another NPRS (Appendix L) and the Algometer (Appendix M) and

Inclinometer (Appendix N) measurements were re-taken by the research assistant.

3.3 Inclusion and Exclusion Criteria

3.3.1 Inclusion Criteria

- Participants were between 18 – 45 years of age
- For this study, mid-back pain included all the following signs and symptoms:
  - ➢ Sharp, shooting or aching mid-back pain (Gatterman, 2005 and Young et al., 2008) and/
  - ➢ Mbp experienced during deep inspiration, sneezing and/or coughing (Gatterman, 2005)
  - ➢ Localized pain (Gatterman, 2005)
  - ➢ Altered end feel resistance (describes the give or 'feel' of the joint when manual pressure is applied to it. The end feel may be boggy, restrictive or lax) (Bourdillon, Day, Bookhout, 1992)
  - ➢ Restricted thoracic facet segments between T3 and T9 (Fryer et al., 2004 and Irwin, 2015)
  - ➢ Restricted costovertebral segments between ribs three and nine

3.3.2 Exclusion Criteria

- Individuals who did not sign or understand the letter of informed consent (Appendix N)
- Individuals with contraindications to manipulation in the thoracic spine (Bergmann and Peterson, 2011; Bourdillon et al., 1992 and Gatterman, 1995)
- Weakened bone due to
  - ➢ Osteoporosis
  - ➢ Infection
  - ➢ Neoplasm
- Severe acute disc herniation
- Joint hypermobility
- Spinal or rib fracture
- Transverse process fracture
- Intercostal muscle tear

- Congenital or acquired spinal deformities such as, Scoliosis, hyperkyphosis, Scheuermann's disease, Butterfly/ block vertebrae (Patinharayil et al., 2008; Trenga, Singla, Feger and Abel, 2016)
- Neurological disease
- Individuals on anticoagulant therapy
- Individuals with viral/ bacterial/ fungal infections

3.4 Measurement Tools

3.4.1 Numerical Pain Rating Scale (NPRS) (Appendix L)

- The NPRS provides a numerical representation for pain perception.
- Pain is rated on a scale of zero to ten. Zero represents no pain and ten represents the most pain experienced. The greater the pain experienced, the higher the number on the scale.
- Prior to and after treatment, the researcher requested that the participant rate their pain on a scale of zero to ten. Zero being no pain and ten being the worst pain experienced. The greater the patient's pain intensity, the higher the number on the scale.
- The NPRS has good sensitivity and yields data that can be statistically analyzed for audit purposes (Williamson and Hoggart, 2004). This was also indicated in Ismail, Ghafar, Shamsuddin, Roslan, Kaharuddin and Muhamad's (2015) study, which compared the NPRS to the Visual Analogue Scale (VAS). The 3-month cross-sectional study analyzed the pain scores of 130 participants. The pain scores for both methods were taken pre- and post-hospitalization. The results reflected a good correlation between the scores for the NPRS and VAS (Ismail et al., 2015). These findings were statistically significant and the NPRS had a *p*-value = 0.001. Thus, indicating that the NPRS was a reliable and valid tool for the measurement of pain perception.

3.4.2 Wagner Algometer (Appendix M)

Figure 3.1 Wagner Force Dial FDK 20 Algometer (Petersen, 2017)

- Manufacturer: Wagner Instruments
- Model: Force Dial FDK 20
- The Algometer was used to measure the PPT.
- The researcher placed the algometer over the restricted thoracic facet and costovertebral joints between T3 to T9 vertebrae, and ribs 3 to 9, with the participant in a prone position. An axial pressure was applied through the algometer, the participant was asked to report when they began to experience pain with the prompt “now”. The measurements were taken prior to and after the application of the manipulative techniques. The Algometer can provide highly reliable measures of PPT (Chesterton, Sim, Wright, Foster, 2007). This study investigated the algometry reliability of PPT using multiple examiners. The first phase of the study involved the training of undergraduate physiotherapists. The second phase of the study involved the trainees i.e. undergraduate physiotherapists measuring the PPT of the first dorsal interosseous muscle of thirteen healthy participants. The results suggested that the Algometer was a valid and reliable tool for the measurement of PPTs (Chesterton et al., 2007).

3.4.3 Saunders Digital Inclinometer (Appendix N)

Figure 3.2 Modified Inclinometer (Petersen, 2017). The Inclinometer was attached to a 1m wooden plank.

- Manufacturer: The Saunders Group Inc.
- Model: Saunders Digital Inclinometer
- The inclinometer was used to determine the relative angle of a surface.
- The participant was asked to sit in the upright position and physically shown, by the research assistant, how to perform the actions of thoracic flexion, extension, and left and right lateral flexion and rotation. The inclinometer (Appendix N) was attached to a 1meter narrow wooden plank (Figure 3.2). The plank was positioned according to the movement being measured. To measure thoracic flexion and extension the plank was placed over the T1 spinous process in a vertical axis position with the inclinometer (Appendix N) on its base. When measuring right and left lateral flexion, the plank was placed over the T6 spinous process in a vertical axis position, with the Inclinometer on its base. When measuring right and left rotation, the plank was placed over the T6 spinous process in a horizontal axis position on a horizontal plane, with the inclinometer on its side.
- The inclinometer produces reliable results and studies have shown that it is useful in studies in which groups are compared (De Winter, Heemskerk, Terwee, Jans, Deville', Van Schaardenburg, Scholten, Bouter, 2004.). An American study (Tucker and Ingram, 2012) investigated the reliability of the digital inclinometer in measuring upward scapular rotation. Thirty male participants were recruited and were required to maintain their arm in the scapular position at varying degrees (i.e. 60°, 90° and 120°) while the researcher used the digital protractor and digital inclinometer (Tucker and Ingram, 2012). The results showed that that the digital

inclinometer measurements were reproducible and showed a *p*-value = 0.001. These findings suggested that the digital inclinometer is a valid and reliable tool for the measurement on ROM.

3.5 Interventions

3.5.1 Thoracic Facet Joint Manipulation

The participants in Group A received either the Bilateral Hypothenar (Figure. 1 of Appendix O) or the Cross Bilateral Hypothenar manipulation (Figure. 2 of Appendix O) of the restricted facet joints between T3 to T9.

3.5.2 Thoracic Facet (Appendix O) and Costovertebral Joint Manipulation (Appendix P)

The participants in Group B received a combination of either the Bilateral Hypothenar (Figure. 1 Appendix O) or the Cross Bilateral Hypothenar manipulation (Figure. 2 of Appendix O) of the restricted facet joints, and either the Hypothenar Costal (Figure. 1 of Appendix P) or the Ilial Hypothenar Costal manipulation (Figure. 2 of Appendix P) of the restricted vertebral joints between T3 to T9 and costovertebral joints between ribs 3 and 9.

3.6 Ethical Considerations

The participants of this study were not encouraged to or coerced into participating. They were not offered any gifts or means of reimbursement for their participation in this study. Participation was of free will and participants were informed of the context of the study and what was expected of them during the period of the study. The participants were given a letter of information (Appendix G) that outlined the study and their role in it, and were required to read, understand and sign before they began the study. By doing so, they gave their informed consent for their participation in the study in the form of a signature. There was no prejudice in the selection of the participants for the study. All applicants that fitted the inclusion criteria were given an equal opportunity to be part of this study i.e. no bias was placed on factors such as, gender and occupation. When addressing non-maleficence, the participant was not at risk of sustaining any permanent harm during the study. This study included the use of manipulation interventions only, which is a non-invasive treatment and unlikely to cause any permanent damage i.e.

provided the participant does not have contra-indications to manipulation (Puentedura and O'Grady, 2015). However, the participants were informed that transient discomfort and/or mild pain following spinal manipulative therapy may be experienced. Although, according to the aim of this study, it was suggested that participants would have relief of the symptoms of mbp. Participants who wished to leave the study were free to do so at any point and did not encounter any repercussions because of it. Confidentiality of the participant's personal and medical information was maintained. The names and personal details were not included in this study. The personal information that was acquired during the study was kept safely, in a locked and secure area on the DUT CDC premises for a period of five years, after such time, the file will be shredded.

3.7 Data Analysis

Upon completion of this study the data was entered into an excel spreadsheet. Data analysis was done using the latest version of SPSS. A p-value of less than 0.05 was used to determine statistical significance. Descriptive statistics in the form of univariate analysis describe the data in terms of measures of central tendency and measures of dispersion. To test the hypothesis of the study, the student t-test and ANOVA were used if the data was normally distributed. If there was no normal distribution of data, then non-parametric tests like Wilcoxon ranked and Mann Whitney test were used. Chi squared test was used for nominal and ordinal data, as per email communication with the statistician at DUT, D Singh on the 11th November 2015.

Chapter Four

Statistical Analysis and Results

4.1 Introduction

This chapter provides a comprehensive statistical analysis and interpretation of the data obtained from this study. The hypothesis tests were conducted at a 5% level of significance. A test yielding a p-value < 0.05 is then regarded as significant. The confidence intervals were with a confidence co-efficient of 95%. The null hypothesis of this study was that there would be no difference in the pre-manipulative and post-manipulative readings for the NPRS, algometer and inclinometer. The alternative hypothesis was that there would be an improvement in the post-manipulative readings.

Statistical tests

The statistical analysis for this study was done by G. Matthews, a statistician at DUT, as per email correspondence and meetings, between 13 December 2016 and 28 March 2017.

In a comparison of pre-test with post-test readings, a paired test was performed for the entire group. To test the change in pre-test and post-test readings, a difference was calculated and a two-sample t-test was used to compare groups A and B. Where the sample sizes for groups was too small, a non-parametric test, namely the Wilcoxon-Mann-Whitney test was used, as per email correspondence and meetings, with G Matthews, between 13 December 2016 and 28 March 2017.

The following is a key to describe and define the terms used in the tables showing the analysis and results of the data obtained in this study:

Key

Group A	- Thoracic facet joint manipulation
Group B	- Thoracic facet and costovertebral joint manipulation
N	- Number
Pre/Post	- NPRS before or after intervention
Diff	- Difference between Group A and Group B
NPRS	- Numerical Pain Rating Scale measurements
Flex	- ROM measurement in flexion
Ext	- ROM measurement in extension
RLF	- ROM measurement in right lateral flexion
LLF	- ROM measurement in left lateral flexion
RR	- ROM measurement in right rotation
LR	- ROM measurement in right rotation
V4L/R	- Thoracic vertebral level, in the left/ right facet joint
CV4L/R	- Rib level, of the left/ right costovertebral joint

4.2 Demographic Data Analysis

4.2.1 Mean Age

Table 4.1 Mean age within the sample of 50 participants

	N	Minimum	Maximum	Mean	Standard deviation
Age	50	19	45	26.18	6.317

Table 4.1 shows that the mean age of participants was 26.18 years of age in the sample of 50 participants.

4.2.2 Gender Frequency and Distribution

Table 4.2 Gender frequency within the sample of 50 participants and Groups A and B

Gender	Frequency in the sample (N = 50)	Group A	Group B	Total %
F	31	16	15	62%
M	19	9	10	38%

Table 4.2 shows the frequency of males and females in the sample of 50 participants and the distribution of males and females across Groups A and B. The results indicated that there was a higher frequency of females in the total sample. Although there was a higher frequency of female participants within Groups A and, they were evenly distributed across the groups.

4.2.3 Race Frequency and Distribution

Table 4.3 Race frequency within the sample of 50 participants and Groups A and B

Race	Frequency in the sample (N = 50)	Group A	Group B	Total %
Black	26	12	14	52%
Mixed race	13	6	7	26%
Asian	4	2	2	8%
Caucasian	7	5	2	14%

Table 4.3 shows the frequency of races in the sample of 50 participants and the distribution between Groups A and B. The results indicated that there was a higher frequency of black participants (52%), than mixed race (26%), Asian (8%) and Caucasian (14%) participants within the sample.

4.2.4 Frequency of Occupation

Table 4.4 Occupation frequency

Occupation	Frequency	Percent (%)
Administrator	1	2
Amateur soccer player	1	2
Biokinetist	1	2
Construction	1	2
Flight attendant	1	2
Freelancer	1	2
Homeopath	1	2
Manager	2	4
Nurse	1	2
Paramedic	1	2
Police officer	1	2
Receptionist	1	2
Sales	10	20
Self employed	1	2
Site supervisor	1	2
Telesales	1	2
Tertiary Student	21	42
Unemployed	3	6
Total	50	100

Table 4.4 shows the frequency of occupations in the sample size of 50 participants. The results indicated that there was a high frequency of tertiary student participants (42%) followed by participants in the sales industry (20%).

4.3 Prevalence and Distribution of Participants with a History of Chiropractic Treatment

Table 4.5 Prevalence and distribution of history of treatment

Previous chiropractic treatment	Frequency in the sample (N = 50)	Group A	Group B	Total %
Yes	35	7	7	70%
No	15	18	18	30%

Table 4.5 shows the prevalence of participants with a history of chiropractic treatment, in the sample of 50 participants and in Groups A and B. The results indicated that there was a higher percentage of participants with a history of chiropractic treatment (70%) than participants without (30%) in the sample of 50 participants. Similarly, the percentage of participants with a history of chiropractic treatment was higher in Group A at 68% and Group B at 64%. Whereas, participants without a history of chiropractic treatment accounted for 32% in Group A and 36% in Group B.

4.4 Frequency and Distribution of Vertebral Manipulative Techniques Used

Table 4.6 Frequency and distribution of vertebral manipulative techniques

Vertebral manipulative technique	Frequency in sample (N = 50)	Group A	Group B	Total %
Bilateral Hypothenar	12	7	5	24
Cross Bilateral	38	18	20	76

Table. 4.6 shows the frequency and distribution of vertebral manipulative techniques used in the sample of 50 participants, and in Group A and Group B. The results indicated that the Cross bilateral (76%) technique was used more often than the Bilateral hypothenar technique (24%) in the sample of 50 participants. Similarly, the cross bilateral

technique was used more often in Group A (72%) and Group B (80%). Whereas the bilateral hypothenar technique was less often in Group A (28%) and Group B (20%).

4.5 Frequency of Costovertebral Manipulative Techniques Used

Table 4.7 Frequency and distribution of costovertebral manipulative techniques

Technique	**Frequency in sample (N = 50)**	**Group A**	**Group B**	**Total %**
Ilial Hypothenar Costal	18	0	18	36
Hypothenar Costal	7	0	7	14
No costovertebral manipulation (group A)	25	25	0	50

Table 4.7 shows the frequency and distribution of costovertebral manipulative techniques used in the sample size of 50 participants and in Groups A and B. Group A i.e. half the sample size, did not received cvj manipulation. In Group B the Ilial hypothenar costal technique (36%) was used more often than the Hypothenar costal technique (14%).

4.6 Frequency of Thoracic Facet and Costovertebral Joint Restrictions

Table 4.8 Frequency of restricted thoracic facet and costovertebral joints

Vertebral Level	Frequency of restrictions found in sample (N = 50)	Costovertebral Level	Frequency of restrictions found in sample (N = 50)
T3	10	CV3L	7
T4	31	CV3R	4
T5	30	CV4L	20
T6	34	CV4R	7
T7	24	CV5L	21
T8	8	CV5R	15
T9	3	CV6L	14
		CV6R	13
		CV7L	7
		CV7R	9
		CV8L	0
		CV8R	1
		CV9L	0

Table. 4.8 shows the frequency of the most common restrictions found in the sample size of 50 participants. The results indicated that the thoracic vertebral levels that

occurred most commonly with restrictions were T4 - T7. The costovertebral levels that were most commonly restricted were the left 4th to 6th and right 5th costovertebral joints.

4.7 Subjective Measurements - Numerical Pain Rating Scale Results

4.7.1 Intra-group t-test Analysis

Within each group, we have used a paired t-test to test whether there was a reduction in pain perception from pre-manipulation to post-manipulation readings of the NPRS.

Table 4.9 Group A - Paired Samples Statistics

	Mean	N	Standard deviation	Standard error mean
PreNPRS	5.24	25	2.026	0.405
PostNPRS	2.76	25	2.166	0.433

Table 4.8 shows the mean readings of the NPRS pre-manipulation and post-manipulation in Group A.

Table 4.9 Group A - Paired samples t-test (Paired differences)

				95% confidence interval of the difference				
	Mean	**Standard deviation**	**Standard error mean**	**Lower**	**Upper**	**T**	**Df**	**Significance (2-tailed)**
PreNPRS – PostNPRS	2.480	1.584	0.317	1.826	3.134	7.827	24	0.000

Table 49 shows the mean difference of the NPRS post-manipulation and pre-manipulation in Group A. The difference between the post-manipulation and pre-manipulation readings was statistically significant, with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was a reduction in pain perception in Group A.

Table 4.10 Group B - Paired Samples Statistics

	Mean	**N**	**Standard deviation**	**Standard error mean**
PreNPRS	5.48	25	1.503	0.301
PostNPRS	3.48	25	2.434	0.487

Table 4.10 shows the mean readings of the NPRS pre-manipulation and post-manipulation in Group B.

Table 4.11 Group B - Paired samples t-test (Paired differences)

				95% confidence interval of the difference				
	Mean	**Standard deviation**	**Standard error mean**	**Lower**	**Upper**	**T**	**Df**	**Significance (2-tailed)**
PreNPRS – PostNPRS	2.000	2.236	0.447	1.077	2.923	4.472	24	0.000

Table 4.11 shows the mean difference of the NPRS post-manipulation and pre-manipulation in Group B. The difference between the post-manipulation and pre-manipulation readings was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was a reduction in pain perception in Group B.

4.7.2 Intergroup t-test Analysis

In this section we have taken the differences in pre-manipulation and post-manipulation readings of Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences, for the NPRS.

Table 4.12 Group statistics

	Group	N	Mean	Standard deviation	Standard error mean
DiffNPRS	**A**	25	2.4800	1.58430	0.31686
	B	25	2.0000	2.23607	0.44721

Table 4.12 shows the mean difference of the NPRS post-manipulation and pre-manipulation for Group A and the mean difference between the post-manipulation and pre-manipulation for Group B.

Table 4.13 Independent samples t-test for equality of means

							95% confidence interval of difference	
		T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
DiffNPRS	**Equal variances assumed**	0.876	48	0.386	0.48000	0.54809	-0.62200	1.58200

Table 4.13 shows the mean difference of the NPRS, comparing the means of Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.386 (> 0.05). Therefore, these results supported the null hypothesis and indicated that there was no difference in pain perception across the two groups.

4.8 Objective Measurements

4.8.1 Inclinometer results

4.8.1.1 Flexion - Intra-group t-test analysis

Within each group, we have used a paired t-test to test whether there was an increase in thoracic spine range of motion from pre-manipulation to post-manipulation inclinometer measurements in the thoracic spine for flexion.

Table 4.14 Group A – Paired Sample t-test

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffFlex	7.285	24	0.000	6.14000	4.4004	7.8796

Table 4.14 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in flexion, in Group A. The mean difference in Group A was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in flexion, in Group A.

Table 4.15 Group B – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffFlex	9.060	24	0.000	7.10000	5.4825	8.7175

Table 4.15 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in flexion, in Group B. The mean difference in Group B was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in flexion, in Group B.

4.8.1.2 Flexion - Intergroup t-test analysis

In this section we have taken the differences in pre-manipulation and post-manipulation inclinometer measurements for flexion, in Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences.

Table 4.16 Mean, standard deviation and error of the mean for Group A and B.

	Group	**N**	**Mean**	**Standard deviation**	**Standard error mean**
DiffFlex	**A**	25	6.1400	4.21436	0.84287
	B	25	7.1000	3.91844	0.78369

Table 4.16 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in flexion, in Group A and in Group B.

Table 4.17 Independent samples T-test for equality of means

							95% confidence interval of the difference	
DiffFlexion		**T**	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
	Equal variances assumed	-0.834	48	0.408	-0.96000	1.15091	-3.27407	1.35407

Table 4.17 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in flexion, across Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.408 (> 0.05). Therefore, these results supported the null hypothesis and indicated that there was no difference in the thoracic spine ROM in flexion, across both groups.

4.8.1.3 Extension - Intra-group t-test analysis

Within each group, we have used a paired t-test to test whether there was an increase in thoracic spine range of motion from pre-manipulation to post-manipulation inclinometer measurements in the thoracic spine for extension.

Table 4.18 Group A – Paired Sample t-test

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffExt	7.829	24	0.000	4.58000	3.3726	5.7874

Table 4.18 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in extension, in Group A. The mean difference in Group A was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null

hypothesis and indicated that there was an increase in the thoracic spine ROM in extension, in Group A.

Table 4.19 Group B – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffExt	7.098	24	0.000	4.86000	3.4469	6.2731

Table 4.19 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in extension, in Group B. The mean difference in Group B was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in extension, in Group B.

4.8.1.4 Extension - Intergroup t-test analysis

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation readings of Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for extension.

Table 4.20 Mean, standard deviation and error of the mean for Group A and B.

	Group	**N**	**Mean**	**Standard deviation**	**Standard error mean**
DiffExt	**A**	25	4.5800	2.92504	0.58501
	B	25	4.8600	3.42333	0.68467

Table 4.20 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in extension, in the thoracic spine, Group A and Group B.

Table 4.21 Independent samples T-test for equality of means

							95% confidence interval of the difference	
DiffExt		**T**	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
	Equal variances assumed	-0.311	48	0.757	-0.28000	0.90056	-2.09069	1.53069

Table 4.21 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in extension, across Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.408 (> 0.05). Therefore, these results supported the null hypothesis and indicated that there was no difference in the thoracic spine ROM in change, across both groups.

4.8.1.5 Right lateral flexion - Intra-group t-test analysis

Within each group, we have used a paired t-test to test whether there was an increase in thoracic spine range of motion from pre-manipulation to post-manipulation inclinometer measurements in the thoracic spine for right lateral flexion.

Table 4.22 Group A – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffRLF	8.877	24	0.000	5.36000	4.1138	6.6062

Table 4.22 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in right lateral flexion, in Group A. The mean difference in Group A was

statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in right lateral flexion, in Group A

Table 4.23 Group B – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffRLF	7.035	24	0.000	5.40000	3.8158	6.9842

Table 4.23 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in right lateral flexion in Group B. The mean difference in Group B was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in right lateral flexion, in Group B.

4.8.1.6 Right lateral flexion - Intergroup t-test analysis

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation readings of Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for right lateral flexion.

Table 4.24 Mean, standard deviation and error of the mean for Group A and B.

	Group	N	Mean	Standard deviation	Standard error mean
DiffRLF	**A**	25	5.3600	3.01911	0.60382
	B	25	5.4000	3.83786	0.76757

Table 4.24 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in right lateral flexion, in Group A and in Group B.

Table 4.25 Independent samples T-test for equality of means

							95% confidence interval of the difference	
DiffRLF		**T**	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
	Equal variances assumed	-0.041	48	0.967	-0.04000	0.97661	-2.00361	1.92361

Table 4.25 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in right lateral flexion, across Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.967 (> 0.05). Therefore, these results supported the null hypothesis and indicated that there was no difference in the thoracic spine ROM in right lateral flexion, across both groups.

2.8.1.7 Left lateral flexion - Intra-group t-test analysis

Within each group, we have used a paired t-test to test whether there was an increase in thoracic spine range of motion from pre-manipulation to post-manipulation inclinometer measurements in the thoracic spine for left lateral flexion.

Table 4.26 Group A – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffLLF	7.148	24	0.000	5.80000	4.1254	7.4746

Table 4.26 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in left lateral flexion, in Group A. The mean difference in Group A was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in left lateral flexion, in Group A.

Table 4.27 Group B – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffLLF	6.933	24	0.000	4.94000	3.4693	6.4107

Table 4.27 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in left lateral flexion, in Group B. The mean difference in Group B was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected

the null hypothesis and indicated that there was an increase in the thoracic spine ROM in left lateral flexion, in Group B.

4.8.1.8 Left lateral flexion - Intergroup t-test analysis

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation readings of Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for left lateral flexion.

Table 4.28 Mean, standard deviation and error of the mean for Group A and B.

	Group	N	Mean	Standard deviation	Standard error mean
DiffLLF	**A**	25	5.8000	4.05689	.81138
	B	25	4.9400	3.56289	.71258

Table 4.28 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in left lateral flexion, in Group A and in Group B.

Table 4.29 Independent samples test T-test for equality of means

							95% confidence interval of the difference	
DiffLLF		**T**	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
	Equal variances assumed	0.796	48	0.430	0.86000	1.07986	-1.31121	3.03121

Table 4.29 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in left lateral flexion, across Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.408 (> 0.05).

Therefore, these results supported the null hypothesis and indicated that there was no difference in the thoracic spine ROM in left lateral flexion, across both groups.

4.8.1.9 Right rotation - Intra-group t-test analysis

Within each group, we have used a paired t-test to test whether there was an increase in thoracic spine range of motion from pre-manipulation to post-manipulation inclinometer measurements in the thoracic spine for right rotation.

Table 4.30 Group A – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffRR	7.639	24	0.000	7.68000	5.6051	9.7549

Table 4.30 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in right rotation, in Group A. The mean difference in Group A was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in right rotation, in Group A.

Table 4.31 Group B – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffRR	9.244	24	0.000	8.14000	6.3226	9.9574

Table 4.31 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in right rotation, in Group B. The mean difference in Group B was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in right rotation, in Group B.

4.8.1.10 Right rotation - Intergroup t-test analysis

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation readings of Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for right rotation.

Table 4.32 Mean, standard deviation and error of the mean for Group A and B.

	Group	**N**	**Mean**	**Standard deviation**	**Standard error mean**
DiffRR	**A**	25	7.6800	5.02676	1.00535
	B	25	8.1400	4.40293	0.88059

Table 4.32 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in flexion, in Group A and in Group B.

Table 4.33 Independent samples test T-test for equality of means

							95% confidence interval of the difference	
DiffRR		**T**	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
	Equal variances assumed	-0.344	48	0.732	-0.46000	1.33648	-3.14716	2.22716

Table 4.33 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in right rotation, across Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.408 (> 0.05). Therefore, these results supported the null hypothesis and indicated that there was no difference in the thoracic spine ROM in right rotation, across both groups.

4.8.1.11 Left rotation - Intra-group t-test analysis

Within each group, we have used a paired t-test to test whether there was an increase in thoracic spine range of motion from pre-manipulation to post-manipulation inclinometer measurements in the thoracic spine for left rotation.

Table 4.34 Group A – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffLR	8.105	24	0.000	8.64000	6.4400	10.8400

Table 4.34 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in left rotation, in Group A. The mean difference in Group A was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null

hypothesis and indicated that there was an increase in the thoracic spine ROM in left rotation, in Group A.

Table 4.35 Group B – Sample t-test Statistics

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffLR	11.330	24	.000	9.04000	7.3933	10.6867

Table 4.35 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in left rotation, in Group B. The mean difference in Group A was statistically significant with a *p*-value = 0.000 (< 0.05). Therefore, these results rejected the null hypothesis and indicated that there was an increase in the thoracic spine ROM in left rotation, in Group B.

4.8.12 Left rotation - Intergroup t-test analysis

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation readings of Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for left rotation.

Table 4.36 Mean, standard deviation and error of the mean for Group A and B.

	Group	N	Mean	Standard deviation	Standard error mean
DiffLR	**A**	25	8.6400	5.32979	1.06596
	B	25	9.0400	3.98936	0.79787

Table 4.36 shows the mean difference of the Inclinometer measurements for thoracic spine ROM in left rotation, in Group A and in Group B.

Table 4.37 Independent samples test T-test for equality of means

							95% confidence interval of the difference	
DiffLR		**T**	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
	Equal variances assumed	-0.300	48	0.765	-0.40000	1.33648	-3.07714	2.27714

Table 4.37 shows the mean difference of the Inclinometer measurements for the thoracic spine ROM in left rotation, across Group A and Group B. The mean difference between the groups was not statistically significant, with a *p*-value = 0.765 (> 0.05). Therefore, these results rejected the null hypothesis and indicated that there was no difference in the thoracic spine ROM in left rotation, across both groups.

4.8.2 Algometer Results

4.8.2.1 Intra-Group t-test Analysis - Thoracic vertebral algometry results

The same method used to test for reduction of pain and increased range of motion was used to test for increased PPT in the thoracic spine. Within each group, we have used a paired t-test to test whether there was an increase in PPT of the affected thoracic facet joints, from pre-manipulation to post-manipulation algometer measurements.

Table 4.38 Group A – One Sample t-test

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffV4L	3.545	12	0.004	1.56154	0.6018	2.5213
Diff4R	3.655	12	0.003	1.81538	0.7333	2.8975
Diff5L	4.025	15	0.001	1.33125	0.6263	2.0362
Diff5R	4.703	15	0.000	1.32500	0.7245	1.9255
Diff6L	5.673	14	0.000	2.15333	1.3392	2.9675
Diff6R	6.164	14	0.000	2.13333	1.3910	2.8756
Diff7L	3.148	10	0.010	1.79091	0.5232	3.0586
Diff7R	4.749	10	0.001	1.93636	1.0279	2.8448

Table 4.38 shows the mean differences of the thoracic vertebral Algometry measurements in Group A. The differences of the pre-manipulation and post-manipulation measurements for most the costovertebral levels between T4 and T7 were statistically significant, with *p*-values < 0.05. Therefore, these results rejected the null

hypothesis and indicated that there was a decrease in the PPT of the restricted thoracic vertebral levels in Group A.

Table 4.39 Group B – One Sample t-test

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffV4L	5.481	16	0.000	1.94118	1.1903	2.6920
Diff4R	6.857	16	0.000	2.09412	1.4467	2.7415
Diff5L	6.921	13	0.000	2.02143	1.3905	2.6524
Diff5R	5.768	13	0.000	2.00000	1.2509	2.7491
Diff6L	4.729	16	0.000	1.77647	0.9800	2.5729
Diff6R	6.988	16	0.000	2.27059	1.5818	2.9594
Diff7L	3.869	12	0.002	1.67692	0.7326	2.6212
Diff7R	7.953	12	0.000	2.11538	1.5358	2.6949

Table 4.39 shows the mean differences of the thoracic vertebral Algometry measurements in Group B. The differences of the pre-manipulation and post-manipulation measurements for most the costovertebral levels between T4 and T7 were statistically significant, with *p*-values < 0.05. Therefore, these results rejected the null hypothesis and indicated that there was a decrease in the PPT of the restricted thoracic vertebral levels in Group B.

4.8.2.2 Intra-group t-test analysis - Costovertebral algometry results

Within each group, we have used a paired t-test to test whether there was an increase in the PPT of the affected costovertebral joints from pre-manipulation to post-manipulation algometer measurements.

Table 4.40 Group A – One Sample t-test

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffCV4L	5.023	6	0.002	2.34286	1.2016	3.4842
DiffCV5L	2.741	12	0.018	1.46923	0.3013	2.6372
DiffCV5R	8.419	6	0.000	1.80000	1.2768	2.3232
DiffCV6L	3.109	6	0.021	1.80000	0.3832	3.2168
DiffCV6R	2.917	5	0.033	1.83333	0.2175	3.4491

Table 4.40 shows the mean differences of the costovertebral Algometry measurements in Group A. The differences of the pre-manipulation and post-manipulation measurements for most the costovertebral levels between T4 and T7 were statistically significant, with *p*-values < 0.05. Therefore, these results rejected the null hypothesis and indicated that there was a decrease in the PPT of the restricted costovertebral levels.

Table 4.41 Group B – One Sample t-test

					95% confidence interval of the difference	
	T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Lower**	**Upper**
DiffCV4L	5.023	6	0.002	2.34286	1.2016	3.4842
DiffCV5L	2.741	12	0.018	1.46923	0.3013	2.6372
DiffCV5R	8.419	6	0.000	1.80000	1.2768	2.3232
DiffCV6L	3.109	6	0.021	1.80000	0.3832	3.2168
DiffCV6R	2.917	5	0.033	1.83333	0.2175	3.4491

Table 4.41 shows the mean differences of the costovertebral Algometry measurements in Group B. The differences of the pre-manipulation and post-manipulation measurements for most the costovertebral levels between T4 and T7 were statistically significant, with *p*-values < 0.05. Therefore, these results rejected the null hypothesis and indicate that there was a decrease in the PPT of the restricted costovertebral levels.

4.8.2.3 Inter-group descriptive statistics - Thoracic vertebral algometry results

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation algometer measurements of the affected thoracic facet joints, for Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for PPT.

Table 4.42 Group A – Pre-manipulation thoracic vertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PreT3L	4	5.6	8.5	7.325	1.2920
PreT3R	4	4.2	8.7	6.925	2.0532
PreT4L	14	3.5	10.0	5.821	1.7516
PreT4R	14	4.4	9.5	5.971	1.5269
PreT5L	16	2.4	7.5	5.056	1.4966
PreT5R	16	3.2	8.1	5.081	1.5638
PreT6L	17	3.4	10.0	5.859	1.7107
PreT6R	17	4.0	10.0	5.659	1.7063
PreT7L	11	3.0	9.0	5.664	1.7551
PreT7R	11	2.4	7.5	5.455	1.8184
PreT8L	5	4.0	7.1	5.600	1.4089
PreT8R	5	4.3	7.2	5.060	1.2095
PreT9L	2	3.5	6.0	4.750	1.7678
PreT9R	2	3.0	5.5	4.250	1.7678

Table 4.42 shows the means of the pre-manipulation thoracic vertebral measurements and the frequency of the restricted thoracic vertebral in Group A.

Table 4.43 Group A Descriptive statistic – Post-manipulation thoracic vertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PostT3L	4	.35	10.0	7.900	3.0670
PostT3R	4	5.9	10.0	7.331	1.9627
PostT4L	13	4.0	10.0	7.331	1.9627
PostT4R	13	5.1	10.0	7.631	1.8737
PostT5L	17	4.0	10.0	6.600	2.0424
PostT5R	17	4.0	10.0	6.618	2.0938
PostT6L	15	5.0	10.0	7.887	1.9497
PostT6R	15	4.2	10.0	7.607	2.0810
PostT7L	11	3.5	10.0	7.455	2.4386
PostT7R	11	3.6	10.0	7.391	2.6159
PostT8L	5	4.2	9.3	6.420	2.0303
PostT8R	5	4.8	10.0	6.660	2.0107
PostT9L	2	3.0	6.0	4.500	2.1213
PostT9R	2	4.7	5.5	5.100	0.5657

Table 4.43 shows the means of the post-manipulation thoracic vertebral measurements and the frequency of the restricted thoracic vertebral levels within group A.

Table 4.44 Group B - Pre-manipulation thoracic vertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PreT3L	6	1.8	6.1	4.150	1.6453
PreT3R	6	1.7	7.0	4.683	2.0566
PreT4L	17	4.0	7.3	5.388	0.9949
PreT4R	17	3.2	7.5	5.176	0.9941
PreT5L	14	1.6	7.0	5.164	1.5123
PreT5R	14	1.3	8.0	5.314	1.7324
PreT6L	17	3.2	7.5	5.124	1.1903
PreT6R	17	2.0	7.8	5.276	1.6088
PreT7L	13	2.5	7.0	5.038	1.3727
PreT7R	13	3.3	7.2	5.208	1.2520
PreT8L	3	5.5	6.2	5.933	0.3786
PreT8R	3	6.0	6.5	6.233	0.2517
PreT9L	1	2.0	2.0	2.000	.
PreT9R	1	1.8	1.8	1.800	.

Table 4.44 shows the means of the pre-manipulation thoracic vertebral measurements and the frequency of the restricted thoracic vertebral in Group B.

Table 4.45 Group B Descriptive statistics – Post-manipulation thoracic vertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PostT3L	6	2.3	10.0	6.167	2.7645
PostT3R	6	2.4	10.0	6.217	2.7051
PostT4L	17	5.4	10.0	7.329	1.5016
PostT4R	17	5.2	10.0	7.271	1.4439
PostT5L	14	2.1	10.0	7.186	2.0806
PostT5R	14	2.2	10.0	7.314	2.2491
PostT6L	17	4.0	9.5	6.900	1.6329
PostT6R	17	4.8	10.0	7.547	1.9564
PostT7L	13	3.5	9.0	6.715	1.8380
PostT7R	13	5.1	10.0	7.323	1.5600
PostT8L	3	6.5	10.0	8.000	1.8028
PostT8R	3	6.5	8.9	8.000	1.3077
PostT9L	1	2.5	2.5	2.500	
PostT9R	1	2.6	2.6	2.600	

Table 4.45 shows the means of the post-manipulation thoracic vertebral measurements and the frequency of the restricted thoracic vertebral levels within group B.

Table 4.46 T-test group statistics – T5, T6 and T7 differences

	Group	N	Mean	Standard deviation	Standard error mean
DiffT4L	A	13	1.5615	1.58826	0.44050
	B	17	1.9412	1.46033	0.35418
DiffT4R	A	13	1.8154	1.79065	0.49664
	B	17	2.0941	1.25920	0.30540
DiffT5L	A	16	1.3313	1.32299	0.33075
	B	14	2.0214	1.09276	0.29205
Diff5R	A	16	1.3250	1.12694	0.28174
	B	14	2.0000	1.29733	0.34673
DiffT6L	A	15	2.1533	1.47011	0.37958
	B	17	1.7765	1.54900	0.37569
DiffT6R	A	15	2.1333	1.34040	0.34609
	B	17	2.2706	1.33967	0.32492
DiffT7L	A	11	1.7909	1.88704	0.5689
	B	13	1.6769	1.56267	0.43341
DiffT7R	A	11	1.9364	1.35224	0.40771
	B	13	2.1154	0.95903	0.26599

Table 4.46 shows the t-test results for the differences in Algometer measurements for Group A and Group B for the vertebral levels of T4 to T7. Only these levels were used because there being high frequencies.

Table 4.47 Independent samples T-test for equality of means

							95% confidence interval of the difference	
		T	Df	Significance (2-tailed)	Mean difference	Standard error difference	Lower	Upper
DiffT4L	**Equal variances assumed**	-0.679	28	0.502	-0.37964	0.55873	-1.52414	0.76487
DiffT4R	**Equal variances assumed**	-0.501	28	0.620	-27873	0.55636	-1.41838	0.86091
DiffT5L	**Equal variances assumed**	-1.544	28	0.134	-0.69018	0.44702	-1.60587	0.22551
DiffT5R	**Equal variances assumed**	-1.526	28	0.138	-0.67500	0.44246	-1.58135	0.23135
DiffT6L	**Equal variances assumed**	0.703	30	0.487	0.37686	0.53587	-0.71753	1.47125
DiffT6R	**Equal variances assumed**	-0.289	30	0.774	-0.13725	0.47469	-1.10671	0.83220
DiffT7L	**Equal variances assumed**	0.162	22	0.873	0.11399	0.70370	-1.34540	1.57338
DiffT7R	**Equal variances assumed**	-0.379	22	0.709	-0.17902	0.47296	-1.15988	0.80184

Table 4.47 shows the mean difference of the Algometer measurement of T4 to T7 comparing the means of Group A and Group B. The level of statistical significance was

$p \geq 0.05$, which was not statistically significant. Therefore, these results supported the null hypothesis and indicated that there was no difference in the PPT in the thoracic spine between Group A and Group B. Although none of the differences were statistically significant, T5L and T5R had the lowest p-values and show the largest difference across groups.

4.8.2.4 Inter-group descriptive statistics - Costovertebral Algometry Results

For the intergroup comparison, we have taken the differences in pre-manipulation and post-manipulation algometer measurements of the affected costovertebral joints, for Group A and Group B, and used an independent samples t-test to test whether there was a significant difference between these mean differences for PPT.

Table 4.48 Group A – Pre-manipulation costovertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PreCV3L	3	3.9	4.8	4.400	0.4583
PreCV3R	2	3.5	6.1	4.800	1.8385
PreCV4L	7	1.8	7.8	3.800	2.0199
PreCV4R	4	2.9	5.5	4.400	1.0985
PreCV5L	13	3.0	10.0	5.631	1.9298
PreCV5R	7	2.4	6.3	4.443	1.5789
PreCV6L	8	2.6	7.5	5.088	1.8161
PreCV6R	6	3.0	6.5	4.833	1.3677
PreCV7L	5	2.5	10.0	6.240	2.8077
PreCV7R	4	2.1	7.5	4.875	2.7208
PreCV8L	0				
PreCV8R	0				
PreCV9L	0				
PreCV9R	0				

Table 4.48 shows the means of the pre-manipulation costovertebral measurements and the frequency of the restricted costovertebral levels in Group A.

Table 4.49 Group A Descriptive statistic – Post-manipulation costovertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PostCV3L	8	4.2	9.9	6.838	1.9146
PostCV3R	3	4.2	7.6	6.300	1.8358
PostCV4L	34	2.0	10.0	5.706	2.3100
PostCV4R	23	0.0	10.0	3.713	3.0986
PostCV5L	21	4.0	10.0	7.195	1.7828
PostCV5R	13	3.3	8.5	5.900	1.5748
PostCV6L	13	2.5	9.8	6.769	2.0336
PostCV6R	14	3.6	10.0	6.714	2.1071
PostCV7L	6	4.2	10.0	6.617	2.1922
PostCV7R	9	3.0	10.0	7.056	2.3195
PostCV8L	0				
PostCV8R	1	6.1	6.1	6.100	.
PostCV9L	0				
PostCV9R	0				

Table 4.49 shows the means of the post-manipulation costovertebral measurements and the frequency of the restricted costovertebral levels within group A.

Table 4.50 Group B – Pre-manipulation costovertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PreCV3L	4	2.1	5.5	4.250	1.5022
PreCV3R	2	5.2	6.1	5.650	0.6364
PreCV4L	13	1.9	6.5	4.185	1.1704
PreCV4R	3	4.5	5.4	4.800	0.5196
PreCV5L	8	2.1	6.5	4.713	1.3228
PreCV5R	8	1.7	5.9	3.363	1.3989
PreCV6L	6	1.8	6.8	4.067	1.6170
PreCV6R	7	4.0	6.0	4.986	0.7647
PreCV7L	2	4.2	6.8	5.500	1.8385
PreCV7R	5	1.2	4.8	3.700	1.4816
PreCV8L	0				
PreCV8R	1	4.5	4.500		
PreCV9L	0				
PreCV9R	0				

Table 4.50 shows the means of the pre-manipulation costovertebral measurements and the frequency of the restricted costovertebral levels in Group B.

Table 4.51 Group B – Post-manipulation costovertebrae

	N	Minimum	Maximum	Mean	Standard deviation
PostCV3L	4	4.2	7.2	5.700	1.2356
PostCV3R	2	7.1	7.6	7.350	0.3536
PostCV4L	12	2.1	9.0	6.167	2.3449
PostCV4R	4	2.7	10.0	7.175	3.1553
PostCV5L	8	5.9	8.8	7.350	0.9928
PostCV5R	6	3.7	7.0	5.500	1.4071
PostCV6L	6	2.5	8.3	6.567	2.1491
PostCV6R	7	4.0	8.6	6.929	1.7298
PostCV7L	1	4.2	4.2	4.200	.
PostCV7R	5	6.5	8.7	7.180	0.8871
PostCV8L	0				
PostCV8R	1	6.1	6.1	6.100	.
PostCV9L					
PostCV9R					

Table 4.51 shows the means of the post-manipulation costovertebral measurements and the frequency of the restricted costovertebral levels in Group B.

Table 4.52 T-test group statistics – CV3, CV4, CV5 and CV6 differences

	Group	N	Mean	Standard deviation	Standard error mean
DiffCV3L	A	13	1.5615	1.58826	0.44050
	B	17	1.9412	1.46033	0.35418
DiffCV3R	A	13	1.8154	1.79065	0.49664
	B	17	2.0941	1.25920	0.30540
DiffCV4L	A	7	2.3429	1.23404	0.46642
	B	12	2.1750	1.85331	0.53501
DiffCV4R	A	4	1.7750	1.19826	0.59913
	B	3	3.8667	0.80829	0.46667
DiffCV5L	A	13	1.4692	1.93278	0.53606
	B	8	2.6375	1.31033	0.46327
DiffCV5R	A	7	1.8000	0.56569	0.21381
	B	6	2.2833	0.63692	0.26002
DiffCV6L	A	7	1.8000	1.53188	0.57900
	B	6	2.5000	1.33417	0.54467
DiffCV6R	A	6	1.8333	1.53970	0.62858
	B	7	1.9429	1.38427	0.52320

Table 4.52 shows the results for the differences in Algometer measurements for Group A and Group B for the costovertebral levels of CV3 to CV6. Only these levels were used because there were higher frequencies.

Table 4.53 Independent samples test T-test for equality of means

							95% confidence interval of the difference	
		T	**Df**	**Significance (2-tailed)**	**Mean difference**	**Standard error difference**	**Lower**	**Upper**
DiffCV3L	**Equal variances assumed**	-0.679	28	0.502	-0.37964	0.55873	-1.52414	0.76487
DiffCV3R	**Equal variances assumed**	-0.501	28	0.620	-27873	0.55636	-1.41838	0.86091
DiffCV4L	**Equal variances assumed**	0.212	17	0.834	0.16786	0.79011	-1.49414	1.83485
DiffCV4R	**Equal variances assumed**	-2.584	5	0.049	-2.09167	0.80931	-4.17207	-0.01126
DiffCV5L	**Equal variances assumed**	-1.503	19	0.149	-1.16827	0.77726	-2.79510	0.45856
DiffCV5R	**Equal variances assumed**	-1.450	11	0.175	-0.48333	0.33332	-1.21696	0.25029
DiffCV6L	**Equal variances assumed**	-0.871	11	0.403	-0.70000	0.80413	-2.46988	1.06988
DiffCV6R	**Equal variances assumed**	-0.135	11	0.895	-1.0952	0.81058	-1.89361	1.67456

Table 4.48 shows the mean difference of the Algometer measurement of CV3 to CV6 comparing the means of Group A and Group B. The level of statistical significance was

$p \leq 0.05$. The mean difference between the groups was not statistically significant, most of the costovertebral levels did not have a *p*-value ≤ 0.05. However, the Algometer results for CV4R were statistically significant with a *p*-value = 0.04 (< 0.05) Therefore, these results supported the null hypothesis and indicated that there was no difference in the PPT in the costovertebral joints (excluding CV4R) between Group A and Group B.

Chapter Five
Discussion of the Results

5.1 Introduction

This chapter serves to discuss the statistical results of this study. It will cover the demographics and the subjective and objective results obtained.

5.2 Demographics

5.2.1 Age

**Please refer to Table 4.1*

The age parameters set for this study was between 18 and 45 years of age. The results from this study of 50 participants indicated a mean age of 26.18 years. This youthful age may be because this study was conducted in a University setting (i.e. DUT), enabling students of the institution (DUT), to readily apply for treatment.

Similar results were found in studies conducted in a University setting such as Irwin's (2015) study which revealed an age mean of 23.30 years; Dimopoulos (2002) found that 45% of the participants were between the ages of 18 and 24 years old, and 40% were between the ages of 25 and 34 years old. Similarly, Schiller's (1999) results indicated that approximately 47% of the study participants were between the ages of 16 and 24 years old, and 30% were between the ages of 25 and 34 years of age. The results of these studies suggested that mbp studies conducted in a university setting had a prevalence of participants in the second decade of life.

Mbp is common in young adults and is supported by Frontera, Silver and Rizzo (2008), who stated that mbp may be caused by thoracic sprain or strain, which occurs across all age groups. But may be more common in young adults. Similarly Briggs' (2009a) systematic review found that although there may be a higher prevalence for mbp amongst young children compared to young adults, for one month prevalence. The converse was true for one year prevalence.

This may account for the high frequency of student and young adults in this study sample, which the results will show favour the student demographic.

5.2.2 Gender

**Please refer to table 4.2*

The results of this study indicated a high frequency of women participants. The females accounted for 62% (Figure. 5.1) and the males accounted for 38% (Figure. 5.1) of the participants in this study.

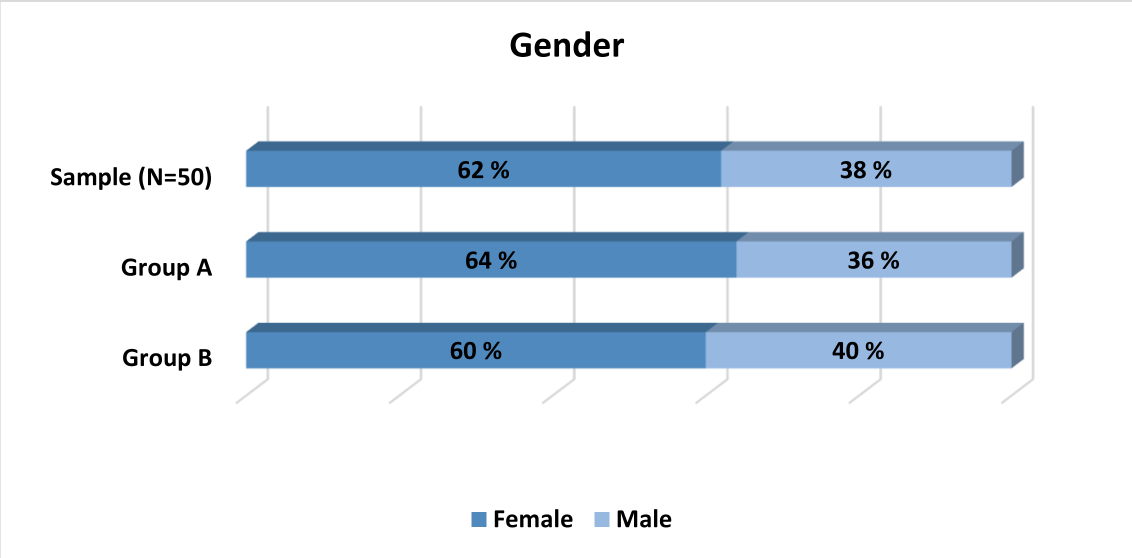


Figure. 5.1 Illustrates the distribution of males and females in the sample of 50 participants and in Group A and Group B (Table 4.2).

Similar results were found in comparable studies on mbp undertaken by Pillay, (2001) and Tsolakis (2001). Their studies indicated a prevalence of 52% and 68% respectively, for female participants in each study's sample. These findings were reproduced in Benjamin's (2007) study on the thoracic spine cases seen at the DUT CDC. Benjamin (2007) found that between 1995 and 2005, 54.8% of the patients that presented with mbp were female. These results suggested that there was higher frequency of female patients that presented at the DUT CDC with mbp, over a 10-year period. Similar results were obtained from a survey, undertaken by Roquelaure et al. (2014), in which 3 710 returned questionnaires indicated that 68.8% of the sample were female participants with mbp (Roquelaure et al., 2014). The results of these studies suggested that mbp is common in women and provided comparable data which correlated with the results of this study.

The gender distribution between Group A and Group B also reflected a higher percentage of female participants. Group A was composed of 65% female and 36% male participants. Whereas, Group B consisted of 60% female participants and 40% male participants (Figure. 5.1). These findings suggested that there was a similar distribution of the genders across Group A and Group B.

5.2.3 Race

**Please refer to Table 4.3*

The results in the sample of 50 participants, indicated a racial prevalence of 52% Black, 14% Caucasian, 8% Asian and 26% mixed race (Figure. 5.2). This was fairly representative of the general population in the greater Durban area (Mapping Diversity, 2016).

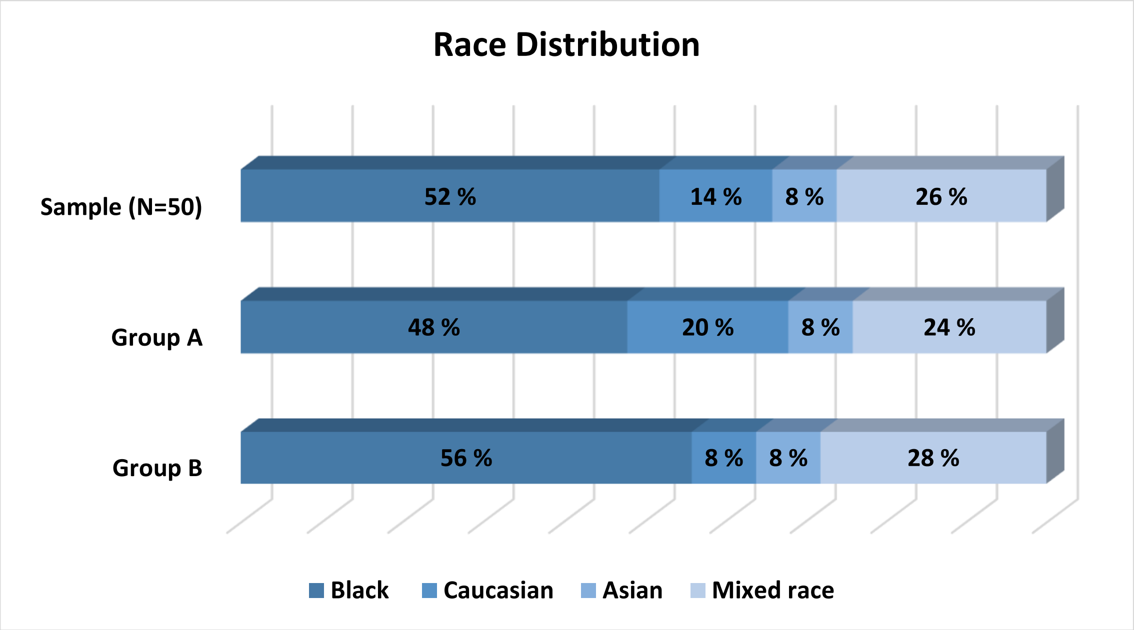


Figure. 5.2 Illustrates the distribution of races in the sample of 50 participants and in Group A and B (Table 4.3).

5.2.4 Occupation

**Please refer to Table 4.4*

The results for this study revealed a high frequency of tertiary students, accounting for 42% of the participants. The high frequency of student participants in this study may be attributed to the study being conducted in a university setting i.e. the DUT CDC. Thus, the study was easily accessible to the students of the institution.

These results correlated with the findings of previous mbp studies also conducted at the DUT CDC in which Schiller's (1999) study indicated 33% of the study sample were students; Tsolakis' (2001) study showed 63% of the participants were students and Pillay's (2001) and Dimopoulos' (2002) studies showed 65% and 40% of their sample were also students. Mbp may be caused by poor posture. Students are subjected to postural disturbances from extended periods of time in the flexion position during studying, Therefore, predisposing them to the development of mbp (Schuldt, Ekholm, Harms-Ringdahl, Nemeth and Arborelius, 1986). Research has suggested that there is an increased risk of mbp in students (Roquelaure et al., 2014). The results of Roquelaure's et al. (2014) study highlighted the correlation between sustained poor posture and mbp. The findings in Roquelaure's et al. (2014) study suggested that 61.3% of the study sample with mbp, was subjected to frequent and sustained forward flexion positions. These findings indicated that postural disturbances were a common cause and risk factor for mbp in the student population.

Similarly, Briggs (2009b) and Wong and Fielding (2011) stated that participants in sedentary profession may be more likely to develop mbp. Therefore, there is likely to be a higher prevalence of mbp in individuals with sedentary lifestyles i.e students and may result in a higher number of participants that fall into this demographic being included in this study.

The results of these studies suggested that students are pre-disposed to the development of mbp and provided comparable data which correlated with the results of this study.

5.3 Prevalence of Participants with a History of Chiropractic Treatment

**Please refer to Table 4.5*

The results of this study indicated that 70% (Figure.5.3) of the sample size of 50 participants, had a history of chiropractic treatment. Whereas, 30% of the participants did not. This may be because this study was conducted at a teaching chiropractic clinic on the DUT premises and was easily accessible to returning patients and DUT students that have received prior treatment from the clinic. These results may also be have been influenced by the increasing popularity of alternative treatment such as: chiropractic, which is now often recommended as a treatment to reduce the symptoms of back pain (Okoro, Zhao, Li, Balluz, 2013).

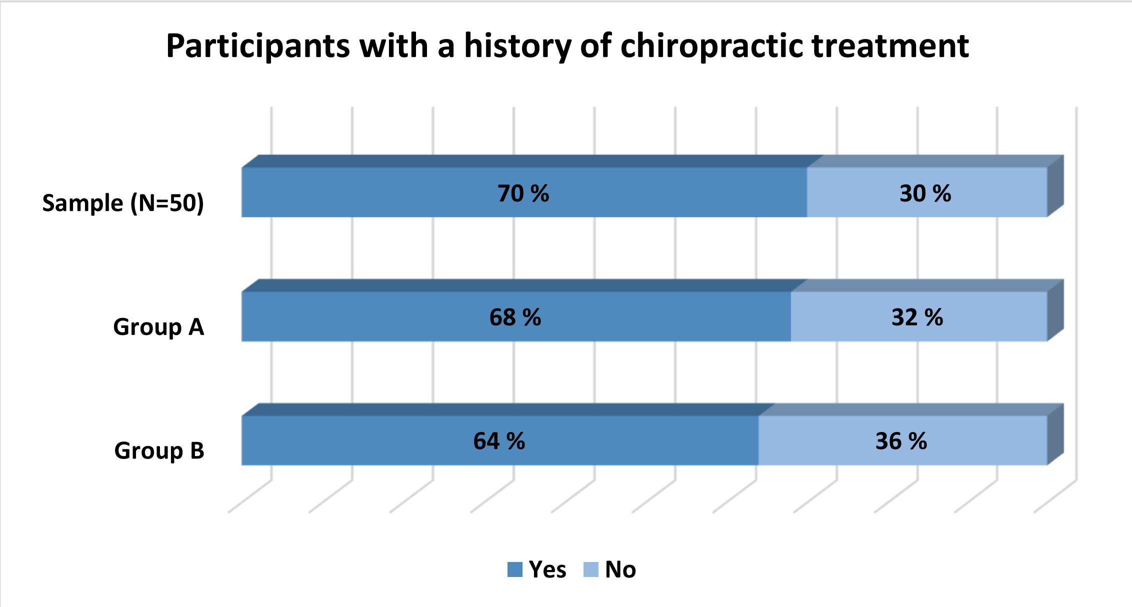


Figure 5.3 Illustrates the prevalence and distribution of participants that had a history of chiropractic treatment in the sample of 50 participants and in Groups A and B (Table 4.5).

There was a similar distribution of participants with a history of chiropractic treatment between Group A and Group B. Majority of the participants in Group A (68%) and Group B (64%) had a history of chiropractic treatment. Whereas, 32% of the participants in Group A and 36% of the participants in Group B, did not.

5.4 Frequency and Distribution of Vertebral Techniques Used

**Please refer to Table 4.6*

This study included the use of two thoracic vertebral manipulative techniques (Appendix O), namely the Bilateral Hypothenar Technique (Figure. 1 of Appendix O) and Cross Bilateral Technique (Figure. 2 of Appendix O). Within the sample size of 50 participants 24% (Figure. 5.4) received the Bilateral Hypothenar technique and 64% (Figure. 5.4) received the Cross bilateral technique. The Cross bilateral technique was favoured over the Bilateral hypothenar technique, within the sample of 50 participants. Resulting in a statistically significant difference in the type of vertebral manipulative technique used.

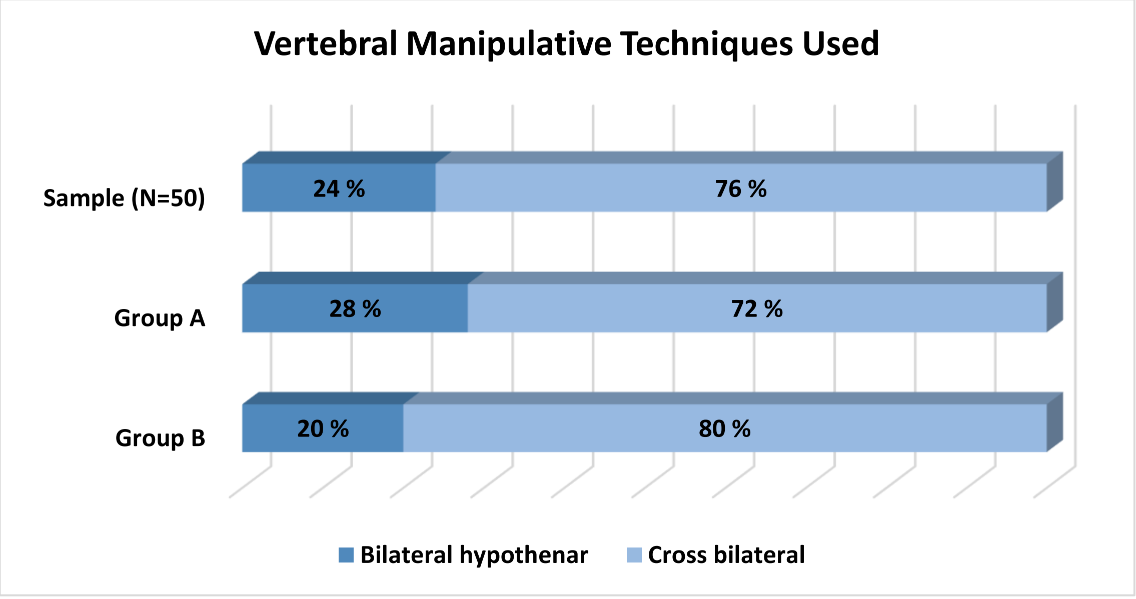


Figure 5.4 Illustrates the frequency and distribution of vertebral manipulative techniques used in the sample of 50 participants and in Groups A and B (Table 4.6).

However, when comparing the use of these manipulative techniques across Group A and B, there was no statistically significant difference. In Group A, 28% (Figure. 5.4) of the participants received the Bilateral Hypothenar technique (Figure. 1 of Appendix O) and 62% (Figure. 5.4) of the participants received the Cross Bilateral Technique (Figure 2 of Appendix O). In Group B, 20% (Figure. 5.4) of the participants received the Bilateral Hypothenar Technique (Figure 1 of Appendix O) and 80% (Figure. 5.4) of the participants received the Cross Bilateral technique (Figure. 2 of Appendix O). These findings did not indicate a statistically significant difference in the vertebral manipulative techniques used in Group A and in Group B. Suggesting a similar distribution of the thoracic vertebral manipulative techniques used in both groups.

5.5 Frequency of Costovertebral Manipulative Techniques Used

**Please refer to Table 4.7*

This study included the use of two costovertebral manipulative techniques, namely, the Hypothenar Costal (Figure 1 of Appendix P) and the Ilial Hypothenar Costal manipulative techniques (Figure. 2 of Appendix P). Group B received costovertebral manipulations, however Group A did not (Figure. 5.5).

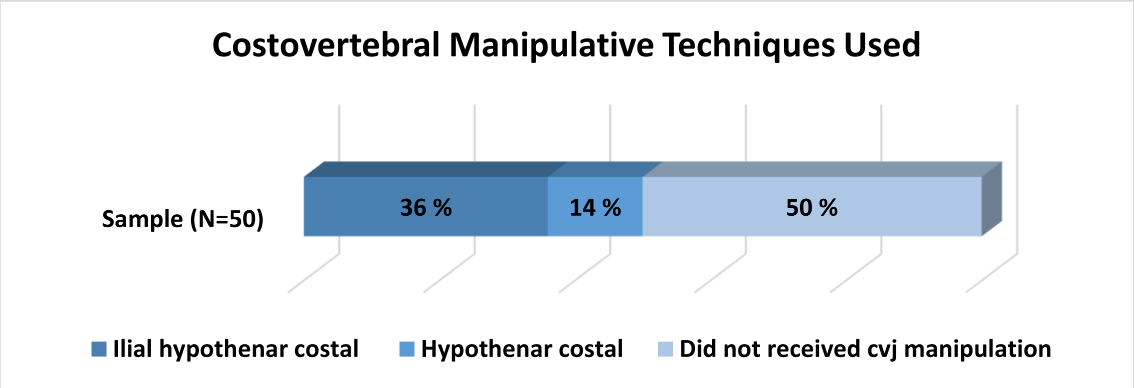


Figure 5.5 Illustrates the frequency and distribution of costovertebral manipulative techniques used in the sample of 50 participants (Table 4.7).

Of the sample size of 50 participants 36% (Figure. 5.5) received the Ilial Hypothenar Costal technique (Figure. 2 of Appendix P), 14% (Figure. 5.5) received the Hypothenar Costal technique (Figure 1 of Appendix P) and 50% did not receive cvj manipulations. These findings indicated that the Ilial Hypothenar Costal technique (Figure. 2 of Appendix P) was favoured over the Hypothenar Costal technique (Figure 1 of Appendix P). Indicating a statistically significant difference in the costovertebral manipulative techniques used in the sample of 50 participants.

5.6 Frequency of Restricted Vertebral and Costovertebral Levels

**Please refer to Table 4.8*

The results of this study indicated that a number of the participants had restrictions of the vertebral levels between T3 and T8. The vertebral levels restricted most often in the sample size of 50 participants were T4 (23%), T5 (22%) and T6 (25%).

Costovertebral joint restrictions were found most often in the region between the 4^{th} and 7^{th} ribs. The costovertebral levels restricted most often in the sample size of 50 participants were the left 4^{th} rib, left 5^{th} rib and the right 5^{th} rib.

The results for the frequency of vertebral restrictions correlate with those found in similar studies. Schiller's (1999) study indicated that 77% of the vertebral restrictions were found between the levels of T5 and T9. Dimopoulos' (2002) study indicated that 57.5% of the vertebral restrictions found were between the levels of T5 and T9. Similarly, Tsolaki's (2001) study found that most of the vertebral restrictions in her study sample were between the thoracic levels of T5 and T9. Benjamin's (2007) study, in the form of a 10-year (1995 - 2005) survey, yielded comparable results and indicated that the most frequently restricted thoracic levels were between T5 and T8 (58.5%), T1 and T4 (41.5%), and T9 and T12 (23%). The results of these studies correlate with the findings in this study and highlight that the mid-back (i.e T3 to T9) is the area in the thoracic spine with the highest likelihood of restriction.

5.7 Discussion of Subjective Results - Numerical Pain Rating Scale (NPRS)

The results for the intra-group analysis of the NPRS (Appendix L), indicated a statistically significant difference within Group A (p = 0.000) (Table 4.9) and within Group B (p = 0.000) (Table 4.11). These results indicated that according to the NPRS, both groups had a decrease in pain perception. These results suggest that one application of thoracic facet joint manipulation and one application of combined thoracic facet and costovertebral joint manipulation effectively reduced pain perception in participants with mbp.

Wassinger, Rich, Cameron, Clark, Davenport, Lingelbach, Baxter and Davidson (2016) investigated the effects of spinal manipulation on shoulder pain and found that the combination of cervical, cervicothoracic and thoracic facet manipulation significantly reduced pain perception ($p = 0.001$). Vieira-Pellenz's et al. (2014) study on spinal manipulation had a statistically significant effect on reducing pain of a single lumbar spine L5/S1) ($p \leq 0.001$). These studies provided comparable data which correlated with the results of this study and highlighted the effectiveness of spinal manipulation in the reduction of pain perception.

However, the results for the inter-group analysis did not indicate a statistically significant difference between the pre-manipulation and post-manipulation readings ($p = 0.386$) (Table 4.13) across Group A and Group B. These findings suggested that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation similarly reduced pain perception in participants with mbp.

5.8 Discussion of Objective Results

5.8.1 Inclinometer Results

5.8.1.1 Flexion

The results for the intra-group analysis of Inclinometer measurements of thoracic spine ROM in flexion, indicated a statistically significant difference in Group A ($p = 0.000$) (Table 4.14) and Group B ($p = 0.000$) (Table 4.15). These results indicated that both groups had an increase in thoracic spine ROM in flexion. Therefore, this suggests that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased thoracic spine ROM in flexion, in participants with mbp.

Similarly, the spinal manipulation groups in Tsolakis' (2001) and Dimopoulos' (2002) studies indicated a statistically significant difference in thoracic spine ROM in flexion. The manipulation group in Tsolakis' (2001) study showed a mean increase of 16° after the first treatment and Dimopoulos' (2002) manipulation group had a statistically significant improvement, with $p < 0.001$, after the third treatment. These results correlate with the findings in this study and indicate that spinal manipulation effectively increased the thoracic ROM in flexion.

However, the inter-group results did not indicate a statistically significant difference (*p* = 0.408) (Table 4.17) in pre-manipulation and post-manipulation thoracic flexion ROM measurements across Group A and Group B. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the thoracic flexion ROM in participants with mbp.

5.8.1.2 Extension

The results for the intra-group analysis of Inclinometer measurements of thoracic spine ROM in extension, indicated a statistically significant difference within Group A (*p* = 0.000) (Table 4.18) and within Group B (*p* = 0.000) (Table 4. 19). These results indicated that both groups had an increase in thoracic spine ROM in extension, suggesting that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased thoracic spine ROM in extension in participants with mbp.

Similarly, the spinal manipulation groups in Tsolakis' (2001) and Dimopoulos' (2002) studies indicated a statistically significant difference in thoracic spine ROM in extension. The manipulation group in Tsolakis' (2001) study had a mean increase of 18° after the first treatment and Dimopoulos' (2002) manipulation group had a statistically significant improvement with *p* = 0.000 after the third treatment. These results correlate with the findings in this study and indicate that spinal manipulation effectively increased the thoracic ROM in extension.

However, the inter-group results did not indicate a statistically significant difference (*p* = 0.757) (Table 4.21) in pre-manipulation and post-manipulation thoracic extension ROM measurements across Group A and Group B. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the thoracic extension ROM in participants with mbp.

5.8.1.3 Right lateral flexion

The results for the intra-group analysis of Inclinometer measurements of thoracic spine ROM in right lateral flexion indicated a statistically significant difference in Group A (*p* = 0.000) (Table 4.22) and Group B (*p* = 0.000) (Table 4.23).These results indicated that both groups had an increase in thoracic spine ROM in right lateral flexion. This suggests that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased thoracic spine ROM in right lateral flexion in participants with mbp.

Similarly, the spinal manipulation groups in Tsolakis' (2001) and Dimopoulos' (2002) studies indicated a statistically significant difference in thoracic spine ROM in right lateral flexion. The manipulation group in Tsolakis' (2001) study had a mean increase of 10° after the first treatment and Dimopoulos' (2002) manipulation group had a statistically significant improvement with $p = 0.000$ after the third treatment. These results correlate with the findings in this study and indicate that spinal manipulation effectively increased the thoracic ROM in right lateral flexion.

However, the inter-group results did not indicate a statistically significant difference ($p = 0.967$) (Table 4. 25) in pre-manipulation and post-manipulation thoracic right lateral flexion ROM measurements across Group A and Group B. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the thoracic right lateral flexion ROM in participants with mbp.

5.8.1.4 Left lateral flexion

The results for the intra-group analysis of Inclinometer measurements of thoracic spine ROM in left lateral flexion indicated a statistically significant difference within Group A ($p = 0.000$) (Table 4.26) and within Group B ($p = 0.000$) (Table 4. 27). These results indicated that both groups had an increase in thoracic spine ROM in left lateral flexion. Therefore, the results suggested that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased thoracic spine ROM in left lateral flexion in participants with mbp.

Schiller's (1999) study revealed that spinal manipulation effectively increased thoracic spine ROM in left lateral flexion and indicated a 5° increase by the sixth treatment**.** Similarly, the spinal manipulation groups in Tsolakis' (2001) and Dimopoulos' (2002) studies indicated a statistically significant difference in thoracic spine ROM in left lateral flexion. The manipulation group in Tsolakis' (2001) study had a mean increase of 15° after the first treatment and Dimopoulos' (2002) manipulation group had a statistically significant improvement with $p = 0.006$ after the third treatment. These results correlate with the findings in this study and indicate that spinal manipulation effectively increased the thoracic ROM in left lateral flexion.

However, the inter-group results did not indicate a statistically significant difference ($p = 0.430$) (Table 4.29) in pre-manipulation and post-manipulation thoracic left lateral flexion ROM measurements across Group A and Group B. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the thoracic left lateral flexion ROM in participants with mbp.

5.8.1.5 Right rotation

The results for the intra-group analysis of Inclinometer measurements of thoracic spine ROM in right rotation indicated a statistically significant difference within Group A ($p = 0.000$) (Table 4. 30) and within Group B ($p = 0.000$) (Table 4. 31). These results indicated that both groups had an increase in thoracic spine ROM in right rotation. These, the results indicated that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased thoracic spine ROM in right rotation in participants with mbp.

Schiller's (1999) study revealed that spinal manipulation effectively increased thoracic spine ROM in right rotation and indicated a 15° increase by the sixth treatment**.** Similarly, the spinal manipulation groups in Tsolakis' (2001) and Dimopoulos' (2002) studies indicated a statistically significant difference in thoracic spine ROM in right rotation. The manipulation group in Tsolakis' (2001) study had a mean increase of 17° after the first treatment and Dimopoulos' (2002) manipulation group had a statistically significant improvement with $p = 0.000$ after the third treatment. These results correlate with the findings in this study and indicate that spinal manipulation effectively increased the thoracic ROM in right rotation.

However, the inter-group results did not indicate a statistically significant difference (*p* = 0.732) (Table 4.33) in pre-manipulation and post-manipulation thoracic right rotation ROM measurements across Group A and Group B. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the thoracic right rotation ROM in participants with mbp.

5.8.1.6 Left rotation

The results for the intra-group analysis of inclinometer measurements of thoracic spine ROM in left rotation indicated a statistically significant difference within Group A (*p* = 0.000) (Table 4. 34) and within Group B (*p* = 0.000) (Table 4.35). These results indicated that both groups had an increase in thoracic spine ROM in left rotation. These results suggested that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased thoracic spine ROM in left rotation in participants with mbp.

Schiller's (1999) study revealed that spinal manipulation effectively increased thoracic spine ROM in left rotation and indicated a 10° increase by the sixth treatment**.** Similarly, the spinal manipulation groups in Tsolakis' (2001) and Dimopoulos' (2002) studies indicated a statistically significant difference in thoracic spine ROM in left rotation. The manipulation group in Tsolakis' (2001) study had a mean increase of 17° after the first treatment and Dimopoulos' (2002) manipulation group had a statistically significant improvement with *p* = 0.000 after the third treatment. These results correlate with the findings in this study and indicate that spinal manipulation effectively increased the thoracic ROM in left rotation.

However, the inter-group results did not indicate a statistically significant difference (*p* = 0.765) (Table 4. 37) in pre-manipulation and post-manipulation thoracic left rotation ROM measurements across Group A and Group B. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the thoracic left rotation ROM in participants with mbp.

Collectively, the Inclinometer results for this study indicated that the combination of thoracic facet and costovertebral joint manipulation treatments (Group B) was not more effective than thoracic facet joint manipulation treatment (Group A) alone, in increasing the thoracic ROM in flexion, extension, lateral flexion and rotation.

5.8.2 Algometry Results

The Wilcoxon signed test was used to analyse the data for statistical significance of the restricted vertebral and costovertebral levels. The levels that were commonly restricted were analyzed for statistical significance. However, the vertebral and costovertebral levels that were fewer in frequency, were difficult to analyze for statistical significance using the software because an "unable to compute" result was reported back due to there being an insufficient number to adequately draw a comparison. Therefore, some vertebral and costovertebral results were not included.

5.8.1.1 Thoracic Vertebral Results

The results for the intra-group analysis of the Algometry measurements indicated a statistically significant difference in Group A ($p < 0.05$) (Table 4.38). Group A showed statistical differences in the Algometry measurements of the T4 to T7 facets, bilaterally. Similarly, Group B ($p < 0.05$) (Table 4.39) showed statistical differences in the Algometry measurements of the same levels (i.e. T4 to T7 facets, bilaterally). This indicated an increase in the PPT of both Groups. Therefore, the results suggested that thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased the PPT of the thoracic facet joints, in participants with mbp.

Similarly, the results of Irwin’s (2015) study on mbp indicated spinal manipulation Group showed a statistically significant difference ($p = 0.000$) in the PPT of participants with mbp. The effect of spinal manipulation was also highlighted in a study (Fernandez-Del-las-Penas et al., 2008) that investigated the effect of a cervicothoracic manipulation on the PPT of C5 – C6 facet joints in asymptomatic participants. The results indicated that spinal manipulation ($p \leq 0.05$) produced a statistically significant increase in PPT over the C5 – C6 facet joints (Fernandez-Del-las-Penas et al., 2008). These studies provided comparable data which correlated with the results of this study and highlighted the effectiveness of spinal manipulation in increasing PPT.

However, the results for the inter-group analysis of the Algometry measurements did not indicate a statistically significant difference ($p > 0.05$) (Table 4.47) across Group A and Group B. This was determined by the comparison of the Algometry measurements of the T4 to T6 facets joints, bilaterally. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the PPT of the thoracic facet joints in participants with mbp.

5.8.1.2 Costovertebral Results

The results for intra-group analysis of Algometry measurements indicated a statistically significant difference in Group A ($p \leq 0.05$) (Table 4.40). Group A showed statistical differences in the Algometry measurements of the costovertebral joints of the left fourth rib and ribs 5 to 6, bilaterally. Group B ($p \leq 0.05$) (Table 4.41) showed statistical differences in the Algometry measurements of the costovertebral joints of ribs 4 to 6, bilaterally. This indicated an increase in the PPT of the costovertebral joints in both Groups. Therefore, according to these results thoracic facet joint manipulation and the combination of thoracic facet and costovertebral joint manipulation effectively increased the PPT of the costovertebral joints in participants with mbp.

However, similar to the thoracic vertebral Algometry results for the inter-group analysis, the results for the inter-group analysis of costovertebral joints did not indicate a statistically significant difference between Group A ($p > 0.05$) and Group B ($p > 0.05$) (Table 4. 53). This was determined by the comparison of the Algometry measurements of the costovertebral joints of ribs 4 to 7, bilaterally. These findings suggested that thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation similarly increased the PPT of the costovertebral joints in participants with mbp.

The results of this study indicate that manipulation of the thoracic facet joints alone or combined with manipulation of the costovertebral joints, resulted in similar effects in participants with mechanical mbp. Both interventions were shown to effectively reduce pain perception, improve thoracic spine range of motion and increase pressure pain thresholds. Thus, indicating that both interventions may effectively treat mbp in clinical practice. In patients with more severe costovertebral joint dysfunction, it may be useful to include the manipulation of those joints in the management of mbp. However, all participants in this study did present with both thoracic facet and costovertebral joint restrictions, both of which improved in the thoracic facet joint manipulation - only group. This may be because of the biomechanical relationship existing between these two joints, whereby positively altering the dynamics in one joint effected change in the other. Therefore, based on the results of this study it may not be necessary to include costovertebral joint manipulation in the management of mbp, but to rather modify the treatment based on the severity of the costovertebral dysfunction present.

Chapter Six
Conclusions and Recommendations

6.1 Conclusions

This study obtained relevant data relating to the demographics and clinical implications of two different chiropractic manipulative approaches for the treatment of mbp.

The following conclusions may be drawn from the results of this study:

- Thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation produced a similar effect in reducing pain perception in participants with mbp.
- Thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation produced a similar effect in increasing the PPT in the thoracic spine of participants with mbp.
- Thoracic facet joint and the combination of thoracic facet and costovertebral joint manipulation produced a similar effect in increasing the thoracic ROM in flexion, extension, left lateral flexion, right lateral flexion, left rotation and right rotation in participants with mbp.

The intra-group results for the comparison between the pre-manipulation and post-manipulation measurements of the sample of 50 participants, indicated that there was a statistically significant difference in the subjective and objective results when compared with baseline measurements. However, the inter-group comparison of the pre-manipulation and post manipulation measurements indicated no statistical difference in the subjective and objective results between Group A (thoracic facet joint manipulation) and Group B (thoracic facet and costovertebral joint manipulation). Therefore, the results of this study suggest that there is no statistically significant difference between the two groups, based on the outcome measures used. The findings of this study offer insight that these treatments may have a similar effect. Thus the null hypothesis was rejected, suggesting that the addition of costovertebral joint manipulation may not be necessary for the effective treatment of mbp.

6.2 Recommendations

6.2.1 Recommendations to improve the study design

- The sample size for this study was small and the findings obtained, however insightful, were inconclusive. Future researchers should consider a fully powered study with a larger sample size. The sample size for a fully powered study may be generated using statistical methods with the results of the outcome measures of the sample of 50 participants in this study.
- This study did not have a control/ blinded group. The addition of a control / blinded group in future studies may help reduce bias in the study.
- Although the research assistant was blind to the participant group allocation and conducted the spinal and rib screening, which reduced bias of ‘finding restrictions’ by the researcher. The researcher captured the data. To further reduce bias, future studies should consider allowing the research assistant to capture the data. Alternatively, a third party may be asked to capture the data.
- This study had high concentration of tertiary student participants, thus was focused on a specific demographic. Therefore, the data may not be entirely generalizable. Future researchers should consider conducting future studies in a non-university setting. Alternatively, a restriction on the number of student participants may be enforced to ensure a more even demographic distribution within the study.
- Similarly, there was a significantly higher number of participants with a history of chiropractic treatment. Individuals who have not had previous chiropractic treatment may experience some tenderness/ pain immediately after manipulative therapy. This side effect may influence some of the measurement outcomes i.e NPRS. Future researchers should consider a sample with an even distribution of participants with a history of chiropractic treatment and those. Alternatively, the sample may be limited to participants with or participants without a history of chiropractic treatment.
- This study divide the measurement outcomes into subjective and objective data. Future researchers should consider clarifying these outcomes into primary and secondary outcomes. This draws focus to the most important outcomes of the study first.

6.2.2 Recommendations for Clinical Practice

- The findings of this study are insightful but inconclusive. They suggest that the manipulation of the thoracic facet joints and the combination of the manipulation of the thoracic facet and costovertebral joints, will produce similar effects. However, it is important to note the following when considering a treatment regime for mbp:
  - A co-dependent biomechanical relationship exists between the two joints. Rather than treating only the one link in the kinematic chain, it may be beneficial to address both in this compact functional unit.
  - The incorporation of costovertebral manipulation in the treatment of mbp, may further aide in pain modulation as explained by Gatterman's theory of Altered somatic afferent input (2005). The manipulation of both these joints i.e multiple sensory inputs may alter pain modulation and interpretation at a spinal cord level.

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Appendices

Appendix A Letter of Ethical Clearance

Appendix B Clinic Director Letter of Permission

Appendix C Gatekeeper Permission Letter

Appendix D NHREC Registration of Clinical Trial

Appendix E Advertisement

Appendix F DUT CDC Patient Information Sheet

Appendix G Research Letter of Informed Consent

Appendix H Case History Form

Appendix I Senior Physical Examination Form

Appendix J Thoracic Spine Examination Form

Appendix K S.O.A.P. E NOTE

Appendix L Numerical Pain Rating Scale (NPRS)

Appendix M Wagner Algometer

Appendix N Saunders Digital Inclinometer

Appendix O Thoracic Vertebral Manipulative Techniques

1. Bilateral Hypothenar
2. Cross Bilateral

Appendix P Costovertebral Joint Manipulative Techniques

1. Hypothenar Costal
2. Ilial Hypothenar Costal

Appendix A – Letter of Ethical Clearance

DUT DURBAN UNIVERSITY OF TECHNOLOGY

Institutional Research Ethics Committee
Faculty of Health Sciences
Room MS 49, Mansfield School Site
Gate 8, Ritson Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2900
Fax: 031 373 2407
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

11 August 2016

IREC Reference Number: **REC 48/16**

Ms G E D Petersen
29 Sol Harris Crescent
22 Connemara
North Beach
Durban

Dear Ms Petersen

The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mid-back pain

I am pleased to inform you that Provisional Approval has been granted to your proposal REC 48/16 subject to:

- Obtaining and submitting the necessary gatekeeper permission/s to the IREC.

Full approval is subject to meeting the above condition.

The Proposal has been allocated the following Ethical Clearance number **IREC 080/16**. Please use this number in all communication with this office.

Approval has been granted for a period of two years, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

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 IREC according to the IREC SOP's.

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

Yours Sincerely

[redacted]

Professor J K Adam
Chairperson: IREC

DUT DURBAN UNIVERSITY OF TECHNOLOGY

2016 -08- 11

INSITUTUTIONAL RESEARCH ETHICS COMMITTEE
P O BOX 1334 DURBAN 4000 SOUTH AFRICA

Appendix B – Clinic Director Letter of Permission

MEMORANDUM

To	:	Prof Ross Chair : RHDC
		Prof Adam Chair : IREC
From	:	Dr Charmaine Korporaal Clinic Director : FoHS Clinic
Date	:	08.06.2016
Re	:	Request for permission to use the Chiropractic Day Clinic for research purposes

---

Permission is hereby granted to :

Ms Gabriela Elisa DaSilva Petersen (Student Number: 20801697)

Research title: "The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mid-back pain."

It is requested that Ms Petersen submit a copy of her RHDC / IREC approved proposal to the Clinic Administrators before she starts with her research in order that any special procedures with regards to her research can be implemented prior to the commencement of her seeing patients.

Thank you for your time.

Kind regards

[redacted]

Dr Charmaine Korporaal

Clinic Director : FoHS Clinic

Cc: Mrs Linda Twiggs : Chiropractic Day Clinic
Dr L O'Connor : Research co-ordinator
Dr H Kretzmann : Research supervisor

Appendix C – Gatekeeper Permission Letter

DUT DURBAN UNIVERSITY OF TECHNOLOGY
DIRECTORATE FOR RESEARCH AND POSTGRADUATE SUPPORT

Directorate for Research and Postgraduate Support
Durban University of Technology
Tromso Annexe, Steve Biko Campus
P.O. Box 1334, Durban 4000
Tel.: 031-3732576/7
Fax: 031-3732946
E-mail: moyos@dut.ac.za

18th August 2016

Ms Gabriela Petersen
c/o Department of Chiropractic and Somatology
Faculty of Health Sciences
Durban University of Technology

Dear Ms Petersen

PERMISSION TO CONDUCT RESEARCH AT THE DUT

Your email correspondence in respect of the above refers.

I am pleased to inform you that the Institutional Research Committee (IRC) has granted full permission for you to conduct your research "The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mid-back pain" at the Durban University of Technology.

We would be grateful if a summary of your key research findings can be submitted to the IRC on completion of your studies.

Kindest regards.
Yours sincerely

[redacted]

PROF. S. MOYO
DIRECTOR: RESEARCH AND POSTGRADUATE SUPPORT

Appendix D – NHREC Registration of Clinical Trial

NHREC

South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	4503	**DOH Number**	**Pending**	Page:	1/3

Applicant Details

Organisation :	Durban University of Technology
Applicant Type :	Academic Investigator
Contact Name :	Laura O'Connor
Address :	Chiropractic Programme Durban University of Technology PO Box 1334 Durban 4000
Telephone :	0313732923
Fax :	0865324209
E-mail :	lauraw@dut.ac.za
Responsible Contact person (for public)	L. O'Connor
Telephone :	03137372923
Research contact person	H. Kretzmann
Telephone :	0313732923

Trial Application Details

Issue Date :	2016/08/12
Sponsors :	Durban University of Technology
Primary Sponsor :	Durban University of Technology
FundingType :	Not Funded
Research Site Names :	Durban University of Technology Chiropractic Clinic
Primary Research Site Name :	
Total National Budget for Trial :	R 5916.07
Protocol / Grant Reference Number	IREC 080/16

Study Descriptive Information

Brief Tiltle of Study :	The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mid-back pain
Full Title of Study :	The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mid-back pain
Anticipated Start Date :	2016/08/29
Anticipated End Date :	2016/10/31
Target Sample Size :	50
Study Phase :	Other
Study Scope :	Single Site
Study Type :	Interventional
Disease Type Heading :	Muscle, Bone and Cartilage Diseases
Disease Type Condition :	Musculoskeletal Diseases
Intervention Name (Generic) :	Manipulation
Intervention Duration :	No. Type 1 Minutes

NHREC

South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	4503	DOH Number	Pending	Page:	2/3

Interventional

Intervention Type :	Procedure
Purpose :	Treatment
Allocation :	Randomised
Masking :	Single Blind
Control :	Active
Assignment :	Parallel
Endpoints :	Efficacy

NHREC

South African Human Research Electronic Application System

TRIAL APPLICATION

Application ID:	4503	DOH Number	Pending	Page:	3/3

Study Descriptive Information

Recruitment Status as at Date:	2016/08/12
Recruitment Status :	Not Yet Recruiting
Gender :	Both
Ethnicity :	All
Age :	From 18 Years To 45 Years
Qualifying Disease Condition for Inclusion :	2. Mid-back pain may be defined within the limits of this study as : • Sharp, shooting or aching thoracic back pain AND/ OR • Thoracic back pain experienced during deep inspiration, sneezing and/or coughing • Localised pain • Altered end feel resistance (describes the give or 'feel' of the joint when manual pressure is applied to it. This may be boggy, restrictive or lax) (Bourdillon, 1992) • Restricted thoracic range of motion • Restricted thoracic facet segments between T3 and T9 • Restricted costovertebral segments between ribs three and nine
Major Exclusion Criteria :	1. Patients who do not sign or understand the letter of informed consent (Appendix B) 2. Patients with contraindications to manipulation (Gatterman,1995:169 and Bourdillon, 1992: 286-292, Bergmann et al, 2011: 102-103) • Weakened bone due to - Osteoporosis - Infection - Neoplasm • Disc extrusion due to forced flexion • Joint hypermobility • Verebro-basillar insufficiency • Uncontrolled hypertension • Congenital abnormalities – Block vertebrae • Spinal or rib fracture • Transverse process fracture 3. Congenital or acquired spinal deformities 4. Neurological disease 5. Individuals on anticoagulant therapy
Key Primary Outcome :	Pain and pain pressure threshold
Key Secondary Outcomes :	Range of motion

Appendix E – Advertisement

Upper back pain? Mid-back Pain or stiffness? Pain in between the shoulder blades?

If you are experiencing pain or stiffness in the upper back, mid-back or in-between t\he shoulder blades, you could qualify to participate in a Research study using chiropractic treatment that may relieve your mid-back pain and/or stiffness. The study is being conducted at the Durban University of Technology Chiropractic Day Clinic.

For more information please contact Gabriela on:

Contact number: **074 653 9126/ 031 373 2205**

Email: **gabidasilvapetersen@gmail.com**

Appendix F – DUT CDC Patient Information Sheet

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

Chiropractic Day Clinic

CONFIDENTIAL PATIENT INFORMATION

Date:	Title:
Male / Female:	Initials:
Surname:	I.D. number:
First name:	Marital status:
Birthdate:	Medical aid:
Occupation:	M/A number:
Med doctor:	Last visit:
Chiropractor:	Last visit:
Postal address:	Residential address:
Tel - work:	Tel - home:
Cell number:	
Employer:	
Employer's address:	

NB: Please ensure that you supply your Medical Aid No for refund purposes

FINANCIAL INFORMATION

The current fee schedule of the Chiropractic Day Clinic is :

Student (5th Year Students)		Student (6th Year Students)	
Initial visit:	R 130.00	Initial visit:	R 150.00
Subsequent visits	R 90.00	Subsequent visits	R 110.00

All consumables (e.g. needles) : Prices are available on request at the reception desk.

PTO for more information and in order to sign for consent.

Medical Aid schemes pay in varying degrees for coverage of Chiropractic Services. This coverage is therefore medical aid dependant and we request that you check with your medical aid in this respect. **The DUT Chiropractic Day Clinic is contracted out of medical aid**, which means that we run on a **strictly cash only basis**, whereby you are requested to pay cash in advance of services rendered. You will be sent a monthly statement which you must submit to your medical aid for them to refund you directly. This statement will be sent out at the **end of each month.**

Charges are **not** applicable to **research patients**

Medico-Legal Reports:
As the Chiropractic Day Clinic is a teaching facility we are not in a position to generate any reports required for medico-legal purposes, claims that relate to injury on duty (IOD) or workman's compensation

Report of findings:
It is imperative that the student treating you explains fully your diagnosed condition, both as an educational requirement for the student but also, **and more importantly**, such that you are able to make an informed decision about the type of treatment that you wish to receive.

Treatment options:
It is imperative that the student explains all treatment options that are available for you based on the diagnosed condition/(s) that was/were given to you in respect of the above.

Risks/Benefits:
The student must explain to your satisfaction/understanding all risks and benefits in relation to treatment of your reported diagnosis/condition(s).

As a Patient at this, the Chiropractic Day Clinic, I understand that I am attending an educational facility and I give my permission to allow observation, and if necessary the video recording of supervised examination and treatment by Doctors of Chiropractic and Students. In addition I, as the patient note, that information generated through my attendance of the clinic, may be used for research purposes (either through my direct participation in the research or alternatively through data collected in my patient file).

By signing this form I agree that

a) I understand and take full financial responsibility for consultations.
b) I understand that I cannot request records for medico legal reasons.
c) I understand that should I be on medical aid, that my diagnosis and treatment information will be shared for the purposes of medical aid reimbursing me according to that which I am contractually bound in terms of my medical cover (and that only a written request or instruction from myself will be accepted in terms of discontinuing this practice by my health care provider – the Chiropractic Day Clinic).
d) Should I need to be referred that my medical information (pertinent to my condition) will be shared with the doctor / specialist to whom I have been referred.
e) I understand that with my attendance at the Chiropractic Day Clinic, that my medical information will be discussed between the student responsible for my care and the supervising clinician who is responsible for overall oversight of my care.

Date:		**Patient Signature:**	
Parent/legal guardian signature: (in the case of patient's who are under the age of 12 years and those requiring assistance between the ages of 12-18 years)			
Relationship of guardian to the minor:			
Date:		**Student Signature:**	
Date:		**Clinician Signature:**	

By signing this section of the form I agree that (to be completed after you have been assessed and prior to your treatment / referral):

a) The student has discussed with me to my satisfaction, and I fully understand, my / my minor child's diagnosed condition(s) that I have.
b) The student has discussed with me to my satisfaction, and I fully understand all treatment and/or non treatment options and their relative successes and/or failures as applicable to the diagnosed condition(s).
c) I am making an informed decision with regard to, and will submit to / consent to my minor child being submitted to, the treatment protocol as explained.

Based on the above I therefore give consent for the treatment of my named complaint by signing the form hereunder:

Date:		**Patient Signature:**	
Parent/legal guardian signature: (in the case of patient's who are under the age of 12 years and those requiring assistance between the ages of 12-18 years)			
Relationship of guardian to the minor:			
Date:		**Student Signature:**	
Date:		**Clinician Signature:**	

Appendix G – Research Letter of Informed Consent

Letter of Information and Informed Consent

Dear Participant

Title of the research study:

The effect of thoracic spine manipulation compared to thoracic spine and costovertebral joint manipulation on mid-back pain

Principal Investigator/s/ researcher:

Gabriela Elisa da Silva Petersen B. Tech: Chiropractic

Co-Investigator/s/ supervisor/s:

Dr. Heidi Kretzmann, M. Tech: Chiropractic

Brief Introduction and Purpose of the Study:

This study aims to determine which strategy of manipulation is best for patients that present with mid-back pain. To do this, 50 individuals between the ages of 18 and 45 years of age will be selected to participate in the study. If you have been selected to participate in this study, you may fall into one of two groups of 25 participants. Both groups will have chiropractic manipulative techniques performed on them; however, the combination of these techniques will vary.

Outline of the Procedures:

You will be required to attend one consultation, of approximately two hours' duration at the Durban University of Technology Chiropractic Clinic. During this time, it will be decided whether you meet the inclusion criteria and should you meet these criteria, you will be required to sign a letter of information and informed consent, indicating that you agree to participate voluntarily in this study.

At the two hour initial consultation, you will be asked questions concerning your medical history, answering questions posed by the researcher pertaining to the presenting problem, as well as your family medical history and lifestyle. Following the case history, the researcher will conduct a physical examination on you. This is a general examination of the body and its systems. To do this, you will be required to change into a clinic gown and a pair of shorts. Thereafter, the researcher will conduct the examination of your thoracic spine (mid-back) complaint. This will include assessments of the ROM, observations, palpation and orthopedic testing of the thoracic spine.

Throughout this assessment, the researcher will need to make sure that you meet the study's inclusion criteria. Therefore, it is important to understand that the following may be reasons for your exclusion from the study;

- Participants who do not sign or comprehend the letter of informed consent.
- Participants with contraindications to manipulation such as;
    - Weakened bone due to osteoporosis/ infection and / or cancer
    - Disc pathologies
    - Joint hypermobility
    - Verebro-basilar insufficiency
    - Uncontrolled hypertension (very high blood pressure)

    - Congenital abnormalities (problems that you have had from birth which may be negatively affected by manipulating your spine) (e.g. block vertebrae)
    - Fractures of the vertebrae (e.g. transverse process) and / or the ribs
    - Muscle tears of the intercostal muscles or accessory respiratory muscles
- Congenital or acquired spinal deformities
- Neurological disease (e.g. any disorder of the nervous system)
- Individuals on anticoagulant therapy (e.g. any blood thinning medication)

By contrast the following conditions must be met for your inclusion into the study:

- Participants must be between 18 – 45 years of age
- Mid-back pain defined within the limits of this study is:
    - Sharp, shooting or aching pain in the thoracic region of the back (between the shoulder blades) AND/ OR thoracic back pain experienced while breathing in deeply, sneezing and/or coughing
    - Localized pain (i.e. the pain is only felt in the region between the shoulder blades)
    - Altered end feel resistance to joint movement (describes the give or 'feel' of the joint when manual pressure is applied to it
    - Restricted thoracic range of motion generally
    - Restricted thoracic facet segment motion between T3 and T9
    - Restricted costovertebral motion segments between ribs three and nine.

When it is determined that you meet the study requirements, the researcher will request you complete a Numerical Pain Rating questionnaire. The researcher will thereafter measure your pain tolerance using the Algometer (pressure threshold meter). Lastly the researcher will measure your range of motion in the thoracic spine with the use of the digital inclinometer.

Once all the measurements have been taken, the researcher will apply the manipulative procedures as defined by the group that you have been randomly assigned to. Once the manipulative therapy has been performed, you will be required to complete another

Numerical pain rating questionnaire. The researcher will re-take the pain tolerance and range of motion measurements.

This will conclude your involvement in the study.

Risks or Discomforts to the Participant:

Based on the interventions (manipulation) that you are to receive in this study, there may be transient discomfort and/ or discomfort following spinal manipulative therapy. This should relieve within 24 hours. If symptoms persist, you are asked to contact the researcher.

Benefits:

It is expected that the application of manipulation to your thoracic spine and ribs will result in some changes in joint movement, however because there has been no research in this area we can only suggest that there may be a decrease in your symptoms. Therefore, we ask you to be honest and truthful in your responses so that we can better document these changes and help other patients in the future.

Reason/s why the Participant May Be Withdrawn from the Study:

There will be no penalties imposed on you should you decide to withdraw from the study. You are free to withdraw from the study at any point and for whatever reason.

Remuneration:

There will be no remuneration for your participation in the study.

Costs of the Study:

Participation is free of charge and the participant will not incur any expenses other than transport costs to arrive at the consultation at Durban University of Technology.

Confidentiality:

Your personal information obtained during this study will remain confidential. This information will be stored as a hardcopy on the secure and locked property of the Durban University of Technology Chiropractic clinic. The research specific electronic data (spreadsheet) will be coded so that no one will be able to identify your results outside of the researcher. Only the computed collective results of the study will be made public. The names and personal details of participants will not be used in this study or its publication.

Research-related Injury:

It is not expected that you will suffer any research related injuries as all standard clinical precautions will be taken whilst you are being assessed to avoid this possibility. If, however you feel that participation in this study has incurred an injury, you are requested to report this to the researcher as soon as possible in order that your injury can be dealt with effectively and efficiently to contain any unwanted long term problems.

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

Head of Department:	Dr. Aadil Docrat	Contact number: 031 373 2589
Research supervisor:	Dr. Heidi Kretzmann	Contact number: 031205 5520
Researcher:	Gabriela Petersen	Contact number: 061 956 8124
The Institutional Research Ethics Administrator:		Contact number: 031 3732900

Consent

Statement of agreement to participate in the research study:

- ✓ I hereby confirm that I have been informed by the researcher, Gabriela Petersen, about the nature, conduct and risks of the study. Research ethics clearance number Rec 48/ 16
- ✓ 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 computerized 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 this study, which may relate to my participation, will be made available to me.

____________________ ____________ _______ __________________

Full Name of Participant **Date** **Time** **Signature**

I, **Gabriela Petersen**, 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	**Date**	**Signature**

(If applicable)

Full Name of Legal Guardian	**Date**	**Signature**

If applicable)

Appendix H – Case History Form

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

DUT DURBAN UNIVERSITY OF TECHNOLOGY

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:

Student's Case History:

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 I – Senior Physical Examination Form

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

PHYSICAL EXAMINATION: SENIOR

Patient Name: ____________________ **File no:** ________ **Date:** ________

Student: **Signature:**

VITALS:					
Pulse rate:				Respiratory rate:	
Blood pressure:	R	L		Medication if hypertensive:	
Temperature:				Height:	
Weight:	Any recent change?	Y / N	If Yes: How much gain/loss		Over what period

GENERAL EXAMINATION:		
General Impression		
Skin		
Jaundice		
Pallor		
Clubbing		
Cyanosis (Central/Peripheral)		
Oedema		
Lymph nodes	Head and neck	
	Axillary	
	Epitrochlear	
	Inguinal	
Pulses		
Urinalysis		

SYSTEM SPECIFIC EXAMINATION:

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

Clinician: **Signature:**

Appendix J – Thoracic Spine Examination Form

DUT DURBAN UNIVERSITY OF TECHNOLOGY | FACULTY OF HEALTH SCIENCES | CHIROPRACTIC DEPARTMENT

THORACIC SPINE REGIONAL EXAMINATION

Patient:______________________________ File:__________ Date:__________________

Student:______________________________ Signature:___________________________

Clinician: ____________________________ Signature:___________________________

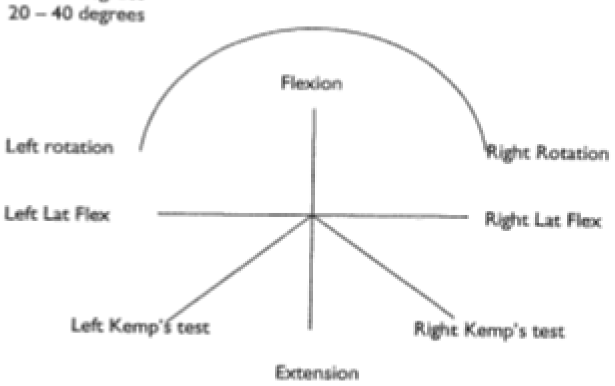
STANDING:

Posture (incl. L/S & C/S)
Muscle tone
Skyline view – Scoliosis
Spinous Percussion
Breathing (quality, rate, rhythm, effort)
Deep Inspiration

Scars
Chest deformity
(pigeon, funnel, barrel)

RANGE OF MOTION:

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
L/R Rotation
Extension
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 EXAM	History	ROM	Neuro/Ortho
LUMBAR			
CERVICAL			

Appendix K – S.O.A.P.E Note

DUT DURBAN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CHIROPRACTIC AND SOMATOLOGY

CHIROPRACTIC PROGRAMME

Patient Name: *File number:* *Page:*

Date: *Visit:* *Student:*
Attending Clinician: *Signature:*

S: *Numerical Pain Rating Scale (Patient)* *Student Rating* *A:*

Least 0 1 2 3 4 5 6 7 8 9 10 Worst

0: *P:*

E:

Special attention to: *Next appointment:*

Date: *Visit:* *Student:*
Attending Clinician: *Signature:*

S: *Numerical Pain Rating Scale (Patient)* *Student Rating* *A:*

Least 0 1 2 3 4 5 6 7 8 9 10 Worst

O: *P:*

E:

Special attention to: *Next appointment:*

Date: *Visit:* *Student:*
Attending Clinician: Signature

S: *Numerical Pain Rating Scale (Patient)* *Student Rating* *A:*

Least 0 1 2 3 4 5 6 7 8 9 10 Worst

O: *P:*

E:

Special attention to: *Next appointment:*

Appendix L – Numerical Pain Rating Scale

Date:
File number:
Name:

Numerical pain rating scale pre-intervention

This scale is a representation of pain intensity. Its' purpose is to respresent the severity of your mid-back pain as a numerical value. The number zero represents no pain and the number ten represents the worst pain imaginable. The numbers one through nine represent an escalation of pain. The higher the number is, the greater the pain is.
Kindly circle the number that most closely represents the severity of your mid-back pain. Please only circle one number. If you have any questions or are uncertain of what to do, please do not hesitate to ask.

0 1 2 3 4 5 6 7 8 9 10

Date:
File number:
Name:

Numerical pain rating scale post-intervention

This scale is a representation of pain intensity. Its' purpose is to respresent the severity of your mid-back pain as a numerical value. The number zero represents no pain and the number ten represents the worst pain imaginable. The numbers one through nine represent an escalation of pain. The higher the number is, the greater the pain is.
Kindly circle the number that most closely represents the severity of your mid-back pain. Please only circle one number. If you have any questions or are uncertain of what to do, please do not hesitate to ask.

0 1 2 3 4 5 6 7 8 9 10

Appendix M – Wagner Algometer

Figure. 3.1 Wagner Algometer.

Make: Wagner

Model: FDK Force Gage 20

Appendix N – Saunders Digital Inclinometer

Figure 3.2: Saunders Digital Inclinometer

Manufacturer: The Saunders Group Inc.

Model: Saunders Digital Inclinometer

Appendix O - Thoracic Vertebral Manipulative Techniques

1. Bilateral Hypothenar

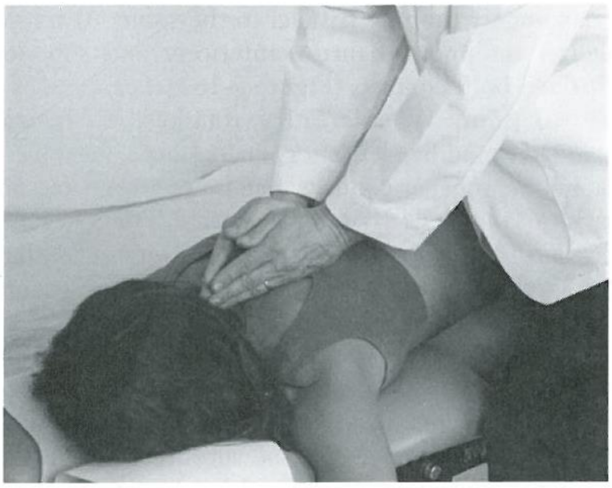


Figure. 1 of Appendix O: Bilateral Hypothenar manipulative technique. This technique is thoracic facet specific (Bergmann, 2011).

Indication: Restrictions between the vertebral levels of T4 to T12 in flexion, extension, lateral flexion and rotation.

Patient position: The patient is in the prone positon (laying on flat with the trunk on the bed).

Doctor position: The doctor (adjustor) stands in the fencer (one foot in front of the other i.e lunge position) in a cephalic direction.

Contact point: Contact is made with bilateral hypothenars parallel to the spine

Specific contact Point: Contact is made over the transverse processors

Vector: To induce flexion, lateral flexion and rotation the vector is in a posterior to anterior and inferior to superior direction to induce flexion. For extensions the vector is only in a posterior to anterior direction.

Procedure: Skin slack was removed until maximal tension was felt and contact with the transverse processors was obtained bilaterally. Thereafter, a thrust was applied through the body, trunk and arms.

If manipulation is intended for lateral flexion restrictions, force is applied unilaterally on the side of the restriction.

2. Cross Bilateral

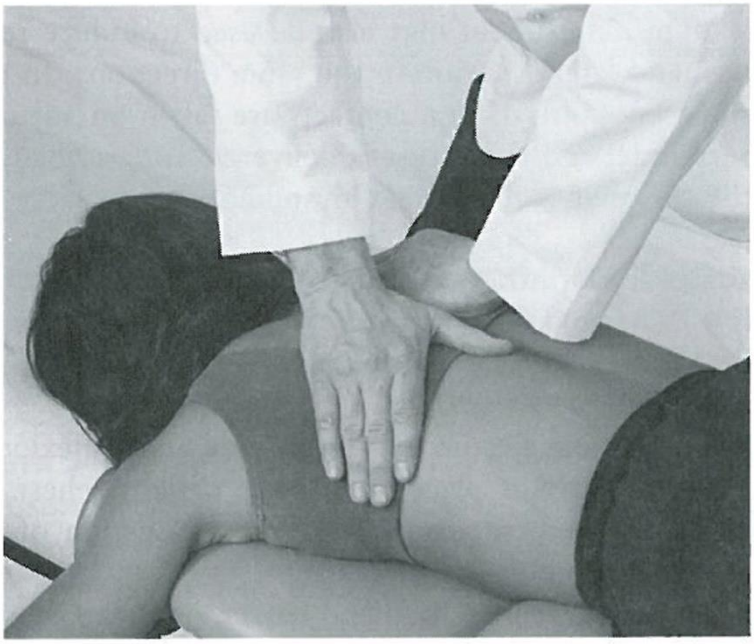


Figure. 2 of Appendix O: Cross bilateral manipulative technique (Bergmann, 2011).

Indication: Restrictions between the vertebral levels of T4 to T12 in flexion, extension, lateral flexion and rotation.

Patient position: The patient is in the prone positon (laying on flat with the trunk on the bed).

Doctor position: The doctor (adjustor) stood in the fencer (one foot in front of the other i.e lunge position) or square (feet shoulder width apart facing participant's lateral aspect) stance on either side of the patient.

Contact point: Contact is made with bilateral hypothenars or a Hypothenar and thenar for the crossing contact.

Specific contact Point: Contact is made over the transverse processors

Vector: The caudal hand applies force in a posterior to anterior and inferior to superior direction. The cephalic hand applies force in a posterior to anterior and superior to inferior direction.

Procedure: Skin slack was removed until maximal tension was felt and contact with the transverse processors was obtained. Thereafter, a thrust was applied through the body, trunk and arms.

Appendix P – Costovertebral Manipulative Techniques

1. Hypothenar Costal

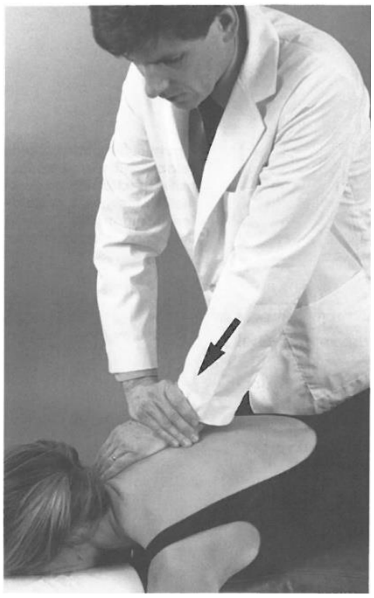


Figure.1 of Appendix P: Hypothenar costal manipulative technique (Bergmann, 2011).

Indication: Restrictions between ribs three to ten.

Patient position: The patient was in the prone positon (laying on flat with the trunk on the bed).

Doctor position: The doctor (adjustor) stood in the fencer (one foot in front of the other i.e lunge position) on the side of the restricted rib.

Contact point: Contact was made with hypothenar of the caudal hand.

Specific contact Point: Contact was made over the rib angle.

Indifferent hand: The cephalic hand provided support over the contact hand.

Vector: The force was applied in a posterior to anterior and inferior to superior direction.

Procedure: Skin slack was removed until maximal tension was felt and contact with the rib angle was obtained. Thereafter, a thrust was applied through the body, trunk and arms.

2. Ilial Hypothenar Costal

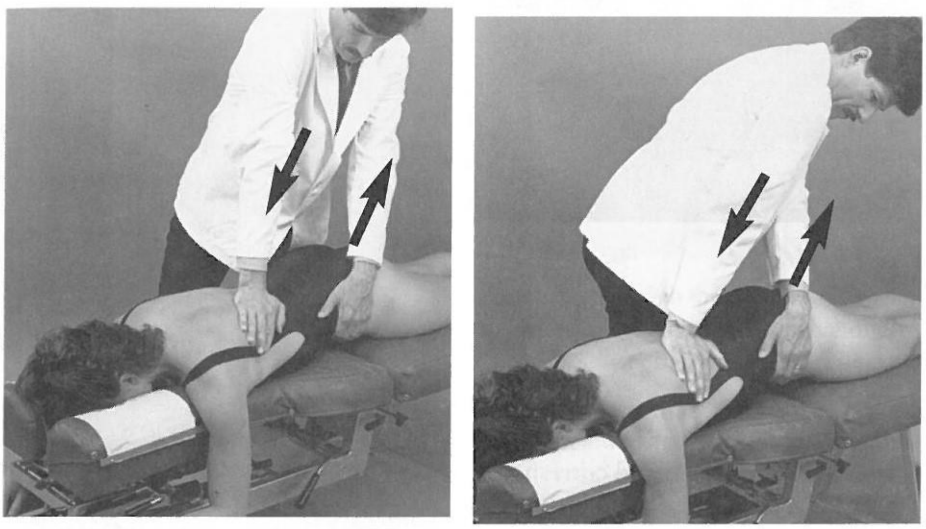


Figure 2 of Appendix P: Ilial Hypothenar costal manipulative technique (Bergmann, 2011).

Indication:	Restrictions between ribs seven and twelve.
Patient position:	The patient was in the prone positon (laying on flat with the trunk on the bed).
Doctor position:	The doctor (adjustor) stood in the square stance on the contralateral side of the restricted rib.
Contact point:	Contact was made with hypothenar of the cephalic hand.
Specific contact Point:	Contact was made over the rib angle.
Indifferent hand:	The caudal hand was used to reach across and grasp over the ilium (anterior superior iliac spine) on the ipsilateral side of the rib restriction.
Vector:	The force was applied in a posterior to anterior, inferior to superior and medial to lateral direction.
Procedure:	Skin slack was removed until maximal tension was felt and contact with the rib angle was obtained. The ilium is lifted with the indifferent hand and traction is created by the contact hand being held firmly over the rib angle. This cause the weight of the trunk to

be transferred anteriorly and superiorly. Thereafter, a thrust was applied through the body, trunk and arms.