THE COMPARATIVE EFFICACY OF SPINAL MANIPULATIVE THERAPY AND EXTRACORPOREAL SHOCKWAVE THERAPY IN THE TREATMENT OF CHRONIC LUMBAR FACET SYNDROME

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

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DECLARATION

I, **Lebogang Khesa**, declare that this dissertation is my own, unaided work. It is being submitted as a partial fulfilment for the Master's Degree in Technology, in the programme of Chiropractic, at the University of Johannesburg. It has not been submitted before for any other degree or University programme.

Lebogang Khesa

Signature of candidate

DEDICATION

I would firstly like to dedicate this research to my parents because without them I wouldn't have been able to reach this level that I currently am at, academically. You have supported and guided me in every way possible during my years in varsity. You never gave up on me and you both always believed in me and my abilities. You always saw more in me that I couldn't even imagine would be possible. I thank you both a million times over and I will forever appreciate you and love you from the bottom of my heart.

Equally, I would also like to dedicate this research to my siblings who have all lived up to the teachings bestowed on us by our parents. All of you are my role models and I know that this journey would have been much more difficult without you pushing me to do great things. We all have our own chosen paths and we all flourish in what we do. I am proud to have siblings like you because with all of you in my corner, I know that I am guaranteed to succeed in life. Keep on being great and I promise that we will all do great things.

To my friends who have been there for me and showed their support through these years, I thank you too. I strongly believe that the bonds that we have formed and the ones that we have fortified will truly stand the tests of time.

To Nompumelelo, you have always been there for me through thick and thin. You have seen me at my worst and at my best, and you have always been my pillar of strength. Through all of that and the years, you have stuck with me, and for that I will always appreciate you and will always love you.

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Lastly, to all my research participants, I thank you for your time and your willingness to participate and see the research trials through to the end. Without all of you, none of this would be possible and so I wish you all peace and prosperity in life and nothing but blessings in everything you do. Thank you.

ABSTRACT

Aim: The aim of this study was to determine whether a single treatment approach of extracorporeal shockwave therapy or chiropractic spinal manipulative therapy, compared to a combined treatment approach of chiropractic spinal manipulative therapy with extracorporeal shockwave therapy is effective with regards to pain, disability and lumbar range of motion in individuals with chronic lumbar facet syndrome. The results were based on the use of the Numerical Pain Rating Scale (NPRS) and the Oswestry Low Back Pain and Disability Questionnaire (ODQ) to assess subjective pain and disability as well as the Digital Inclinometer to assess objective lumbar range of motion. This study also aims to provide chiropractors and other health care practitioners with an alternative/additional modality in treating and managing chronic lumbar facet syndrome.

Method: This was a comparative study utilising convenience sampling and random group allocation methods to split thirty male and female participants between the ages of 18 and 35 years into three groups of ten participants each. All the recruited participants presented with low back pain due to chronic lumber facet syndrome. Group one received spinal manipulative therapy, Group two received extracorporeal shockwave therapy, and Group three received a combination of both interventions.

Procedure: Each participant recruited in this study was required to attend six treatment consultations and a seventh consultation that was for obtaining the final measurements/data only. All the participants were individually assessed over a four-week clinical trial period. Objective data was obtained using a Digital Inclinometer to assess lumbar spine range of motion. Subjective data was obtained using two methods which were the NPRS and the ODQ. The subjective and objective data was recorded at the beginning of the first, fourth and seventh consultations.

Results: The subjective and objective data that was collected by the researcher was analysed by statisticians from STATKON at the University of Johannesburg. With regards to the intragroup and intergroup analysis of this study, non-parametric tests were used to analyse the raw data obtained by the researcher as the Shapiro-Wilk test for normality indicated that the data was not normally distributed. The intragroup analysis was done using the non-parametric Friedman test and post-hoc Wilcoxon Signed Ranks test. The intergroup analysis was done using the Kruskal-Wallis test.

With regards to the intragroup analysis, the numerical pain rating scale and the Oswestry low back pain and disability questionnaire data showed clinically and statistically significant results for all three groups. The Digital Inclinometer data showed clinically and/or statistically significant results for some ranges of motion for certain groups. Lumbar spine flexion, extension, left lateral flexion and right lateral flexion ranges of motion were tested for each group. However, with the intergroup analysis, all three groups showed no statistically significant results with all the data collection methods.

Conclusion: Based on the subjective results obtained in this study, all three groups were effective with regards to the numerical pain rating scale and the Oswestry low back pain and disability questionnaire, with group one showing the largest overall clinical improvement in both. Therefore, the participants of all three groups benefitted from the restoration of their ability to perform normal daily activities. However, spinal manipulative therapy was the most effective in decreasing pain and disability.

Based on the objective results obtained in this study, the Digital Inclinometer results for the three groups made it difficult to establish the best treatment protocol for the restoration of the lumbar spine range of motion. This is due to the fact that most of the results were clinically significant and statistically insignificant. However, group two had the most clinically significant results, but group three demonstrated the most clinically and statistically significant results out of the three groups. This suggests that the combination treatment protocol was the most effective in the treatment of LBP due to chronic lumbar facet syndrome with regards to lumbar ROM.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER ONE: INTRODUCTION

1.1. The Problem Statement

Extracorporeal shockwave therapy is a relatively new non-invasive therapeutic modality and is currently being used primarily to treat orthopaedic musculoskeletal conditions. In the past 15 to 20 years, extracorporeal shockwave therapy has been one of the leading treatment choices for treating conditions such as heel proximal plantar fasciitis, elbow lateral epicondylitis, shoulder calcific tendinitis, patellar tendinopathy, achilles tendinopathy, avascular necrosis of the femoral head and non-union of long bone fractures (Wang, 2012).

The effects of extracorporeal shockwave therapy are achieved via its ability to transduce mechanical energy to tissue which creates a cascade of various biochemical processes within the target tissue. It has been proven that extracorporeal shockwave therapy is an effective modality generally utilised to achieve pain reduction, tissue repair and increased joint function. This was shown in a study where the mechano-transductory effects of extracorporeal shockwave therapy in the treatment of lumbar facet joint pain was compared to steroid injections and radiofrequency medial branch neurotomy (Nedelka, Nedelka, Schlenker, Hankins, and Mazanec, 2014).

Aside from using extracorporeal shockwave therapy on the knee in osteoarthritic patients whereby pain reduction, increased range of motion and an overall increase in knee joint function were achieved (Mishel and Shenouda, 2013), there is little research that has been done on the effects of extracorporeal shockwave therapy on other joints such as the facet joints.

Lumbar facet joint syndrome is a common condition which is said to be one of the main sources of chronic axial low back pain and can be treated by chiropractors using lumbar manipulative therapeutic techniques (Liu, Wu, Du, Lv, Zhang, Xiong, Wang, Liu and Zhang, 2016). These chiropractic techniques include side lying spinal manipulation, the use of drops and/or pelvic blocks to manipulate the facet joints in the lumbar vertebra. These techniques have been proven to be effective in adults for the management of low back pain resulting from facet joint pain irrespective of whether the condition may be acute, subacute, or chronic (Bronfort, Haas, Evans, Leininger and Triano, 2010).

1.2. Aim of the Study

The aim of this study was to determine whether extracorporeal shockwave therapy alone or combined with chiropractic lumbar manipulative therapeutic techniques was effective in decreasing pain and increasing lumbar range of motion in individuals with chronic lumbar facet syndrome.

This study also aimed to provide chiropractors and other health care practitioners with an alternative/additional modality in treating and managing chronic lumbar facet syndrome.

1.3. Study Design

This was a quantitative comparative study utilising convenience sampling and random group allocation methods to split 30 participants (male and female) into 3 groups of 10 participants each. Each participant that took part in this study was assessed over a 4-week period and was required to attend seven consultations in total. The consultations were split into 6 treatment consultations with the last 7th consultation for measurements/data collection only. Measurements/data was collected on the 1st, 4th and 7th consultations.

Group one received spinal manipulative therapy, Group two received extracorporeal shockwave therapy, and Group three received a combination of both therapies. Objective data was obtained using a Digital Inclinometer for lumbar range of motion. Subjective data was obtained using two methods being the Numerical Pain Rating Scale and the Oswestry Pain and Disability Questionnaire. The data was collected and analysed by the researcher with the assistance of an assigned statistician from STATKON.

1.4. Possible Outcomes and Contributions

The outcome of this study could potentially determine whether extracorporeal shockwave therapy is an effective modality to use independently or together with lumbar manipulative therapy to treat and manage chronic lumbar facet syndrome to achieve pain reduction, tissue healing and increased lumbar facet function.

There is limited research available on the efficacy of shockwave therapy on facet joints, so this could provide chiropractors with an alternative/additional tool in treating and managing chronic lumbar facet syndrome. This research study may also contribute to the research pool/body of knowledge relating to extracorporeal shockwave therapy.

Other healthcare practitioners could also utilise this research to substantiate the use of extracorporeal shockwave therapy on patients as a non-invasive means of treating chronic low back pain as compared to other invasive therapies such as steroid injections and radiofrequency medial branch neurotomy (Nedelka *et al.*, 2014).

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

In this chapter, we are looking at a review of the existing literature and focusing on the theoretical information surrounding this study topic. Emphasis is placed on the lumbar spine specifically the zygapophysial (facet) joint anatomy and physiology with its surrounding musculature. This chapter also discusses the theory related to facet joint syndrome, spinal manipulative therapy (SMT) and extracorporeal shockwave therapy (ESWT).

2.2. The Three Joint Complex

Each level of the spine has a three joint complex which is made up of two zygapophysial (facet) joints and the intervertebral disc between two adjacent vertebrae (Cramer and Darby, 2014). In addition to that, the three joint complex also forms part of the *functional spinal unit* (FSU) which is considered to be the basic building block of the spine and it is made up of two adjacent vertebrae, an intervertebral disc, two zygapophysial (facet) joints, and spinal ligaments (Oxland, 2016). Another term used to refer to the FSU is the *spinal motion segment* which is described as the functional unit of the spine (Ebraheim, Hassan, Lee and Xu, 2004). Facet joints are classified as synovial, planar joints. They are responsible for controlling the direction of movement between vertebrae as well as the amount of movement allowed between segments. The amount of segmental movement is formaly known as the joint range of motion (ROM).

Facet joints also contribute to axial load distibution with the intervertebral disc of the spine when weight bearing especially during rotation and extension (Cramer and Darby, 2014). This tripod structure of the three joint complex creates great stability and support thus increasing the amount of axial loading that the spine can withstand.

2.3. Lumbar Vertebrae Anatomy

The lumbar spine is made up of five vertebrae (L1-L5) situated in the lower back between the thoracic spine and sacrum. It is shaped like a backward “C” known as a lordotic curve. The spinal column has two lordotic curves in the cervical and lumbar regions and two kyphotic curves in the thoracic and sacral regions. This increases the spines overall axial strength and centres the upper body’s centre of gravity over the lower limbs (Moore, Dalley and Agur, 2014).

Table 2.1. Lumbar Vertebra (Moore *et al.,* 2014)

Part	Characteristics
Vertebral body	Massive; kidney shaped when viewed superiorly
Vertebral foramen	Triangular; larger than in thoracic vertebrae and smaller than in cervical vertebrae
Transverse processes	Long and slender; accessory process on posterior surface of base of each process
Articular processes	Nearly vertical facets; superior facets directed posteromedially (or medially); inferior facets directed anterolaterally (or laterally); mammillary process on posterior surface of each superior articular process
Spinous processes	Short and sturdy; thick, broad, and hatchet shaped

The lumbar vertebrae are designed for weight bearing and movement. In some cases, people may develop a bony anomaly where they have four (sacralisation) or six (lumbarisation) lumbar vertebra known as an atypical transitional vertebra. This occurs when either L5 undergoes a bony fusion with the sacrum (S1) or S1 fails to fully fuse with the rest of the sacrum (Moore *el al.,* 2014).

One of the main differentiating characteristics of the lumbar vertebrae is their massive kidney shaped vertebral bodies (Figure 2.1. superior view). This is due to the increase in body weight bearing of the vertebral column towards the inferior end of the presacral vertebrae (Moore *et al.,* 2014). In table 2.1., the characteristics of the lumbar spine are explained.

The transverse processes of the lumbar vertebra project lateral and slightly posterosuperiorly. The attachments of the intertransversarii muscles are located posteriorly on the base of the lumbar transverse processes on a surface known as the accessory process, as well as on a tubercle located on the posterior surface of the superior articular process known as the mammillary process. The multifidi muscles also attach to the mammillary processes (Moore *et al.,* 2014).

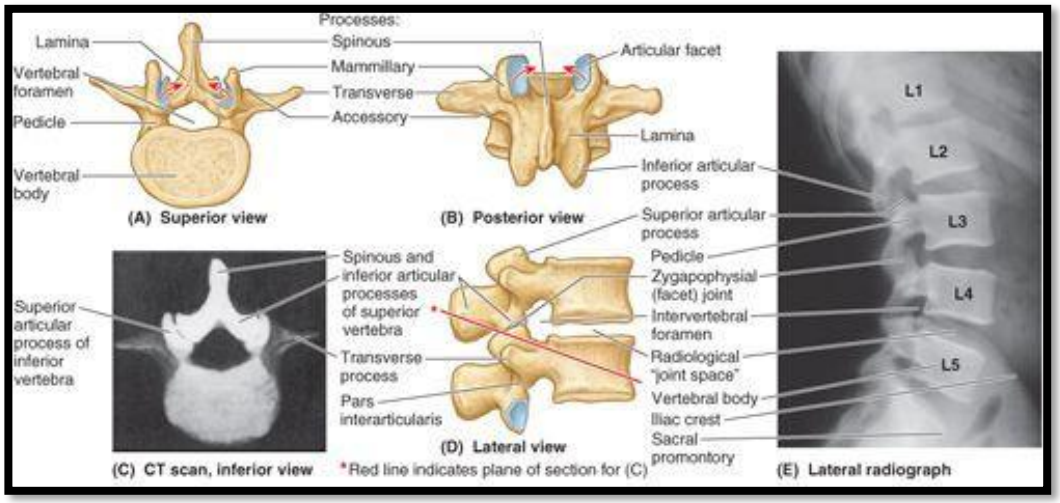


Figure 2.1. Lumbar Vertebra (Moore *et al.*, 2014)

The L5 vertebra has the largest vertebral body and transverse processes of all the lumbar vertebrae, thus making it the biggest vertebra of the entire vertebral column. This is due to its function of transferring the weight of the entire upper body into the lower body via the base of the sacrum formed by the superior sarface of S1. The vertebral body of L5 is longer anteriorly than it is posteriorly therefore L5 is resposible for the lumbosacral angle created between the long axis of the vertebral column at the lumbar region and the sacrum (Moore *et al.*, 2014).

2.3.1. The intervertebral disc

The intervertebral disc (IVD) is a relatively avascular structure situated between two adjacent vertebral bodies and allows for movement between vertebrae. The IVD is made up of two structures which are an outer layer called the annulus fibrosis and an inner nucleus pulposus. The outer annulus fibrosis consists of 10 to 20 layers of collagen fibres. These fibres are arranged concentrically and overlap one another. The outer fibres of the annulus fibrosis are arranged more horizontally allowing the IVD to resist excessive rotational forces/loads while the inner fibres are arranged more vertically allowing the IVD to resist excessive axial forces/loads. The anterior fibres of the annulus pulposus are thicker than the posterior fibres, thus the posterior region of the IVD is more prone to herniation (Ebraheim *et al.*, 2004).

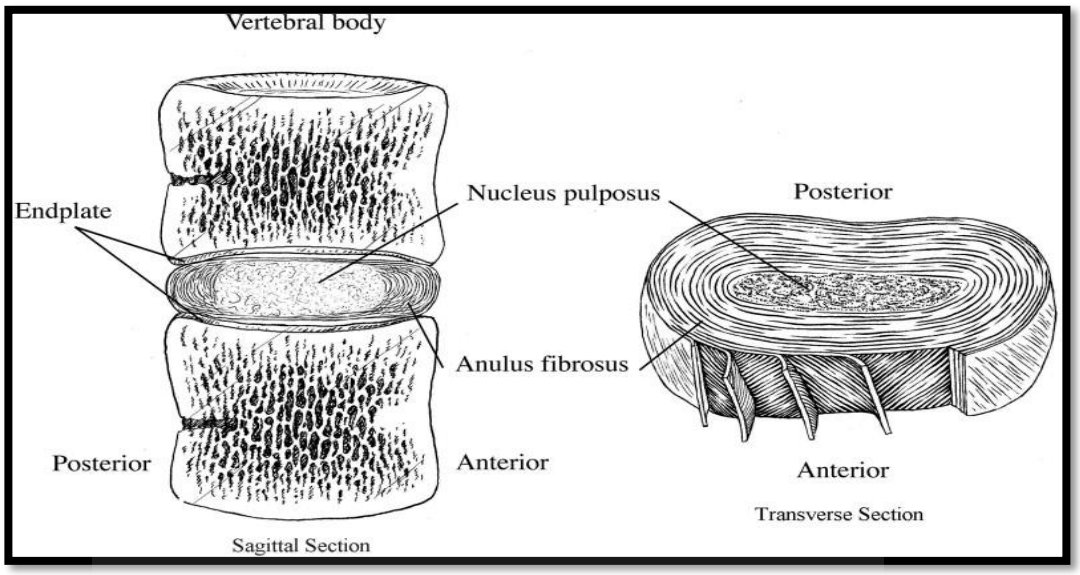


***Figure 2.2. Sagittal and transverse sections of the lumbar disc* (Ebraheim *et. al.*, 2004)**

The nucleus pulposus lies central to the IVD and is enclosed by the annulus pulposus. The nucleus pulposus is a semi-fluid mucoid mass which contains 70% to 90% water. As one ages, the water content of the nucleus pulposus decreases which results in a decrease in IVD height therefore making that segment more prone to injury and/or degeneration. In some literature, the vertebral endplates situated on the superior and inferior aspects of the vertebral bodies are considered as a third component of the IVD. These vertebral endplates act as growth plates for the vertebral bodies and are responsible for the transfusion of nutrients from the vertebral body into the disc (Ebraheim *et al.*, 2004).

2.3.2. Zygapophysial (facet) joints

The zygapophysial (facet) joints of the vertebral column are an important anatomic region in that they play a biomechanical role which allows the vertebra of the spine to articulate with one another. These diarthrodial facet joints are made up of an inferior and superior articular process from the vertebra above and below which have opposing articular hyaline cartilage surfaces that allow for a smooth low friction environment. The facet joints are enclosed by an articular capsule. These joints together with the intervertebral disc transfer load from one vertebra to the next while guiding and constraining motion in the spine. This is due to their mechanical function and geometry (Jaumard, Welch and Winkelstein, 2011). The superior articulating process of the vertebra below bears the transmitted load from the inferior articular process of the vertebra above. Normal health and function of the vertebral column occurs as

a result of the mechanical behaviour of the facet joints during physiological loading. Normally the vertebral body carries 80% of axial compressive forces and the facet joints only carry 20% of the load (Oktenoglu and Ece, 2016), thus dysfunction of these joints occurring as a result of tissue alterations due to injury, degeneration, or surgical modification of the spine (Jaumard, Welch and Winkelstein, 2011) may increase the load experienced by the facet joints to as much as 70% (Oktenoglu and Ece, 2016).

The lumbar articular processes which make up the facet joints extend vertically in the sagittal plane but become more coronally orientated towards the inferior end of the lumbar vertebrae. Thus, the superior articulating process of the L5 vertebra is in the sagittal plane while the inferior articulating process is in the coronal plane (Moore *et al.,* 2014). This prevents anterior slippage of the L5 vertebra on S1 (Hamill, Knutzen and Derrick, 2009). As a result, L5 is known as the typical transitional vertebra of the lumbar spine. In the sagitally oriented superior facet joints of the lumbar spine, the inferior articulating processes of the vertebra above is convex and faces anterolaterally while the superior articulating processes of the vertebra below is concave and faces posteromedially (Figure 2.1. posterior view). Therefore, the orientation of these facet joints allows for flexion, extension, and lateral flexion with no rotational movements to occur in the lumbar spine (Moore *et al.,* 2014).

Posterolaterally, the facet joints are encapsulated by a fibrous joint capsule which is made up of an outer layer and an inner layer. The outer layer is comprised of dense fibroelastic tissue and the inner layer is comprised of synovial tissue which forms an inner synovial membrane. The facet joints are covered anteromedially by the ligamentum flavum. The articular capsule attaches to the dorsal, superior and inferior margins of the adjacent facets/articular procresses. The articular capsule is thin and loose enough to allow for movement and strong enough to provide some stability throughout the joints ROM (Cramer and Darby, 2014). The articular capsule also helps to resist flexion of the spine (Wilke and Volkheimer, 2018).

2.3.3. Intervertebral foramina

The intervertebral foramina is a canal in which the spinal nerves pass through emerging from the nerve roots of the spinal cord. This canal has four boundaries which are:

- Superior: Pedicle of the vertebra above

- Inferior: Pedicle of the vertebra below
- Anterior: IVD and adjacent vertebral bodies
- Posterior: Articular processes of the adjacent vertebrae

2.3.4. Ligaments

Several ligaments that are important for the passive stabilization of the entire spine resisting specific motion directions attach to the lumbar spine (Wilke and Volkheimer, 2018). These ligaments include the ligamentum flava or yellow ligaments, anterior and posterior longitudinal ligaments, as well as the supraspinous and interspinous ligaments (Figure 2.3.). The anterior longitudinal ligament is a long, strong band extending from the skull down to the upper part of the sacrum and attaches to the entire anterior aspect of the vertebral bodies, as well as the intervertebral discs. It is thin laterally and thickens anteromedially. The superficial fibres of this ligament are longer than its deeper fibres as they extend over 3 to 4 vertebrae while its deeper fibres only extend over 2 vertebrae. These deeper fibres attach firmly to the inferior and superior margins of the vertebral bodies. The anterior longitudinal ligament is mainly responsible for resisting excessive extension of the spinal column (Ebraheim *et al.,* 2004).

The posterior longitudinal ligament opposes the anterior longitudinal ligament structurely and functionally in that it extends from the occipital bone to the sacrum, then attaches to the posterior aspect of the vertebral bodies and intervertebral discs. In the cervical region, it is broad and uniform, but as it extends over the thoracic and lumbar regions, it becomes more narrow over the midline of the vertebrae but remains broad over the intervertebral discs. Although the posterior longitudinal ligament has an opposing function to the anterior longitudinal ligament, it extends laterally and fuses with the lateral extensions of the anterior longitudinal ligament in the region of the intervertebral foramen. Its superficial fibres also extend over 3 to 4 vertebrae similar to the anterior longitudinal ligament but its deeper fibres only extend over adjacent vertebrae. The posteriorly longitudinal ligament is mainly responsible for resisting excessive flexion of the spinal column (Ebraheim *et al.,* 2004).

Situated between the adjacent vertebrae are the ligamentum flava. They fuse with one another in the midline and are mainly made up of the yellow elastic fibers running vertically in direction. The ligamentum flavum covers the entire interlaminar space via its attachments

extending from the lower portion of the anterior surface of the upper laminae, to the upper portion of the posterior surface of the lower laminae and fuses with the facet joint articular capsule laterally. It is thickest in the lumbar spine and has a superficial and deep layer. One of the most common causes of spinal stenosis in the lumbar spine result from hypertrophy and thickening of the ligamentum flavum (Ebraheim *et al.,* 2004).

The posterior ligaments of the spinal column are the supraspinous and interspinous ligaments and these connect the spinous processes to one another. The interspinous ligament is a thin band extending from the lower border to the upper border of adjacent spinous processes. The suprasinous ligament extends from the occipital bone to the sacrum attaching to the posterior tips of the spinous processes and it is stronger than the interspinous ligament. There also exists a membranous structure connecting adjacent transverse processes known as the intertransverse ligaments, which are typically present in the lumbar spine. Directly beneath the intertransverse ligaments are where the lumbar nerves lie lateral to the intervertebral foramina (Ebraheim *et al.,* 2004).

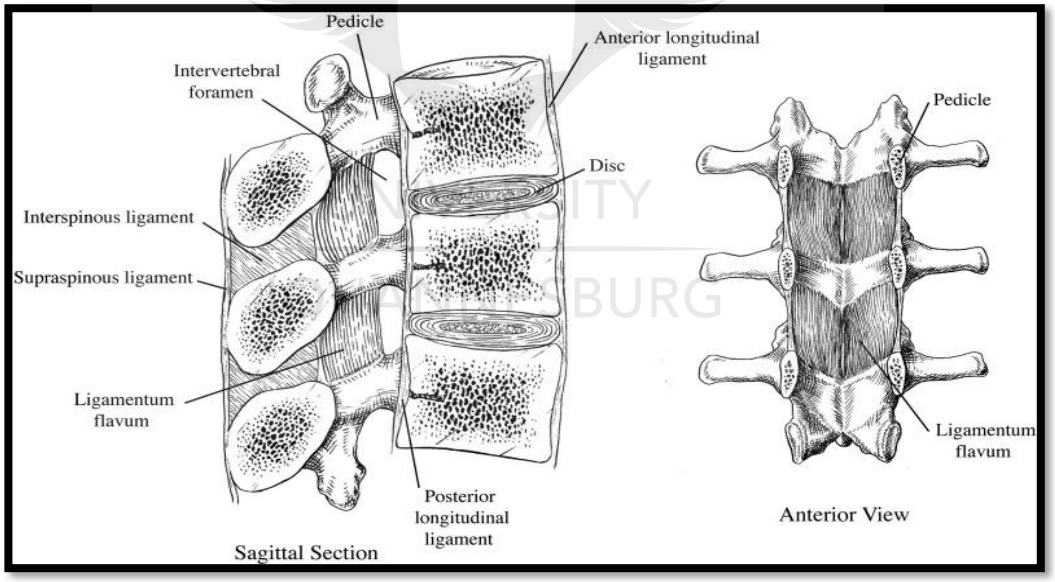


***Figure 2.3. Sagittal and anterior views of the lumbar ligaments* (Ebraheim *et. al.*, 2004)**

Stability of the lumbosacral junction is achieved via the iliolumbar ligament which extends from the transverse process of L5 to the top of the iliac crest. In some cases, the iliolumbar ligament may extend to the transverse process of L4 but this connection is usually not as

strong. This ligament functions to stabilize the lumbosacral junction (Wilke and Volkheimer, 2018).

2.3.5. Lumbar spine innervation

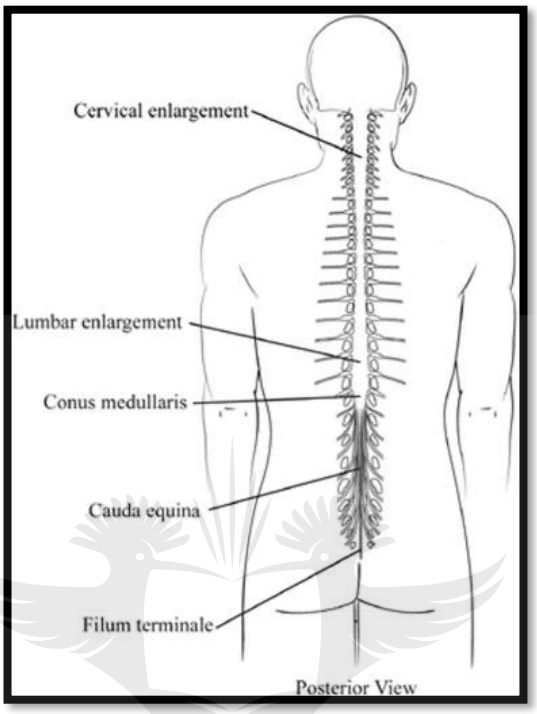


Figure 2.4. Spinal cord posterior view (Ebraheim, *et al.* 2004)

Eleven pairs of spinal nerves arise from the lumbar region. Five of the eleven are lumbar nerves, five are sacral, and one is coccygeal. All spinal nerves are made up of a dorsal and ventral root which contain sensory and motor neuron axons that enter and leave the spinal cord respectively. Lumbosacral spinal nerve roots emerge just below the corresponding vertebrae close to the inferomedial border of the upper pedicle within the superior portion of the intervertebral foramina and divide into a larger ventral ramus and a small dorsal ramus. Most ganglia are situated within the intervertebral foramen (Ebraheim, *et al.* 2004).

Posterior structures such as muscles, spinal ligaments and skin of the back are innervated by the dorsal rami. The longer lumbar ventral rami course inferolaterally to form the lumbar and sacral plexuses which contains nerves innervating structures such as muscles, joints and skin of the lower extremity. The ventral rami of L1-L4 make up the lumbar plexus running inferolaterally anterior to the quadratus lumborum muscle and posterior to the psoas major muscle. The lumbar plexus innervates part of the lower extremity and the lower abdominal

wall. The ventral rami of L4-S4 make up the sacral plexus within the pelvis which innervates the buttocks, perineum, and lower extremity. The largest nerves to branch of each plexus is the femoral nerve from the lumbar plexus and the sciatic nerve from the sacral plexus (Ebraheim *et al.,* 2004). The articular or medial branch from the posterior (dorsal) primary rami of the spinal nerves provides sensory innervate the facet joints. Each medial branch of the posterior primary rami supplies two adjacent joints thus innervation of the facet joints is supplied by two nerves (Moore *et al.,* 2014).

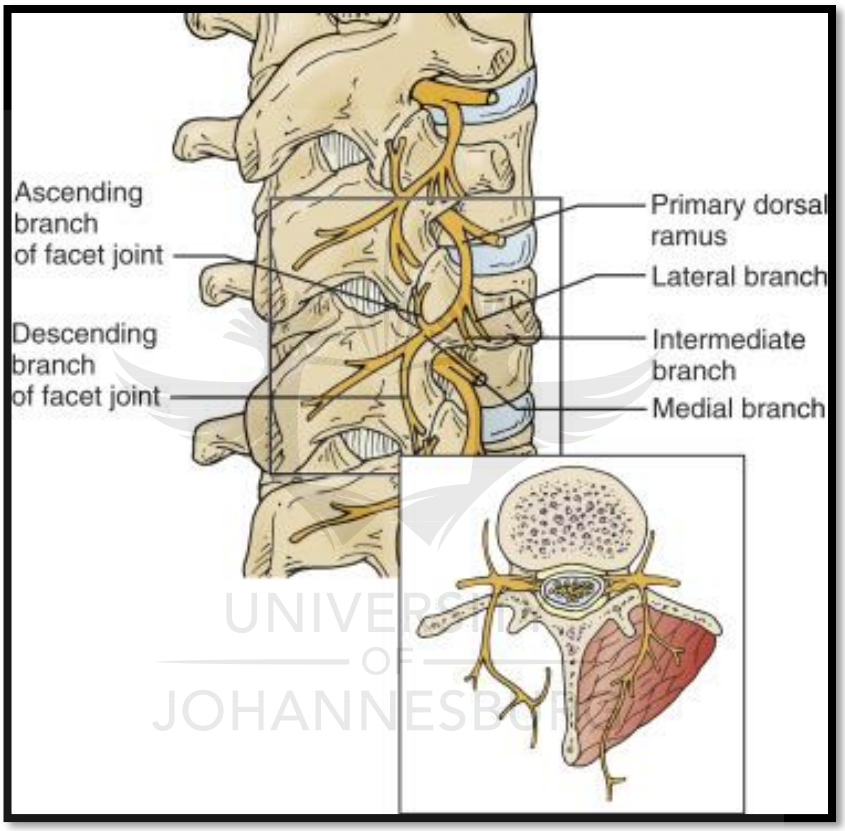


Figure 2.5. Lumbar facet innervation **(Huang-Lionnet, Brummett and Cohen, 2018)**

2.3.6. Blood supply

The lumbar spine and spinal cord are supplied by segmental arteries that branch from intercostal and lumbar arteries. These segmental arteries each give off spinal branches supplying the spinal cord, vertebra and cauda equina. The spinal branches anastomose with spinal arteries above and below and this occurs as the spinal branches enter the spinal canal via the intervertebral foramen. The sacrum and L5 vertebra are both supplied by the fourth lumbar artery, iliolumbar arteries, and both middle and lateral sacral arteries. The anterior

and posterior spinal arteries along with several radicular (medullary) arteries form the main blood supply for the spinal cord. The facet joints are supplied by the posterior branches of the lumbar arteries originating from the dorsal aspect of the abdominal aorta (Ebraheim *et al.*, 2004).

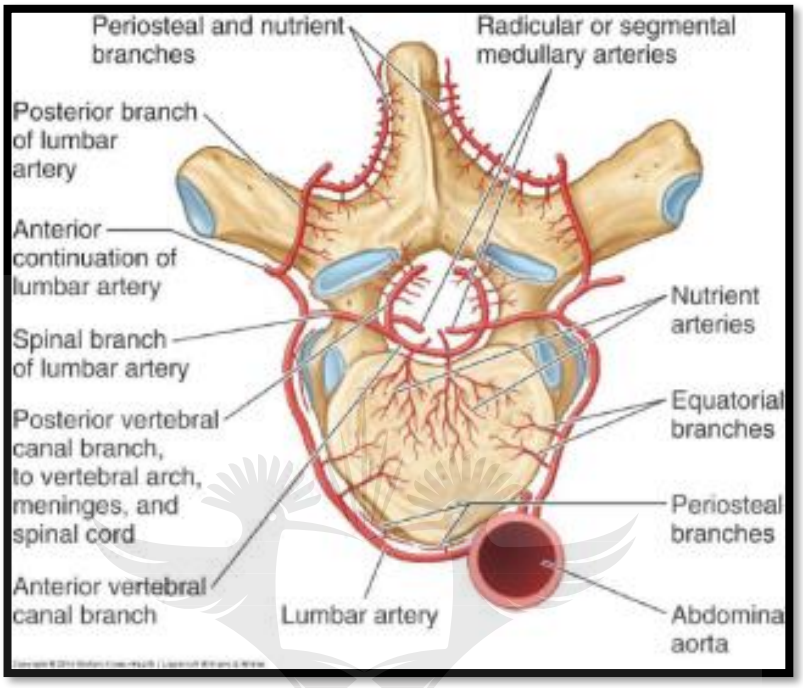


Figure 2.6. Blood supply of vertebrae **(Moore *et al.*, 2014)**

The number of medullary arteries vary in the lower thoracic and lumbar regions ranging from three to four. The largest medullary artery is the most caudal one which has an average diameter of 0.9 mm and is known as the *Adamkiewicz's artery*. The lower intercostal or upper lumbar artery is usually where this artery originates. The anterior spinal artery is mainly supplied by the medullary arteries thus injury of these arteries or compromisation of the anterior spinal artery by osteophytes, disc herniation or fracture greatly increases the possibility of ischemic injury to the spinal cord (Ebraheim *et al.,* 2004).

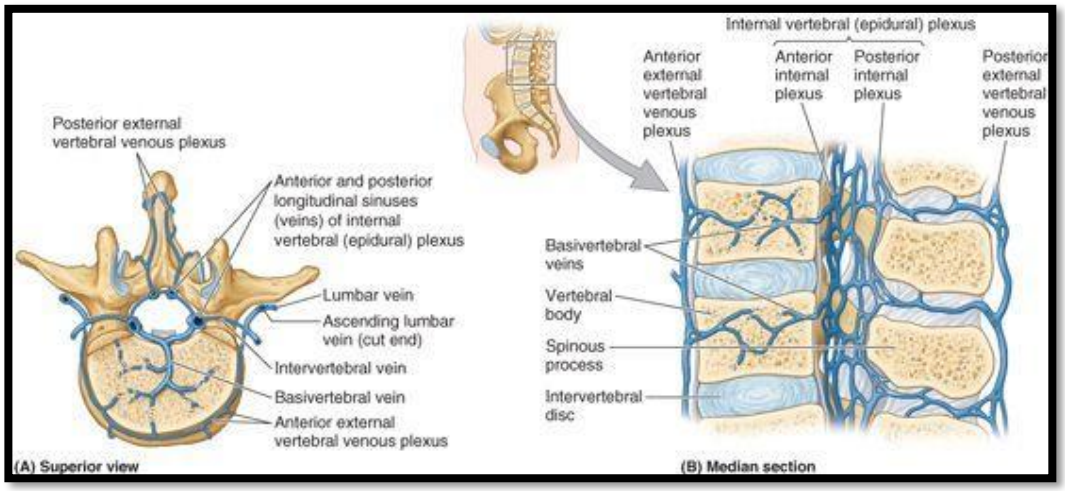


Figure 2.7. Venous drainage of vertebral column (Moore *et al.*, 2014)

The venous drainage of the spinal cord is supplied by the anterior and posterior internal vertebral venous plexuses. Both these venous structures are valveless within the epidural space. The vertebral bodies venous outlet is supplied by the basivertebral sinus which anastomoses with two longitudinal veins between the posterior longitudinal ligament and the pedicles forming the anterior internal venous plexus. The less dense posterior internal venous plexus anastomoses with the anterior internal venous plexus and blood is then drained into segmental veins via the intervertebral foramen (Ebraheim *et al.*, 2004).

2.3.7. Surrounding musculature

Three groups of muscles surround the lumbar spine named according to their location: posterior, lateral, and anterior. The posterior muscle group of the lumbar spine is further subdivided into three layers: superficial, intermediate, and deep. The thoracolumbar fascia makes up the superficial layer in the lumbar region. It is a strong and thick investing membrane which may play a crucial role in trunk rotation and lower back stabilization.

The serratus posterior inferior muscle makes up the intermediate layer in the lumbar region. This muscle attaches to the spinous processes of T10-L3 proximally and distally to the inferior borders of ribs 8-12 (Martini, Nath and Bartholomew, 2012). The erector spinae muscles make up the deep layer in the lumbar region. These vertically orientated muscle bundles are present throughout the entire spinal column extending from the iliosacrolumbar region to the cervical region and have three distinct muscle columns in the lumbar region beneath the thoracolumbar fascia. The three muscle columns that make up the erector

spinae muscles are the iliocostalis laterally, longissimus centrally, and spinalis medially (Ebraheim *et al.,* 2004). The iliocostalis muscle group is futher divided into the iliocostalis-cervicis, -thoracis, and -lumborum which is based on the location and distribution.

The iliocostalis cervicis originates from the superior border of the vertebrosternal ribs near their angles and inserts on the transverse processes of the middle and inferior cervical vertebrae. The iliocostalis thoracis originates from the superior borders of the inferior seven ribs medial to their angles and inserts on the upper ribs and C7 transverse process. The iliocostalis lumborum originates from the iliac crest, sacral crest and spinous processes and inserts on the inferior surface of the inferior seven ribs near their angles (Martini, Nath and Bartholomew, 2012).

The largest muscle of the erector spinae is the longissimus muscle and it is also divided into the longissimus-capitus, -cervicis, and -thoracis. The longissimus capitus originates from the tranverse processes of the inferior cervical and superior thoracic vertebrae and inserts on the mastoid process of the temporal bone. The longissimus cervicis originates from the transverse processes of the superior thoracic vertebrae and inserts on the transverse processes of the middle and superior cervical vertebrae. The longissimus thoracis originates from the broad aponeurosis and transverse processes of the inferior thoracic and superior lumbar vertebrae and joins the iliocostalis muscles. It then inserts on the transverse processes of the superior vertebrae and inferior surfaces of the ribs (Martini, Nath and Bartholomew, 2012).

Out of all the erector spinae muscles, the spinalis muscle group is the smallest and is divided into two muscles being the spinalis-cervicis and -thoracis. The spinalis cervicis originates from the inferior portion of the ligamentum nuchae and C7 spinous process and inserts on the C2 spinous process. The spinalis thoracis originates from the spinous processes of the inferior thoracic and superior lumbar vertebrae and inserts on the spinous processes of the superior thoracic vertebrae (Martini, Nath and Bartholomew, 2012).

Beneath the erector spinae muscle are several deep, short muscles: the semispinalis, multifidus, rotatores, interspinales, and intertransversarii muscles. These muscle are obliquely orientated (except the interspinalis and intertransversarii muscles) and are located between the transverse and spinous processes of the spine. The dorsal rami of spinal nerves

innervates, and the dorsal branches of segmental arteries supply most of the posterior spinal muscles. These muscles mainly function as spine extensors, lateral flexors and/or rotators depending on their location and distribution (Ebraheim *et al.*, 2004).

The psoas major and quadratus lumborum muscles make up the anterolateral and lateral muscles of the lumbar region (Ebraheim *et al.*, 2004). The psoas major muscle originates from the anterolateral surface of the vertebral bodies and discs, and the transverse processes of T12-L5. It then inserts on the lesser trochanter of the femur with the iliacus muscle. It functions as a hip or trunk flexor. The quadratus lumborum muscle is rectangular in shape and originates from the iliac crest and iliolumbar ligament, and inserts on the last rib and transverse processes of the lumbar vertebrae. It functions as a rib depressor if both sides contract together but if one side contracts independently, it will function as a lateral flexor of the vertebral column ipsilaterally. Both of these muscles are innervated by the ventral rami of the spinal nerves (Martini, Nath and Bartholomew, 2012).

2.4. Lumbar Spine Motion

Six degrees of motion occur in the lumbar spine, three rotations around and three translations along the primary axes. Flexion/extension are the terms used to refer to rotations in the sagittal plane, lateral bending/flexion are the terms used to refer to rotations in the frontal plane, and axial rotation is the term used to refer to rotations in the horizontal plane. Therefore, flexion/extension occur about the X-axis, lateral bending/flexion occurs about the Z-axis, and axial rotation occurs about the Y-axis (Wilke and Volkheimer, 2018).

The three translation directions that occur in the lumbar motion segment include anterior, posterior, and lateral motion. The motion segment also experiences axial compression and decompression. Due to the anatomical structure of the motion segment of the lumbar spine, coupled motion occurs meaning that motion in one principal plane is usually coupled with movement in one or two other movement planes. Therefore, pure one-directional rotary movement does not occur in the spine (Wilke and Volkheimer, 2018).

The difference between translation and rotation is that translation is defined with respect to a reference point on a rigid body in motion, whereas rotation occurs independent of a reference point as all points within a rigid body in motion experience the same rotation. Therefore it is generally simpler to calculate measurements of rotations from combined

translatory and rotatory movements than to calculate translatory movements (Wilke and Volkheimer, 2018).

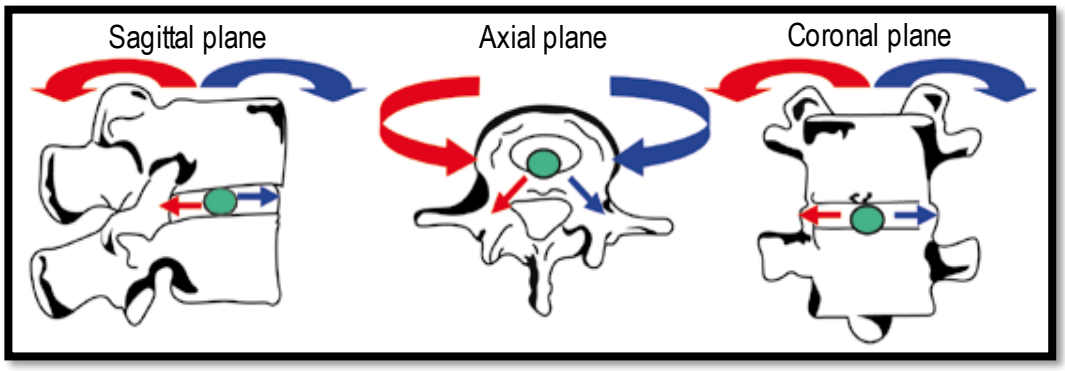


Figure 2.8. Movement of the instant axis of rotation in the three planes of motion (Oktenoglu and Ece, 2016)

The instant axis of rotation (IAR) is a point located within the posterior third of the intervertebral disc where all movements occur around this point. This point moves dynamically during lumbar motion meaning the IAR moves in various directions depending on the motion made in the lumbar spine. During flexion movements, the IAR moves anteriorly within the disc space and posteriorly at the level of the facet joints during extension. Opposing motions occur during lateral flexion movements as the IAR moves to the left during right lateral flexion and to the right during left lateral flexion in the coronal plane. The IAR remains central within the disc space during axial rotation movements (Oktenoglu and Ece, 2016).

The dynamic motion of the IAR is important to prevent trauma to motion segments. In instances where trauma resulting in deterioration of the stability of the column has occurred, the normal position of the IAR changes which then results in further instability and an altered biomechanical behaviour within the lumbar spine. This usually warrants the need for surgical fixation techniques to be applied to restore the normal position and function of the IAR (Oktenoglu and Ece, 2016).

The amount of flexion-extension movement in the lumbar spine increases from 12-14 degrees at the level of L1 to up to 18 degrees at the level of L5. Less motion occurs with lateral flexion of approximately 7-9 degrees occurring at each motion segment and the least amount of motion occurs with axial rotation of approximately 3 degrees occurring at each

motion segment. The limited axial rotation is due to the orientation of the facet joints as the articular processes of adjacent vertebra unilaterally impact against one another during this motion (Oktenoglu and Ece, 2016).

The entire spinal columns motion is 250 degrees in flexion-extension, 150 degrees in lateral flexion, and 100 degrees in axial rotation. Thus the lumbar spine contributes 95 degrees to the entire spinal columns motion in flexion-extension, 40 degrees in lateral flexion, and 18 degrees in axial rotation (Oktenoglu and Ece, 2016).

***Table 2.2. Lumbar Range of Motion* (Oktenoglu and Ece, 2016)**

Segment	Flexion & Extension	Unilateral lateral flexion	Unilateral axial rotation
L1-L2	12	6	2
L2-L3	14	6	2
L3-L4	15	8	2
L4-L5	16	6	2
L5-S1	17	3	1

2.5. Chiropractic

2.5.1. Subluxation

Chiropractic has been practiced for many years all over the world and the definition of the term “subluxation”, a term used by chiropractors, has changed from its original meaning. In the distant past, D.D. Palmer (founder of chiropractic) defined the term *joint subluxation* in a manner of structural terms. He hypothesized that a joint subluxation is a “partial or incomplete separation, one in which the articulating surfaces remain in partial contact” and he believed that vertebral subluxations could cause spinal nerve root compression. This compression would then lead to an obstruction of the neurological pathway emerging from the intervertebral foramina, therefore impeding the vital nerve impulses from the central nervous system from reaching the periphery. This would result in a decreased tissue resistance, thus creating potential disease in segmentally innervated tissues. He then suggested that all disease was primarily caused by subluxations and interruptions of normal tone, saying that nerves were either too tense or too slack. Later in life, his son B.J. Palmer

then promoted a monocausal concept of all disease based off his beliefs. B.J Palmer believed that chiropractic is a "science with provable knowledge of one cause of one disease being as internal interference of the internal flow of abstract mental impulses or nerve force flow supply, from above down, inside out" (Bergmann and Peterson, 2011).

Over the years, the chiropractic profession has matured and changed in that it does not promote a monocausal concept of disease being solely induced by a vertebral subluxation as described by B.J Palmer but rather that joint integrity must also be defined in functional terms and not solely in a structural manner. This concept broadens the definition of a joint subluxation to give it a more dynamic perspective in that a minor joint misalignment does not necessarily mean that the joint is dysfunctional or will be restricted in certain movements, therefore mispositioned joints do not have to be dysfunctional. Thus, joint fixations can arise in any position and it can restrict a joint in multiple planes. Today, disease is seen as a multifactorial issue, in that both static and dynamic components play a role in spinal dysfunction as well as possible joint pain with loading (Bergmann and Peterson, 2011).

Today, there are a few definitions for the term *subluxation,* one of which is "the alteration of the normal dynamic, anatomic, or physiologic relationships of contiguous articular structures" (Bergmann and Peterson, 2011).

2.5.2. Vertebral subluxation complex (VSC)

Although there are a few definitions for the clinical description of the joint subluxation, they all acknowledge that it is not a condition definable by one or two characteristics. It is rather defined as a complex, multifactored pathologic entity which is called the *vertebral subluxation complex* (VSC). The VSC is defined as "a theoretical model of motion segment dysfunction (subluxation) that incorporates the complex interactions of pathological changes in nervous, vascular, ligamentous, connective and muscular tissues" (Bergmann and Peterson, 2011). This is a conceptual model unlike the vertebral subluxation syndrome which define a clinical condition according to its presenting physical signs and symptoms (Bergmann and Peterson, 2011).

The VSC is made up of different components such as (Gatterman, 2005):

1. Kinesiology: Movement restricted at one level may cause compensation to occur at other levels. This component is based on the spinal motion segment.
2. Neuropathology/Neuropathophysiology: The major constituents of this component are the dorsal root ganglia and their spinal nerves.
3. Myopathology: Since muscles and osseous structures have a close relationship to one another, issues that arise in one structure may affect the other structure. Thus, joint immobilisation may result in the associated muscles to undergo a degenerative process, and vice versa. This relationship may result in a vicious self-perpetuating cycle when issues arise in either structure which may lead to severe degeneration.
4. Histopathology: Immobilisation may also cause connective tissue involvement which may result in ligamentous contractures or thickening of the synovial fluid.
5. Biochemical abnormalities: This component of the VSC has to do with the blood supply of the spinal canal. This vascular component comes into play as mechanical forces which may cause nerve root compression, results in the obstruction of certain anastomotic channels, depending on where the obstruction occurred. Inflammation and oedema caused by venous compression may occur as stasis of the blood flow in the vessels may follow. This introduces an inflammatory component which is formed by a biochemical and cellular process that is mediated by the vascular system.

2.5.3. Joint subluxation/dysfunction syndrome

Joint subluxation/dysfunction syndrome (JSDS) is classified as a clinical diagnosis that is defined by a group of signs and symptoms which make the identification of joint dysfunction possible whether it be in the spine, pelvis, or peripheral joints. The JSDS is not a pathoanatomic or structural diagnosis, but rather a biomechanical or functional diagnosis. This diagnosis however does not identify the specific cause of pain within the spinal motion segment unlike traditional structural diagnoses such as spinal stenosis, disc herniation, or sprain or strain. The main characteristic of this diagnosis is local axial spine pain that can be reproduced or accentuated with palpation, static or dynamic. There may be an associated sclerogenic referred pain typically extending into the proximal lower extremity. JSDS is a

condition that can occur on its own, but it is most commonly associated with other pathoanatomical and functional conditions or disorders (Bergmann and Peterson, 2011).

2.6. Lumbar Facet Syndrome

2.6.1. Introduction

The definition of facet pain is pain arising from any structure that forms part of the facet joints, this includes the bone, hyaline cartilage, synovial membrane, and fibrous capsule. The first person to describe the syndrome was Golthwaite in 1911, but Ghormley is the person who coined the term "facet syndrome" in 1933 (Van Kleef, Vanelderen, Cohen, Lataster, Van Zundert and Mekhail, 2010). The lifetime prevalence has been estimated to be as high as 84% for back pain cases. It has been proven that low back pain, amongst other musculoskeletal disorders, is the leading reason why patients seek medical treatment and it is the number-one cause of disability (Huang-Lionnet, Brummett and Cohen, 2018).

Low back pain is often difficult to diagnose as the causes are usually complicated and multifactorial as any associated structure can be the source of pain such as muscles, ligaments, IVD, facet joints, and/or nerve roots (Huang-Lionnet, Brummett and Cohen, 2018). Approximately one third of chronic low back pain cases are commonly caused as a result of a lumbar facet joint dysfunction (Nedelka *et al.*, 2014). The prevalence rate from different studies broadly differs ranging from less than 5% to higher than 90%. However, this is highly dependent on the diagnostic criteria used and the selection methods. Information taken from studies that had well-selected patient populations showed a prevalence rate ranging between 5% to 15% of patients suffering from axial low back pain is caused by structures of the lumbar facets. A common cause of facetogenic pain is arthritis, so there is an increase in the prevalence rate with age (Van Kleef *et al.*, 2010). The facet joints in particular can be a potential source of back pain from the neck down to the lower back and can also cause pain in the extremities such as shoulder or leg pain (Huang-Lionnet, Brummett and Cohen, 2018).

2.6.2. Pathophysiology

Acute injury to the spine is infrequently the cause of facet arthropathy and facet-mediated pain with major spine trauma and whiplash injuries being the exceptions. Facetogenic pain that is caused by acute trauma is usually due to rapid deceleration injuries. Facetogenic pain

usually develops over a long period of time and is mainly caused by years of repetitive strain, degeneration of the IVD, and minor trauma. The correlation between pain experienced by the patient and the degree of degeneration and inflammation is usually poor as in other cases of degenerative joint disease. As mentioned before, age plays a big role in the prevalence rate of facet arthropathy or facetogenic pain, and this is congruous with the degenerative disorder concept (Huang-Lionnet, Brummett and Cohen, 2018).

Overloaded facet joints bear more than 20% of the upper body weight. This is more than its normal capacity and predisposes the joints to degeneration, destruction of the chondral plate with bone spur formation and calcifications. This leads to an inflammatory cascade within the joints and the surrounding soft tissue. A painful vicious cycle may then develop resulting in neurogenic inflammation and/or mechanical compression of the medial branch of the dorsal nerve root (Nedelka *et al.*, 2014).

In cadaveric studies, the greatest degree of motion and strain can be observed at the most caudal levels of L4/L5 and L5/S1 in the lumbar spine as the strain experienced by these joints occurs maximally in forward flexion. The middle level of L3/L4 facet joints experience maximal strain with lateral flexion movements and the opposite occurs at the most cephalad levels of L1/L2 and L2/L3. Degeneration of adjacent levels occur at an accelerated rate when the intervertebral level has undergone fusion (Huang-Lionnet, Brummett and Cohen, 2018).

Fluid accumulation and joint distention can occur as a result of chronic strain and repetitive stimulation thus facetogenic pain is not normally considered as an active inflammatory state. Intervertebral foraminal narrowing due to other pathologies such as osteophyte formation, disc herniation, disc degeneration, etc., can be made worse by facet joint hypertrophy which may cause nerve root compression, resulting in radicular pain. Paraspinal muscle spasm is a common find with patients who suffer from facetogenic pain (Huang-Lionnet, Brummett and Cohen, 2018).

The IVD and the facet joints work together as illustrated in the concepts of the three-joint complex or spinal motion segment. Thus, degeneration in one area will create additional strain in another area, i.e. degeneration of the facet joints will cause additional strain of the IVD and vice versa. Degenerative disc disease is usually associated and occurs at a greater degree at the most caudal facet joints of L4/L5 and L5/S1. L5/S1 facet joints are the most

commonly affected in clinical cases and L4/L5 usually shows the most radiological features. The IVD usually degenerates at a faster rate than the facet joints meaning that changes in the IVD can be seen at an earlier age (Huang-Lionnet, Brummett and Cohen, 2018).

Inflammatory arthritis and pseudocysts are less commonly the cause of facetogenic pain. Whiplash injuries are the most common cause of trauma-induced facetogenic pain accounting for over 50% of chronic neck pain cases due to motor vehicle accidents (Huang-Lionnet, Brummett and Cohen, 2018).

2.6.3. Characteristics

The characteristics of lumbar facet joint syndrome are localised axial pain that's elicited by rotation or hyperextension in the lumbar spine area, with associated referred pain typically to the buttocks and anterolateral or posterior thigh region. The referred pain rarely radiates below the knee. In rare cases, neuropathic sensations may be felt in the mentioned regions such as paraesthesia's, numbness or allodynia, and more rarely, trophic changes and/or hair loss (Nedelka *et al.*, 2014). In another study, there is also tenderness on palpation of the facets joints or transverse processes which is unilateral or bilateral, lack of radicular features, pain made worse with lateral flexion, extension and rotation, pain made better with forward flexion, and associated thigh or groin pain (Saravanakumar and Harvey, 2008).

Diagnosing lumbar facet syndrome can be somewhat difficult, but pain referral patterns can give clinicians a clue to the diagnosis. Referred pain is just one of the symptoms that can give clinicians a general idea of which levels may be affected although facetogenic pain associated pain referral patterns are often variable and overlapping (Huang-Lionnet, Brummett and Cohen, 2018).

The more cephalad facet joints of the lumbar spine usually refer pain to the flanks, hips, and upper lateral thigh. The more caudal facet joints usually refer pain to the posterolateral thigh and sometimes to the calf. In figure 2.9. below, the darkest areas illustrate the most common areas of referred pain being in the lower back and the lightest areas illustrate the less common areas being in the flanks and feet (Huang-Lionnet, Brummett and Cohen, 2018).

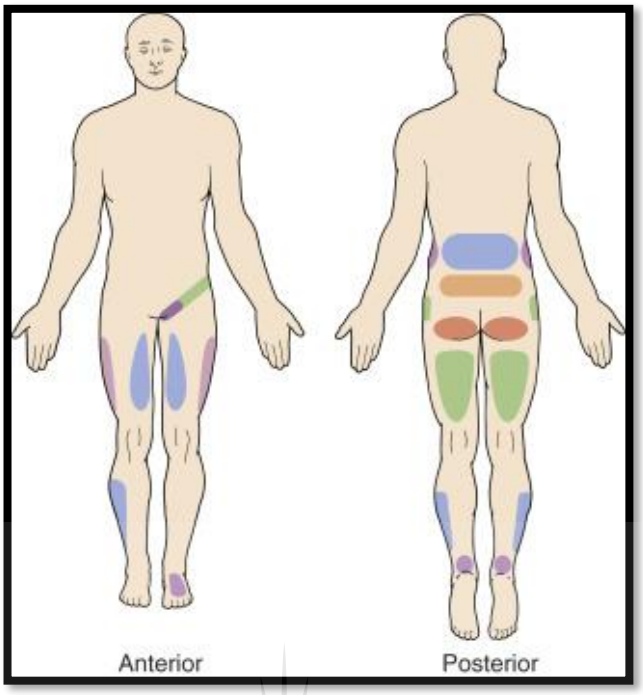


Figure 2.9. Referral pattern of lumbar facets **(Huang-Lionnet, Brummett and Cohen, 2018)**

2.7. Spinal Manipulative Therapy

2.7.1. Introduction

The definition of spinal manipulative therapy (SMT) is the application of a high-velocity, low-amplitude manual thrust to spinal joints slightly beyond the passive range of motion within the paraphysiological zone. The definition of spinal mobilisation is the application of a manual force to spinal joints within the passive range of spinal motion and does not involve a thrust. Specialized treatment tables that apply traction to the spine are also considered as a form of spinal mobilisation (Bronfort, Haas, Evans, Kawchuk and Dagenais, 2008). Both are similar but extracorporeal shockwave therapy (ESWT) acts more as a spinal mobilisation in this case due to its mechano-transductory effects within tissues (Nedelka *et al.*, 2014).

A recent study was done on comparing SMT with other conservative treatments for the management of acute and chronic low back pain in adults. The objective was to develop a clinical practice guideline aiming to provide the best practice recommendations for the assessment and management of low back pain. It was concluded that SMT, used with other commonly used conservative active interventions, self-management advice and education, plus exercise, is a safe and effective treatment strategy for acute or chronic low back pain,

with or without leg pain (Bussières, Stewart, Al-Zoubi, Decina, Descarreaux, Haskett, Hincapie, Page, Passmore, Srbely, Stupar, Weisberg and Ornelas, 2018).

2.7.2. History of spinal manipulation

Spinal manipulation is a nonsurgical, non-invasive form of therapy that has been used to treat chronic low back pain for thousands of years. Although associated with chiropractic, the use of spinal manipulation predates the modern profession which began in 1895, as far back as 2700 BC, where it is believed to have been practiced in China. Spinal manipulation historically practiced in India was done for hygienic purposes and the techniques were also seen as a form of surgery. Hippocrates was the first person to formally define manipulation as a technique as he believed that spine was the most important structure to treat to achieve holistic health of the body (Bronfort *et al.*, 2008).

2.7.3. Subtypes

There are many different subtypes of named spinal manipulative technique systems which combine patient assessment and management. The most commonly used technique system is known as "diversified" as it incorporates various aspects taught in all the different systems. The diversified technique system involves the use of a high-velocity, low-amplitude thrust beyond the passive range of motion into the paraphysiological zone to slightly distract a specific spinal facet joint, all done by hand (Bronfort *et al.*, 2008).

Although many different specific high-velocity, low-amplitude impulse thrusts exist, the most preferred techniques are short-lever spinal manipulative techniques as the thrust is delivered directly to the spine. The force/thrust of long-lever spinal manipulative techniques are not delivered directly to the spine but rather through the rotation of the thigh and leg. These long-lever techniques were originally derived from the osteopathic profession (Bronfort *et al.*, 2008).

Other subtypes of spinal manipulative therapy include the use of instruments to assist in achieving the spinal manipulation (instrument-assisted technique systems) and low-force manual technique systems (Bronfort *et al.*, 2008).

2.7.4. General description

When treating patients with low back pain, the SMT techniques that would typically be used are the side lying manipulative techniques, with the patient lying on a treatment table. The chiropractic practitioner begins by placing the patient in their desired position on the treatment table based on the type of SMT technique they will be performing by making sure that the patients arms, torso, hips, and legs are placed in the appropriate manner (Bronfort *et al.*, 2008).

The practitioner then contacts the patient's arm with their "indifferent/stabilising" hand and the patient's thigh or knee with their thigh or leg. The practitioners "contact/treatment" hand is then placed either with a pisiform contact over the desired ipsilateral facet joint or with a reinforced index contact "hooking" the spinous process of the vertebra above the target spinal motion segment, contralaterally (Bronfort *et al.*, 2008).

The practitioner then preloads the target spinal motion segment slowly to remove any "joint slack" and "lock the joint", and then applies a high velocity, low amplitude impulse thrust in the direction of the joint fixation determined by prior examination. The impulse thrust is accompanied by a "body drop" produced by the practitioners abdominal and leg muscles (Bronfort *et al.*, 2008).

An audible cracking or popping sound is typically heard when SMT is administered to spinal joints. This is due to the rapid formation and dissolution of small gas bubbles within the joint space as pressure changes occur as the joint surfaces briefly separate when a high velocity, low amplitude impulse thrust is administered to those target spinal motion segments (Bronfort *et al.*, 2008).

2.8. Extracorporeal Shockwave Therapy

2.8.1. Introduction

Extracorporeal shockwave therapy (ESWT) is a relatively new non-surgical, non-invasive therapeutic modality which utilises high energy acoustic waves targeted at painful musculoskeletal tissues with subacute, subchronic, and chronic conditions (Notarnicola and Moretti, 2012). It is characterised by pressure disturbances that are short and propagate rapidly at high amplitudes through a medium (Watson, 2015).

Unlike ultrasound therapy, the energy that is produced and transferred into tissues is much higher with ESWT (Gruenwald, Appel, Kitrey and Vardi, 2013). Ultrasound waves are typically biphasic with the generated pressure peaking at 0.5 bar, whereas ESWT has a uni-phasic pattern with the generated pressure peaking as high as 500 bars (Wang, 2012).

The acoustic waves generated by ESWT transmit energy through a medium such as tissue, penetrating through the superficial layers to interact with the deeper layers. This in turn causes a cascade of biological reactions resulting in the promotion of neovascularisation and tissue healing (Gruenwald *et al.*, 2013). When the acoustic waves encounter an area that has an altered state ("boundary/interface") within a medium, energy is given off and that part of the wave is reflected while the rest of the wave passes through it. This interaction causes a dissipation of energy at these "boundaries/interfaces" resulting in the production of the physiological, mechanical and consequent therapeutic effects (Watson, 2015).

The device can be used in many different disciplines such as veterinary medicine, sports medicine, physiotherapy, urology, and orthopaedics. The main goal of this type of therapy is fast pain relief and mobility restoration. The high energy acoustic waves promote tissue repair and regeneration within bone, tendon and other soft tissues (Notarnicola *et al.,* 2012).

2.8.2. Brief history of shockwave

ESWT was originally used as a non-invasive treatment for the removal/destruction of kidney stones known as lithotripsy. This began in the early 1970's, but only became a first line treatment for such conditions in the 1980's (Watson, 2015). Soon afterwards, researchers noticed that there was a positive osteoblastic response pattern present while doing animal studies in mid-1980 (Wang, 2012). They also noticed that positive effects could also be seen in cartilage and the associated soft tissues such as fascia, tendons and ligaments.

These incidental findings then sparked interest in researching the use of ESWT in musculoskeletal disorders and by the early 1990's, reports emerged where ESWT was being used to treat soft tissue conditions (Watson, 2015). These conditions include disorders such as proximal plantar fasciitis and heel spurs, lateral epicondylitis, calcific tendinitis, patellar tendinopathy, and achilles tendinopathy. Other research that was being done was on conditions such as avascular necrosis of the femoral head, and non-union of long bone

fractures. Other disorders include complex regional pain syndrome (RSD or reflex sympathetic dystrophy), osteoarthritis of the knee, and spinal fusion (Wang, 2012).

The most commonly used term for this type of treatment is now extracorporeal shockwave therapy. Some researchers and practitioners have recently begun to name it according to the nature of the wave production used in the therapeutic version which is radial shockwave therapy. This makes it easier to distinguish it from the focused version that is used in other medical professions (Watson, 2015).

2.8.3. Shockwave principles

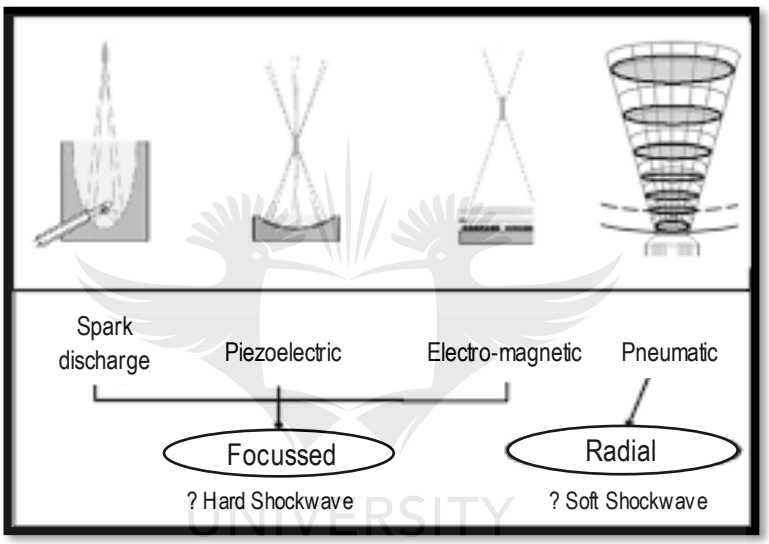


Figure 2.10. Methods of Shockwave Production (Watson, 2015)

There are two main types of shockwave. They are focused and radial shockwaves respectively. Of these two types, there are four different ways of generating shockwaves which are: spark discharge, electromagnetic, piezoelectric, and pneumatic/electrohydraulic. The first three fall under focused shockwave therapy and the last one falls under radial shockwave therapy (illustrated in figure 2.10.). The wave that is produced by each subtype depends on the amount of energy that the wave has and this will also determine the depth of penetration within human tissues (Watson, 2015).

The most common type of shockwave used in therapy is based on the pneumatic system due to its characteristics of producing radial shockwaves. Focused shockwaves are essentially used in surgical interventions such as breaking down kidney stones due to its destructive nature which is not ideal for therapeutic use. Focused shockwaves are also

known as ‘hard’ shockwaves and radial shockwaves are also known as ‘soft’ shockwaves (Watson, 2015).

The shockwave device used in this study is the EMS Swiss Dolorcast Smart 2.0 shockwave unit, which produces radial extracorporeal shockwave.

Radial shockwave utilizes a ballistic mechanism to produce shockwaves by using compressed air to rapidly accelerate a projectile within an enclosed tube towards a treatment head/transmitter. Focused shockwave utilizes a large applicator that is elliptically shaped and targeted at the diseased region where its effects will be produced (Van der Worp, Zwerver, Hamstra, Van den akker-Scheek and Diercks, 2014).

The acoustic energy produced by radial shockwaves diverges and spreads the deeper it goes into tissues. This means that its energy is maximal as it leaves the applicator head and decreases as it spreads out on its way to deeper target tissues. When the energy reaches the target tissue, it dissipates in and around the tissue. With a maximum depth of 4-6 cm (Nedelka *et al.*, 2014) and the nature of radial shockwaves to disperse widely, the resultant effect is that a larger area of tissue will receive therapeutic energy (Van der Worp *et al.*, 2014). This makes this type of shockwave therapy ideal for treating superficial tissues as the therapeutic effects are more based on tissue healing and regeneration (Watson, 2015).

Contrary to radial shockwaves, focused shockwaves behave in an opposing manner. The acoustic waves produced by focused shockwaves converge into a central point within tissues instead of diverging and the energy at that point is at its maximum. Therefore, the energy emitted from the applicator head is minimal and gets stronger as the waves converge the closer it gets to the target tissue. The diameter of the applicator head of a focused shockwave device is larger than that of a radial shockwave device therefore a larger area of skin is in contact with the applicator head. However, due to the nature of focused shockwaves to converge, the energy becomes concentrated and intensified over a much smaller surface area within tissues. Unlike radial shockwaves, focused shockwaves penetrate much deeper into tissues. Thus, the increased depth of tissue penetration along with the ability to generate maximum energy at the target tissue makes it ideal for surgical interventions such as lithotripsy (Watson, 2015).

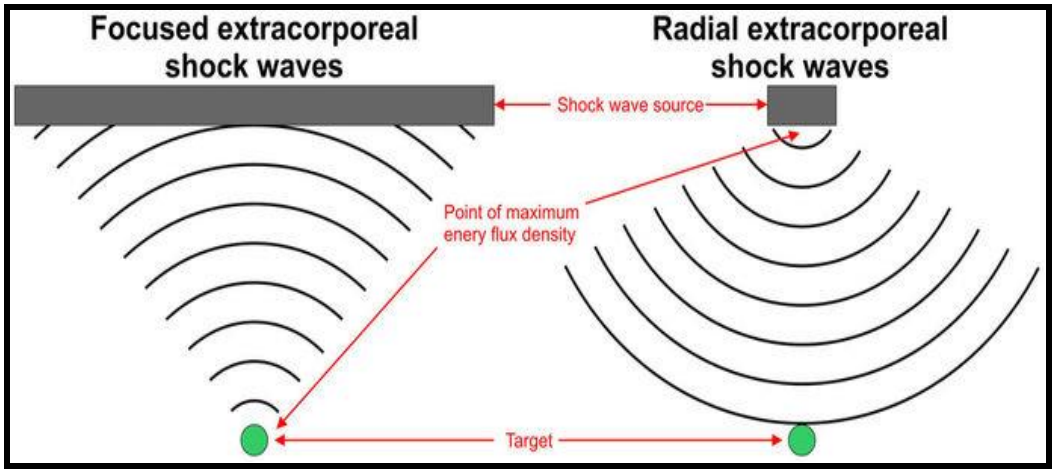


Figure 2.11. Focused Vs Radial ESWT **(Schmitz, Császár, Milz, Schiekar, Maffulli, Rompe and Furia, 2015)**

It is also important to note that with focused shockwaves, any disturbances (such as calcification or bone) between the applicator head and the target tissue will block parts of the acoustic waves which will decrease the intensity of the shockwave energy produced at the target tissue. Contrary to focused shockwaves, radial shockwave energy would not be affected by these same disturbances as the wave pattern diverges to cover a wider surface area (Schmitz *et al.*, 2015)

2.8.4. Effects of extracorporeal shockwave therapy

a) Cellular mechanotransduction

Mechanotransduction is a process in which a cascade of biological events is initiated as a result of mechanical forces being converted within cells into biochemical signals. These mechanical forces play a vital role in the maintenance of cell homeostasis. This is achieved as these forces influence the cells' morpho-physiology and physical properties (Frairia and Berta, 2011).

The pressure disturbances caused by shockwave energy which is propelled through tissues results in mechanotransduction. This causes an increase in cell perfusion, blood flow in the area, and an altered pain signalling process within ischemic tissues which ultimately results in the lengthening of sarcomeres within contracted muscle fibres returning those tissues to its original resting length (Ramon, Gleitz, Hernandez and Romero, 2015).

b) Analgesic effects

Research has shown that ESWT causes a reduction of nociceptive chemicals such as substance P which stimulate pain receptors in the affected region. It has also shown that the production of substance P is also decreased in the spinal cord within the dorsal root ganglion. This neuropeptide is responsible for the stimulation of pain fibres via the A-delta and C- fibres (Schmitz *et al.*, 2010).

c) Tissue healing and regeneration

The mechanotransductory effects of ESWT also stimulates macrophages to produce anti-inflammatory interleukins and cytokines. These are then responsible for the promotion of cell regeneration, healing and further pain reduction (Sukubo, Tibalt, Respizzi, Locati and d'Agostino, 2015)

d) **Medical effects of extracorporeal shockwave therapy** (Notarnicola *et al.*, 2012):

- New blood vessel formation (angiogenesis)
- Reversal of chronic inflammation
- Stimulation of collagen synthesis
- Dissolution of calcified fibroblasts
- Dispersion of pain mediator "Substance P"
- Release of trigger points
- Osteoblastic response

2.8.5. Complications of extracorporeal shockwave therapy

There are minimal risks associated with the use of ESWT when the correct settings and methods of application are used (Gleitz and Hornig, 2012). Usually patients will feel some pain or discomfort during and/or sometimes after the treatment lasting about 1-2 days. There may also be some mild skin irritation, numbness or paraesthesia but this is also temporary (Watson, 2015). Areas overlying the lung tissue should be handled with extra care as the acoustic waves may irritate the lungs due to the cavitational effects of the acoustic waves resulting in a cough (McClure and Dorfmüller, 2003).

CHAPTER THREE: METHODOLOGY

3.1. Introduction

The specific aim of this study was to determine whether extracorporeal shockwave therapy alone or combined with chiropractic lumbar manipulative therapeutic techniques was effective in the treatment and management of individuals with chronic lumbar facet syndrome.

This chapter describes the study design, participant recruitment, sample size and selection, and the randomisation technique used. Detailed explanations are also provided for the treatment protocols, assessments, objective and subjective measurement tools as well as information regarding the ethical considerations and statistical analysis.

3.2. Study Design

This was a quantitative comparative clinical study which utilised convenience sampling and random group allocation methods to split participants into 3 groups. Each participant had to simply choose one of three coloured files to be allocated to a specific group. Each group consisted of 10 participants.

3.2.1. Participant recruitment

Participants were recruited through advertisements (Appendix A) and word of mouth. The advertisements were placed in various locations around and within the vicinity of the University of Johannesburg Doornfontein campus in areas such as: the administration building, student centre, Perskor building, John Orr building, Chiropractic Day Clinic, on- and off-campus libraries, local shopping centres and shops, on- and off-campus gyms, sports centres and other University of Johannesburg campuses.

The researcher explained the research study to the participants in detail and the participants were selected according to whether they complied with the inclusion or exclusion criteria of the study assessed by taking a thorough case history (Appendix B), physical examination (Appendix C) and lumbar spine regional examination (Appendix D). This was all done to assess whether the participants' chronic low back pain was indeed caused as a result of lumbar facet syndrome. Participants who met any condition in the exclusion criteria were not allowed to participate in this study. The eligible participants were also required to read the

information form and sign the institutional consent form (Appendix E) once they fully understood the study in order to complete the recruitment process.

3.2.2. Sample selection and size

The sample size for this study consisted of a total of thirty males and females aged 18 to 35 years old who suffered from chronic low back pain due to lumbar facet syndrome. The participants were selected according to whether they met the requirements of the inclusion or exclusion criteria over and above the process explained in the participant recruitment section above to assess whether their low back pain was indeed caused as a result of lumbar facet syndrome.

Again, those who met any condition in the exclusion criteria were not allowed to participate in this study. The sample was randomly split into three groups of ten participants each. Each participant was required to choose one of three coloured files at the end of the recruitment process to be assigned/allocated to a specific group.

3.2.3. Inclusion criteria

Participants had to comply with the following criteria to be included in this research study:

- Male or female
- Participants aged 18-35 years
    - This eliminates any possible degenerative changes that accompany increasing age (Kelly, Groarke, Butler, Poynton and O'Byrne, 2012).
- Participants presenting with chronic low back pain
    - Chronic low back pain is defined as pain/symptoms that are persistent for 3 or more months (Rozenberg, 2008).
- Participants that presented with at least 2 of the 7 criteria below associated the with joint dysfunction (Bergmann and Peterson, 2011):
    - Local pain which commonly changes with activity
    - Local tissue hypersensitivity
    - Increased, aberrant, or decreased joint movement
    - Altered and/or painful joint movement end-feel resistance
    - Altered or painful joint play
    - Altered alignment

    - Local muscle hypertonicity/rigidity on palpation
- Localised axial pain elicited by hyperextension and rotation with or without referred pain radiating to the buttocks and/or posterior or anterolateral thigh (Nedelka *et al.*, 2014).
- Body mass index (BMI) < 28 due to increased facet joint depth as extracorporeal shockwave therapy (ESWT) has a maximum depth of 4-6 cm. BMI calculated from weight and height recordings (Nedelka *et al.*, 2014).

3.2.4. Exclusion criteria

Participants that presented with any of the following were not considered for this research study as any of these conditions may alter the outcome of the treatment and results (Nedelka *et al.*, 2014):

- Clinical signs of radiculopathy
- Presence of sensory loss
- Motor weakness
- Nerve root compression
- Spondylolisthesis
- Spinal canal tumours
- Spinal stenosis
- History of spinal surgery
- Any contra-indications to chiropractic manipulation (Appendix F) or ESWT (Appendix G)

3.2.5. Group allocation

Participants, male or female, who complied with the inclusion criteria and recruitment process were randomly allocated into one of the three groups. The participants were required to choose one of three coloured files which represented the group that they were to be placed in. The participants did not know which coloured file represented which group. Each group consisted of ten participants. Group one received spinal manipulative therapy (SMT), group two received ESWT, and group three received a combination of the two therapies.

3.3. Treatment Approach

3.3.1. First and follow-up consultations

Each participant was required to attend a total of seven consultations over a four-week period. The participants were requested to visit the University of Johannesburg Chiropractic Day Clinic twice a week during the four-week period to receive treatment. The seventh consultation had no treatment and was for obtaining subjective and objective measurements/data only. Each participant was treated six times with either ESWT, SMT, or a combination of both depending on which group they were randomly allocated to.

3.3.2. Initial consultation

Each participant received an in-depth explanation of how the research study was going to be conducted and was requested to read the information form and sign the consent form (Appendix E) once they fully understood the study. A thorough case history (Appendix B), physical examination (Appendix C), and lumbar spine regional examination (Appendix D) were done to assess whether participants comply with the inclusion or exclusion criteria and if their low back pain was indeed caused by a lumbar facet syndrome. The lumbar spine regional examination also included manual palpation, both static and dynamic, of the lumbar and sacral regions. This was done to make sure that a thorough assessment was performed looking for any areas of local tenderness and inflammation to help identify areas of segmental dysfunction or hypomobility.

The researcher took objective measurements/data using a Digital Inclinometer (Appendix H) to assess lumbar range of motion. Subjective data was collected using a Numerical Pain Rating Scale (Appendix I) and an Oswestry Low Back Pain and Disability Questionnaire (Appendix J), which each participant was requested to complete.

The participants received treatment depending on which group they are allocated to. Group one received SMT, group two received ESWT, and group three received a combination of the two therapies.

3.3.3. Follow-up consultations

After the initial consultation, six follow-up consultations were required where each participant received treatment in all follow-up consultations except for the last consultation which was

for objective and subjective measurement/data collection only. All participants were required to attend two treatment consultations a week over three weeks and one measurement/data collection consultation in the fourth week. Participants were treated only twice a week as tissue recovery post treatment takes at least 2 days to occur (Travell, Simons and Simons, 1999). Objective and subject measurements/data was further taken by the researcher on the fourth and seventh follow-up consultations and was taken prior to the participants receiving treatment on the fourth consultation.

3.4. Motion Palpation

This is a procedure in which joint mobility is assessed using the hands. It is important to have a good understanding of local biomechanics, functional anatomy and pathomechanics as performing this skill is not only reliant on psychomotor training. To master the art of motion palpation, the chiropractic student must have good knowledge of each joints unique pattern and range of motion (ROM). There are three main aspects of motion palpation which are active, passive, and accessory joint movements. These are designed to assess different structures in and around the joint such as the joint capsule, intra-articular effusions, peri-articular muscle splinting, etc (Bergmann and Peterson, 2011). It is important to master this art as this is how joint restrictions are found.

Active joint movements are provided by the patient's muscular efforts to create movement within the joint thus it is internally driven by voluntary muscle contractions. A joints active ROM depends on its articular design and the amount of tension and resilience in peri-articular structures such as the surrounding myofascial, musculature, and ligamentous structures. With reference to figure 3.1., active joint ROM ends at what is known as the physiological barrier (Bergmann and Peterson, 2011).

Passive joint ROM is externally driven by forces which create involuntary movements of joints. The examiner creates the joint movement through its arc while the patient is in a relaxed position. Due to the decrease in muscle activity, passive ROM is generally larger than that of active ROM as there is no resistance from contractile tissues. A joints passive ROM depends on its articular design such as in active movements but also the flexibility of its articular soft tissues. As the joint reaches the end of its passive ROM, the examiner applies an additional overpressure surpassing the physiologic barrier to assess the joints end-play. With reference to figure 3.1., this space known as the end-play zone and is

governed by the physiologic barrier and the elastic barrier. Removal of the examiners overpressure should result in the joint springing back from the elastic barrier. Passive ROM is important for the assessment of the joint's capsule and periarticular soft tissue's elastic properties (Bergmann and Peterson, 2011).

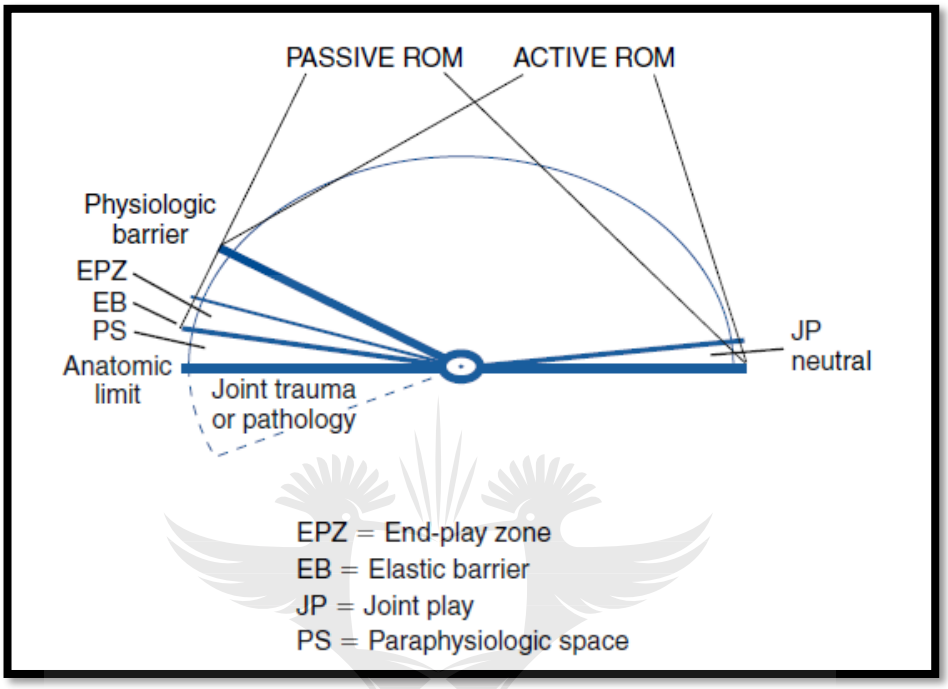


Figure 3.1. Joint ROM **(Bergmann and Peterson, 2011)**

Movement out of the end-play zone beyond the elastic barrier is usually associated with an articular crack/cavitation. When this happens, the joint has moved into the paraphysiologic zone/space (refer to figure 3.1.) which is governed by the elastic and anatomic barriers. This space may be associated with a crack, but no injury occurs to the joint. Joint separation may occur without an articular crack/cavitation in joints that have increased capsule flexibility. This is due to separation occurring without the need for fluid tension build-up between the joints articular surfaces that would be required in a joint with a more rigid/less flexible joint capsule. Any movement beyond the anatomic barrier is associated with joint injury and plastic deformation (Bergmann and Peterson, 2011).

Joint ROM restrictions, whether they are minor or major, can be found anywhere within the joint's active or passive ROM. Restrictions found during active ROM are usually due to myofascial shortening such as muscle splinting, hypertrophy, aging, or contractures.

Restrictions found during passive end ROM are usually due to joint capsule and periarticular tissue shortening (Bergmann and Peterson, 2011).

When performing motion palpation, the examiner uses one hand to palpate joint motion and the other hand to either produce motion such as in passive movements or guide motion with active movements. The palpation hand contacts the spinous processes and peri-articular soft tissues using a broad thumb contact with special attention being placed on the assessment of the joint's ROM, pattern, and quality of motion. It is important to note that the examiner is attempting to assess the joint's quality and quantity of motion permitted by that joint from starting to end of passive ROM. Once a restriction has been noted, the examiner adjusts their contact to either the spinous process, articular pillar, transverse process, rib angle, or mammillary process to get a more specific contact to assess a single spinal motion segment (Bergmann and Peterson, 2011).

3.4.1. Accessory joint motion

These are small, involuntary movements that are important for normal joint function. The articular "give" within each synovial joint's articular soft tissues is what makes these movements possible. It is divided into two key aspects which are joint play (JP) and end play (EP). Both aspects are dependent on the articular soft tissue's flexibility and are qualitative assessments of joint movement (Bergmann and Peterson, 2011).

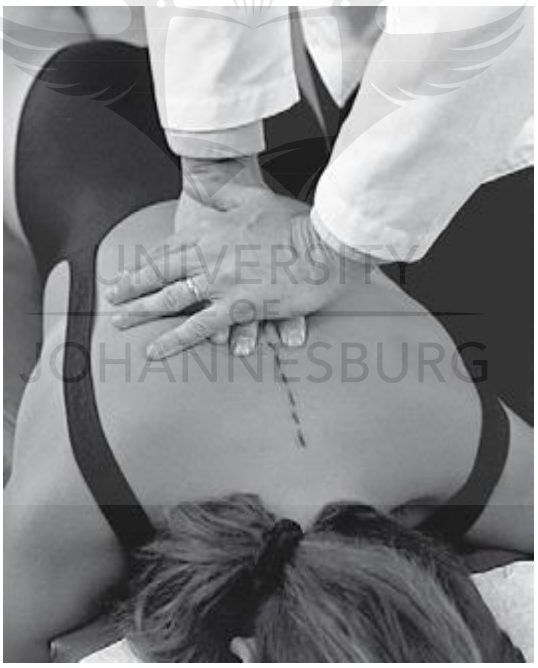
A. Joint play

This is the qualitative assessment of a joint's resistance to movement while the joint is in a loose-packed position. This position is ideal for the isolation of the joint capsule from periarticular muscles and allows for the largest amount of play within the joint. Therefore, this aspect of accessory joint motion is a vital tool to help isolate and differentiate whether the source of the pain and dysfunction is articular-based or a non-articular soft tissue disorder. This can also be used to assess joint instability, looking for excessive translational movements within the joint due to injury of the joint's stabilizing structures (Bergmann and Peterson, 2011).

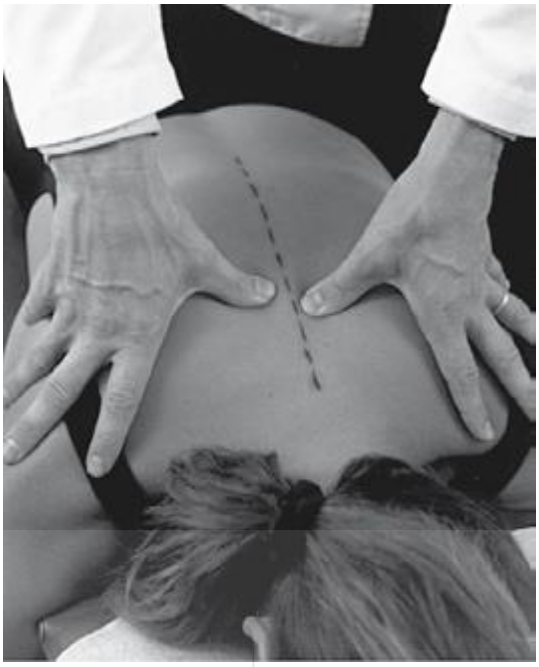
Joint play (JP) assessments are done while the joint is resting in it's loose-packed position with the examiners one hand/palpating hand contacting over the joint line while the other hand assists in providing a gentle springing shallow movement. In the spine, this is

performed by applying a posterior to anterior (P-A) force over the facet joints or a lateral/counter-rotation force contacting the spinous processes on a prone lying patient (FIGURE 3.2. A & B respectively) (Bergmann and Peterson, 2011).

The movements felt when doing JP assessments are miniscule and vary depending on the joint being tested. JP assessments have proven to be reliable in the reproduction of pain but does not yield the same reliability in the assessment of joint hypomobility. Thus, when doing JP assessments, it is important to check for pain reproduction, any resistance encountered, and the quality of joint motion. In normal circumstances, no pain should be induced with some degree of resistance encountered and the joint should be able to withstand the examiners pressure and spring back which will produce short-range movements within the joint. If pain is induced or there is an abnormal increased resistance, then it is safe to assume that the source of the patients local spine pain is due to the tested joint and its articular structures (Bergmann and Peterson, 2011).



(A)



(B)

***Figure 3.2. A) P-A glide joint play, B) Lateral glide/counter-rotation joint play* (Bergmann and Peterson, 2011)**

B. End play

This is a qualitative assessment of joint motion within the end-play zone ending at the elastic barrier. The characteristics of the end-play zone is that there are two points of resistance. The initial point of increasing resistance as the joint approaches the end-play zone moving beyond the physiological barrier, and the final point of peak resistance as the joint approaches the elastic barrier. In normal circumstance, end play (EP) assessments are pain-free (Bergmann and Peterson, 2011).

EP assessments in the spine are done at the end of passive ROM by applying a gentle springing overpressure with the palpating hand and indifferent hand to a specific joint (Figure 3.3.). With EP assessments, it is important to check for the point where resistance begins to be encountered, the quality of that resistance, and the presence of any tenderness associated with that movement (Bergmann and Peterson, 2011).

Figure 3.3. End Play Motion Palpation (Bergmann and Peterson, 2011)

EP evaluations are necessary for the assessment of joint function which is a vital element as synovial joints are dynamic structures. EP evaluations are especially important in the spine as they yield more reliable information than other procedures that assess quantitative changes in the ROM of individual joints as EP evaluations assess qualitative changes in movement. The importance of this is that spinal joints are deep and not easily palpated and have a small segmental ROM (Bergmann and Peterson, 2011).

Each joint in the body has its own characteristic EP quality that is dependent on the bony structure of the joint and the surrounding soft tissue. This is called the physiologic end feel and differs from joint to joint. A normal EP at one joint may be abnormal if felt at another joint. If the physiological end feel is lost/altered within a joint, it usually indicates that there is some disorder either within the joint, the capsule, or surrounding soft tissue. Signs and symptoms such as increased pain or an abnormal EP resistance is a strong finding and is usually indicative of a joint subluxation/dysfunction syndrome (JSDS) (Bergmann and Peterson, 2011).

3.5. Treatment Intervention

The 1st, 4th, and 7th consultations began with the collection of objective and subjective data using a Digital Inclinometer (Appendix H), Numerical Pain Rating Scale (Appendix I) and the Oswestry Pain and Disability Questionnaire (Appendix J). No treatment occurred on the seventh consultation. In the treatment consultations, the researcher motion palpated the lumbar spine looking for any lumbar facet joint restrictions. Since the innervation of the facet joints arise from two segments via the ascending and descending fibres of the medial branch (Nedelka *et al.*, 2014), treatment was applied to both the involved segment and the segment above. This was done for all three groups over a four-week period.

Group one received SMT where participants were positioned in a side lying posture on a chiropractic adjustment bed to receive specific lumbar spine manipulations to restricted lumbar facet joints. Group two received ESWT where participants were asked to lay prone on a plinth. The ESWT was applied in a stroking manner with point application over the restricted lumbar facet joints and the segment above. Group three received a combination of both interventions.

3.5.1. Chiropractic Spinal Manipulative Therapy

A total of twenty participants received lumbar SMT. Ten from group one who only received SMT as their treatment and another ten from group three who received a combination of both treatments. The details of what to expect throughout the procedure was explained to the participants prior to receiving treatment. This included an explanation of what was to be expected when the manipulative technique was to be performed. Participants were informed that they would hear a "cracking or popping" sound and that they should not worry as this was a normal response to manipulation. They were also informed that they may feel some slight discomfort a day or two post treatment.

The type of SMT techniques used in this study were the diversified lumbar manipulations. The specific names of the side posture lumbar manipulations that were used are: Thigh-Transverso-Deltoid, Spinous Hook (Pull), and Push-Pull. These side posture manipulations are the most commonly used manipulations when addressing a lumbar JSDS. Since the patient is lying on their side in a relaxed position, it makes it easier for the chiropractor to

manoeuvre and position their patient appropriately in such a manner that will give the chiropractor leverage and a mechanical advantage (Bergmann and Peterson, 2011).

To perfect the art of manipulation, the chiropractic student must have an in-depth understanding of the technique's mechanical principles and effects. Once the patient has been positioned, the amount of segmental tension at any given level in the lumbar spine is determined by the amount of induced flexion and lateral flexion in the lumbar spine with the amount of induced counter-rotation between the shoulders and pelvis (Bergmann, Peterson and Lawrence, 1993).

It is important that the chiropractic student learns how to use their own body weight to create adequate leverage as this is a critical aspect in the effective application of side-posture manipulations. Side posture manipulations often require the added force that is acquired when the chiropractor's body weight is incorporated in the "patient set up". This assists with the development of joint tension and with the manipulative thrust/body drop (Bergmann, Peterson and Lawrence, 1993). Illustrated in figure 3.4. below, is the side posture lumbar spine manipulation. Note how the examiner uses their own body weight to create the above-mentioned leverage to assist in the development of tension within the lumbar spine joints while creating counter-rotation using the indifferent hand.

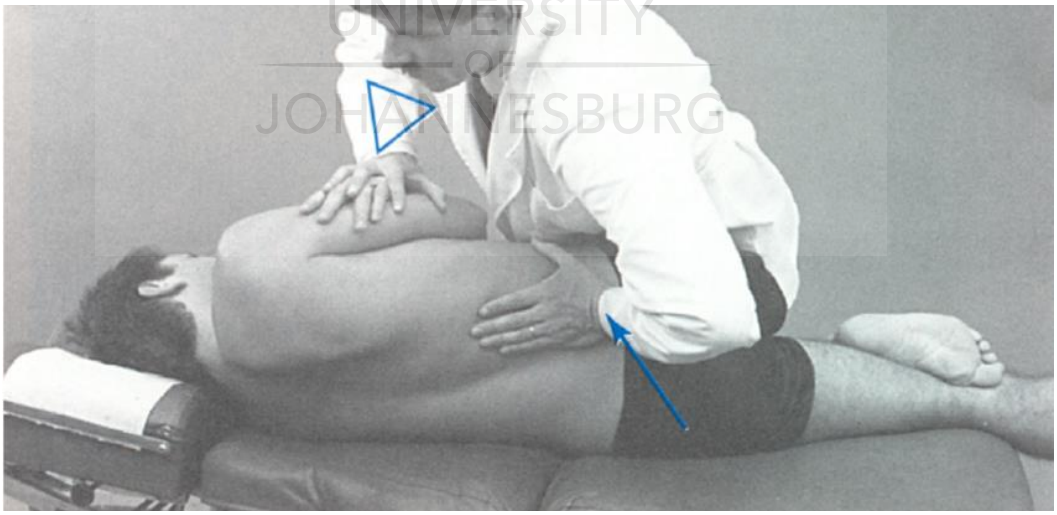


Figure 3.4. Side posture lumbar manipulation **(Evans, 2010)**

Seated diversified lumbar manipulative techniques were also used in this study with patients that had excessive low back pain and found it difficult to get into the side posture position due to increased pain. Seated lumbar manipulations are beneficial in such cases in that the

chiropractor does not have to use their own body weight to develop joint tension. Joint tension can be achieved as seated techniques allow the chiropractor to manoeuvre and modify the patients position in such a way that will create joint tension. The specific names of the two techniques that were used are: Transverso-Deltoid and Spino-Deltoid (Bergmann and Peterson, 2011).

These manipulative techniques are classified as assisted manipulations with the contact hand being placed on the superior vertebra. Once the contact and joint tension has been established, both the indifferent and contact hands thrust together to induce motion in the direction of the restriction. This will induce a distraction force at the motion segments inferior to the contact level (Bergmann and Peterson, 2011).

With seated manipulations, maximal joint tension develops in the motion segments inferior to the contact level and is mostly used for lumbar rotary or combined rotary with lateral flexion restrictions. These manipulations are most frequently and effectively used at the thoracolumbar junction due to this segment being a transitional vertebra (Bergmann, Peterson and Lawrence, 1993).

3.5.2. Extracorporeal Shockwave Therapy

A total of twenty participants received treatment with ESWT, ten from group two who received ESWT treatment only and another ten from group three who received a combination of both treatments. All the details of the procedure were explained to the participants prior to receiving treatment. This included an explanation that the participants should expect to feel intense pressure, discomfort and/or pain during the treatment. They were also informed that the discomfort/pain could persist for the next day or two and that they should not be fazed by it as it will eventually dissipate. Participants were also informed that the machine does produce a loud jack-hammer type of sound when it is operational and were told to verbally inform the researcher if the discomfort/pain was too much to bare at any stage of the research. The unit that was used in this study was the EMS Swiss Dolorcast Smart 2.0 shockwave unit (figure 3.5.).

Figure 3.5. Swiss Dolorcast Smart 2.0 ESWT unit (photograph taken by researcher)

Extracorporeal shockwave therapy treatment protocol:

- Once the participant was motion palpated and lumbar spine restrictions were found, they were asked to lay prone either on a plinth or on a chiropractic manipulation bed.
- The treatment area was exposed adequately and coupling gel was applied so that the acoustic waves could travel through a medium to effectively penetrate the target tissue.
- Therapeutic settings were then calibrated into the shockwave unit. In the previous similar study, the shockwave unit was set to 3.8 bar for 3000 shocks per session (Nedelka *et al.*, 2014). For this study, the shockwave unit was set at 1.5-2.5 bar (depending on the patients BMI) at 12Hz for 1500 shocks per session.
- The transmitter head was then held firmly against the target area. Once the treatment started, the acoustic waves were applied in a stroke manner from inferior to superior and vice versa with some brief moments of point application over the restricted motion segment.

- Both the involved segment and the segment above was treated as the facet joints are innervated by the ascending and descending medial branches of the posterior primary ramus (Nedelka *et al.*, 2014).
- The treatment automatically stopped with this unit as soon as the inputted number of shocks has been reached, in this case 1500 shocks.
- Lastly, any coupling gel residue was then wiped off and the participant was then asked to stand up slowly
- This procedure was also used with the combination group

3.6. Subjective Data

3.6.1. Numerical pain rating scale (Appendix I):

With the use of a scale numbered from zero to ten, the participants were required to select the number which best represented the severity of pain they were experiencing at that moment in time. Zero being no pain at all and ten being the worst pain the participant has ever experienced. Generally, scores ranging from 1-4 points are suggestive of a mild pain intensity, 5-6 points suggests that the pain intensity is moderate and 7-10 points indicates a severe pain intensity (Haneline, 2007). A clinically representable difference is when there is a decrease of 2 points or more in the scale (Grieve, Boyling and Jull, 2004).

This method has been proven to be valid and reliable for assessment of subjective pain measurements (Haefeli and Elfering, 2006). Over time, the numerical pain rating scale (NPRS) has become the standard tool to use in chronic pain studies thus the importance of defining the level of change for there to be a clinically representable difference is worth mentioning (Farrar, Young, La Moreaux, Werth and Michael Poole, 2001). The validity and reliability of the NPRS makes it appropriate for clinical use. The NPRS also has good sensitivity and the data that it produces can be analysed statistically for audit purposes (Williamson and Hoggart, 2005).

The NPRS can either be an 11- (such as the one used in this study), 21- or 101-point scale. The point scale may differ, but the end points remain as the extremes of pain. The NPRS can be used in two different ways, via a graphical illustration or verbal. Graphical illustrations generally have numbers in blocks/boxes arranged in an ascending order and are usually

referred to as 11- or 21-point box scales. The number of boxes depends on the amount of discrimination levels that were offered to the participant (Williamson and Hoggart, 2005).

3.6.2. Oswestry low back pain and disability questionnaire (Appendix J):

This is a table of questions that have been designed to give the researcher information about how the participants low back pain is affecting their ability to manage in everyday life. The question table consists of 10 sections with 6 statements in each section which the participants were required to answer by checking one box in each section for the statement which best applied to them (Haneline, 2007). The 10 questions in each section of the table that the participants were required to answer were standard questions which had to do with performing daily activities such as walking, sitting, lifting and their social life (Fairbank and Pynsent, 2000). The Oswestry Low Back Pain and Disability Questionnaire (ODQ) is also known as the Oswestry Disability Index (ODI) and is a vital tool for researcher and disability evaluators as it allows for the participants' permanent functional disabilities to be measured (Mehra, Baker, Disney and Pynsent, 2008).

This method has been proven to be valid and reliable for assessing the participants' perceived ability to manage in everyday life with low back pain (Fairbank and Pynsent, 2000) and (Davidson and Keating, 2002). This ODQ is also suited for clinical practice as it is a responsive condition-specific assessment tool. It is user friendly with an easy to understand scoring system and it objectifies the participants' complaints, and the therapeutic effects of treatment can be monitored using the ODQ (Vianin, 2008). As far as subjective low back pain assessments go, the ODQ is a 'gold standard' tool in assessing low back functional outcomes and has become one of the main condition-specific outcome measurement tools used to manage spinal disorders (Fairbank and Pynsent, 2000). The ODQ is most commonly used in chronic and severe cases, but the test also shows good, reliable indicators in less severe cases (Vianin, 2008).

The score interpretation of the ODQ is as follows (Fairbank and Pynsent, 2000):

Each section has six statements in which the total score is 5. The score ranges on a scale 0-5 so the first statement is equal to 0 and the last statement is equal to 5, thus the score of each statement increases according to rank. A score of 5 represents the greatest disability.

If multiple boxes are marked in a section, the statement with the highest score is taken as the true indication of disability.

- 0% to 20%: minimal disability
- 21% to 40%: moderate disability
- 41% to 60%: severe disability
- 61% to 80%: crippled
- 81% to 100%: patients either bed-bound or exaggerating symptoms

The score is calculated in two ways depending on if all 10 sections of the ODQ are completed. Therefore, the index score is calculated by taking the sum of the scores obtained from each section (total score), dividing it by the total possible score and multiplying that figure by 100 thus expressing the final score as a percentage, i.e. total score ÷ total possible score (50) × 100 = percentage. Each section/question that is not completed/answered, the denominator (total possible score) is decreased by 5, i.e. total score ÷ total possible score (45) × 100 = percentage (Fairbank and Pynsent, 2000) and (Mehra *et al.*, 2008).

3.7. Objective Data

3.7.1. Digital inclinometer (Appendix H):

A Digital Inclinometer is a small rectangular hand-held device with an LCD screen that displays the participants' degrees of movement. This device was used to obtain objective measurements of the participants' active lumbar ROM in flexion, extension and lateral flexion. Two points of reference were used to obtain the measurements for all the lumbar ROM's being the thoracolumbar junction (T12-L1) and the lumbosacral junction (L5-S1) (Sadeghi, Mosallanezhad, Nodehi-Moghadam, Nourbakhsh, Biglarian and Ezati, 2015). This method has been proven to be valid and reliable for the objective assessment of lumbar spine ROM and can be used in a clinical setting (Tousignant, Morissette and Murphy, 2002).

Lumbar spine flexion and extension:

1. Participants were asked to stand up straight as they would normally
2. The researcher identified and marked the interspinous spaces of T12-L1 and L5-S1
3. The researcher placed the mid-point of the Digital Inclinometer over the marked interspinous space of T12-L1

4. The Digital Inclinometer was zeroed before the lumbar spine ROM was tested
5. Participants were asked to flex the trunk maximally whilst maintaining knee extension
6. Measurements were taken at a fully flexed position and was repeated 2 times to obtain an average
7. The same procedure was used for trunk extension
8. The researcher then placed the mid-point of the Digital Inclinometer over the marked interspinous space of L5-S1 and followed the same procedure used when the inclinometer was placed at the thoracolumbar junction for flexion and extension.

To determine the true ROM value of the lumbar spine, the average measurement obtained from the inclinometer at L5-S1 interspace is subtracted from the average measurement obtained at T12-L1 interspace. This is done for both flexion and extension measurements.

Lumbar spine lateral flexion:

1. Participants were asked to stand up straight as they would normally
2. The researcher identified and marked the interspinous space T12-L1
3. The researcher placed the mid-point of the Digital Inclinometer over the marked interspinous space of T12-L1
4. The Digital Inclinometer was zeroed before the lumbar spine ROM was tested
5. Participants were asked to maximally lateral flex the trunk ipsilaterally whilst maintaining knee extension
6. Measurements were taken at a full lateral flexion ipsilaterally and was repeated 2 times to obtain an average
7. The same procedure was used to obtain measurements contralaterally

For lateral flexion, only one point of reference was marked on the participants T12-L1 interspinous space. Measurements/data was obtained when the participant reached their full active lateral flexion ROM as the true lumbar lateral flexion value (Sadeghi *et al.*, 2015).

3.8. Data Analysis

The subjective and objective measurements/data collected by the researcher over a four-week period per participant from all three collection methods was captured on an excel spread sheet and sent to a statistician at STATKON to be analysed.

The statistician conducted the analyses of the measurements/data using the following steps:

1. Frequencies and Descriptives
    - Frequencies is the percentage of males and females presenting with the same measurement or score in each data capturing method.
    - Descriptives is the mean/average value of the overall sample.
2. Cross-tabulation of gender and age between each group to assess the possible gender or age-based differences within the results.
    - The Fisher's Exact Test was used.
3. Shapiro-Wilk Test to determine the normality of each group.
    - This test determines whether parametric or non-parametric tests will be used for the comparative tests but due to the small group sizes, non-parametric comparative tests were used.
4. Inter-group Analysis: Comparison tests to assess differences between groups.
    - If the Shapiro-Wilk Test results were normal, the One-Way ANOVA Test (parametric) which has a built-in Post-Hoc test would have been used.
    - Since the Shapiro-Wilk Test results were not normal, the Kruskal-Wallis Test (non-parametric) was used. It does not have a built-in Post-Hoc test. This means that the Mann-Whitney test also had to be used to assess where the differences lie.
5. Intra-group Analysis: Comparison tests to assess differences within each group over time.
    - If the Shapiro-Wilk test results were normal, the One-Way Repeated Measures ANOVA Test (parametric) which has a built-in Post-Hoc test would have been used.
    - Since the Shapiro-Wilk test results were not normal, the Friedman Test (non-parametric) was used. It does not have a built-in Post-Hoc test. This means that the Wilcoxon Signed Ranks Test also had to be used to assess where the differences lie over time.

3.9. Ethical Considerations

All participants that partook in this study were requested to read the information form and sign the consent form (Appendix E) specific to this study. The information and consent form outlined the names of the researcher, purpose and benefits of partaking in the study, participant assessment and treatment procedure. Any risks, benefits and discomforts pertaining to the treatments involved were also mentioned in the information letter and explained so that the participant's safety was ensured (prevention of harm). The information and consent form were also explained so that the participant's understood that their privacy will be protected as only the researcher, patient and clinician will be in the treatment room and that anonymity will be ensured as the patient's information will be converted into nameless data and therefore cannot be traced back to the individual. The form also stated that standard doctor/patient confidentiality will be adhered to at all times when compiling the research dissertation. The participants were informed that their participation is on a voluntary basis and that they were free to withdraw from the study at any stage. In the event that the participant had any further questions, these were explained by the researcher; whose contact details were made available. The participants were then required to sign the information and consent form, signifying that they understand all that is required of them for this study. Results of the study were made available on request. As students were possible participants of this study, an institutional consent letter was needed that was signed by the director of the Institutional Research and Planning, Evaluation and Monitoring (IPEM) to conduct research on students as a vulnerable community (Appendix K).

With regards to this particular study, the risks, benefits and discomforts were as follows: discomfort or pain with ESWT initially, however correct techniques of application were used in order to minimise any pain caused by the machine. Localised muscle pain, redness or slight bruising may be present over the area of application for up to two days post-treatment with ESWT. Side posture lumbar SMT may be uncomfortable, especially in severe and chronic cases of low back pain, but the manipulative techniques that were used were modified in such cases to reduce discomfort. Participants benefited from gradual pain relief and increased range of motion throughout the study period. Any pathology that was found on examination, those participants were referred to the appropriate health care professional when needed.

Permission had to be requested from the Institutional Research and Planning, Evaluation and Monitoring (IPEM) to advertise on the University of Johannesburg campus premises as well as to be able to use the University's students as possible participants in this study (Appendix K).

The University of Johannesburg also required that the research be assessed by the Research Ethics Committee as well as the Higher Degrees Committee prior to clinical trials being conducted. Once the research was assessed and approved, each committee issued a letter with the study's clearance number which allowed for the research trials to be conducted. The Clearance numbers from each committee were **REC-01-73-2018** from the Research Ethics Committee (Appendix L) and **HDC-01-38-2018** from the Higher Degrees Committee (Appendix M).

A computer programme called Turnit-in was used to assess this research dissertation for originality. This was done once the dissertation was assessed by the supervisor and the corrections thereof were completed by the researcher. A plagiarism report was generated by the Turnit-in computer programme to confirm that this dissertation is original (Appendix N).

CHAPTER FOUR: RESULTS

4.1. Introduction

In this chapter, we have a look at the results obtained during the clinical trials of this study. The sample size consisted a total number of 30 participants who all had chronic mechanical LBP. The sample was divided into three groups of 10 participants in each group. Group one received SMT, group two received ESWT and group three received a combination of both therapies.

The subjective and objective data obtained in this study was collected on the first, fourth and seventh consultations. All the data was captured on an excel spreadsheet and statistically analysed by a statistician from Statkon to describe the results. Various statistical tests were done using the captured data to determine if there were any clinically or statistically significant changes. These changes were to be observed within each group (intragroup analysis) and between the three groups (intergroup analysis). Due to the small sample size of only 30 participants, the statistical results are not considered to be a true representation of the general population. Therefore, in terms of the population as a whole, no assumptions or generalisations could be made.

The data that was statistically analysed and compared are as follows:

1. Demographical data
    - Analysis of the age and gender distribution of the three groups
2. Subjective data obtained via two methods which are:
    - Numerical Pain Rating Scale (NPRS)
    - Oswestry Low Back Pain and Disability Questionnaire (ODQ)
3. Objective data obtained via one method which is:
    - Digital Inclinometer for lumbar spine ROM. The assessed lumbar ROM was for flexion, extension and lateral flexion.

The probability value (p-value) represents the statistical significance of the results. The p-value for all the tests done in this study was set at **0.05** which represented the level of significance of the obtained results. A statistically significant difference was when the p-value was ≤ 0.05. A p-value of > 0.05 showed that there was no statistical difference between the groups.

Boxplots

In the coming section, you will encounter some boxplots. These are graphs that are useful for the comparison of score distribution of variables. They can be used to discover the distribution of one continuous variable or the scores can be broken down for intergroup comparisons. These graphs are versatile as extra categorical variables can also be added in the comparison of variables (Pallant, 2007).

This is an explanation of what you should expect to see and how to interpret the graphs (Pallant, 2007).

- The box with protruding lines is a representation of each distribution of scores. The box's length represents the variable's interquartile range. The box is made up of 50% of the cases. The median is represented by the line inside the box. The protruding lines (known as whiskers) extend to the variable's largest and smallest values.
- The little circles with the numbers attached to them are known as the outliers. These outliers are cases that have a completely different score from the average distribution of scores within that specific group, either the score is much higher or much lower than the other scores. The number attached to the circle is the case ID number. Cases become outliers when their score extends more than 1.5 box-lengths from the box's edge when making the graph. If scores lie more than three box-lengths from the box's edge, it will be marked with an asterisk "*", which is known as the extreme points/outliers.
- Boxplots also allow for score patterns of various groups to be inspected. This provides you with information of the intragroup and intergroup score distribution of the different variables.
- The data represented on the x-axis is the data that was collected at the beginning of the 1st, 4th, and 7th consultations for all three groups.
- The data represented on the y-axis illustrates the different variables that were being tested. These included the values or measurements of the subjective and objective data which were the NPRS and ODQ values, and the Digital Inclinometer ROM measurements in degrees for flexion, extension and lateral flexion.

4.2. Demographic Data Analysis

The demographic data is a description of the characteristics of the participants in this study. A total number of 30 participants made up the sample size of this study with 10 participants in each group.

- Group one: Spinal manipulative therapy (SMT)
- Group two: Extracorporeal shockwave therapy (ESWT)
- Group three: Combination of both treatments

4.2.1. Age and gender analysis

Table 4.1. Number of participants with regards to gender, age and group placement

Group		Gender		Total	Age distribution (years)	Mean age (years)
		Male	Female			
Group one: SMT	Count	4	6	10	23-26	24.90
	% within Group	40,0%	60,0%	100,0%		
Group two: ESWT	Count	5	5	10	24-27	24.70
	% within Group	50,0%	50,0%	100,0%		
Group three: Combination	Count	5	5	10	23-27	24.70
	% within Group	50,0%	50,0%	100,0%		
Total Sample	Count	14	16	30	23-27	24.77
	% within Group	46,7%	53,3%	100,0%		

Clinical analysis

Table 4.1. above and figure 4.1. below consists of the demographic data that was analysed with regards to the gender and age distribution in all three groups of this study. The total sample of the age distribution ranged from 23 to 27 years with a mean age of **24.77** years.

The total sample of the gender distribution of those participated in this study is 14 males (**46.7%**) and 16 females (**53.3%**).

Group one consisted of 4 males (**40%**) and 6 females (**60%**) aged 23 to 26 years with a mean age of **24.90** years. Group two consisted of 5 males (**50%**) and 5 females (**50%**) aged 24 to 27 years with a mean age of **24.70**. Group three consisted of 5 males (**50%**) and 5 females (**50%**) aged 23 to 27 years with a mean age of **24.70** years. The Pearson Chi-Square test was also used to show a comparison of the gender distribution of the participants. There was no statistical difference between the groups as the p-value was **0.875** which is higher than a p-value of 0.05.

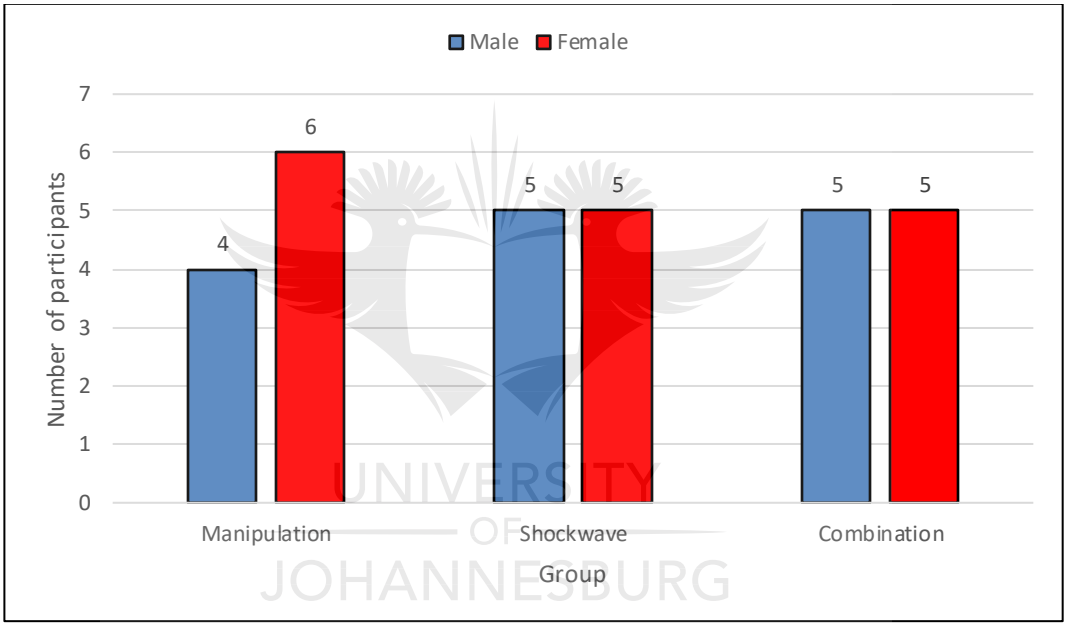


Figure 4.1. Illustration of the distribution of gender in all three groups

4.3. Subjective Data

This data was obtained using two methods, which are the Numerical Pain Rating Scale (NPRS) and the Oswestry Low Back Pain and Disability Questionnaire (ODQ).

4.3.1. Numerical pain rating scale

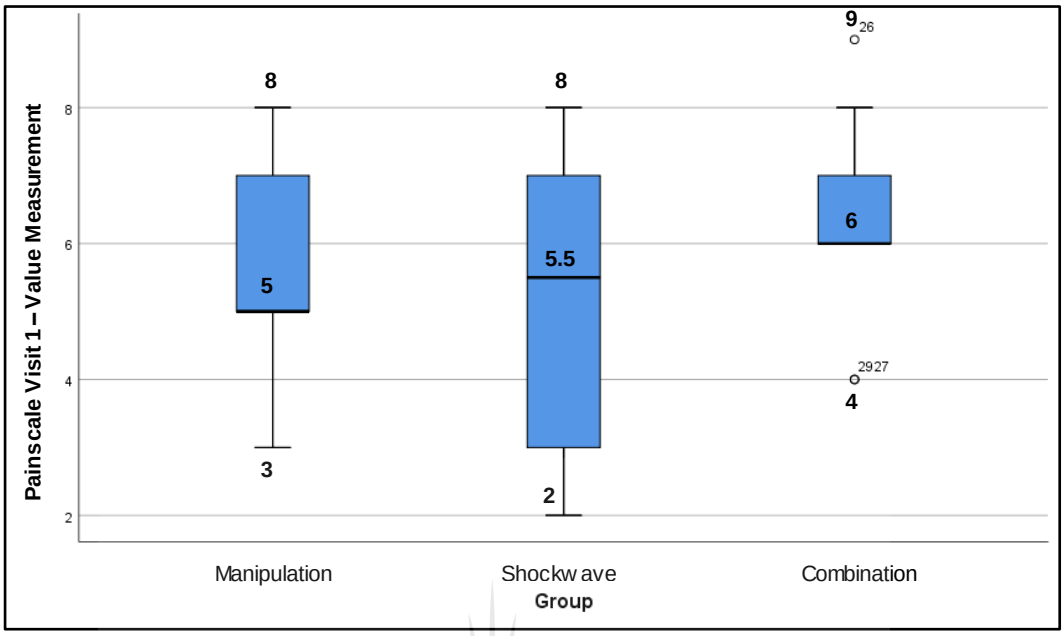


Figure 4.2. Boxplot comparing the distribution of scores between the three groups for the NPRS visit 1

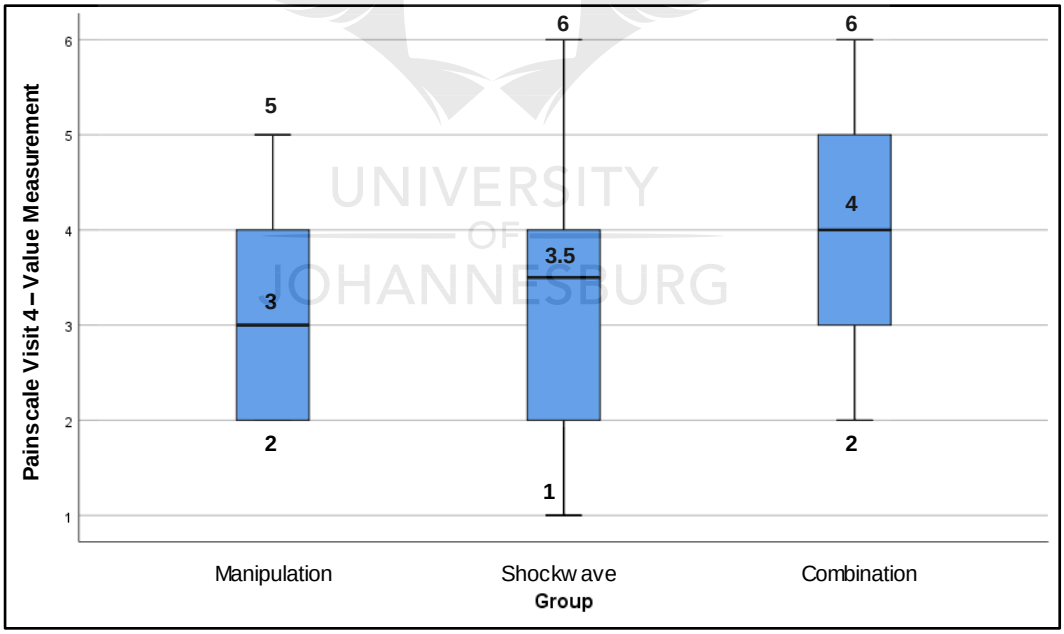


Figure 4.3. Boxplot comparing the distribution of scores between the three groups for the NPRS visit 4

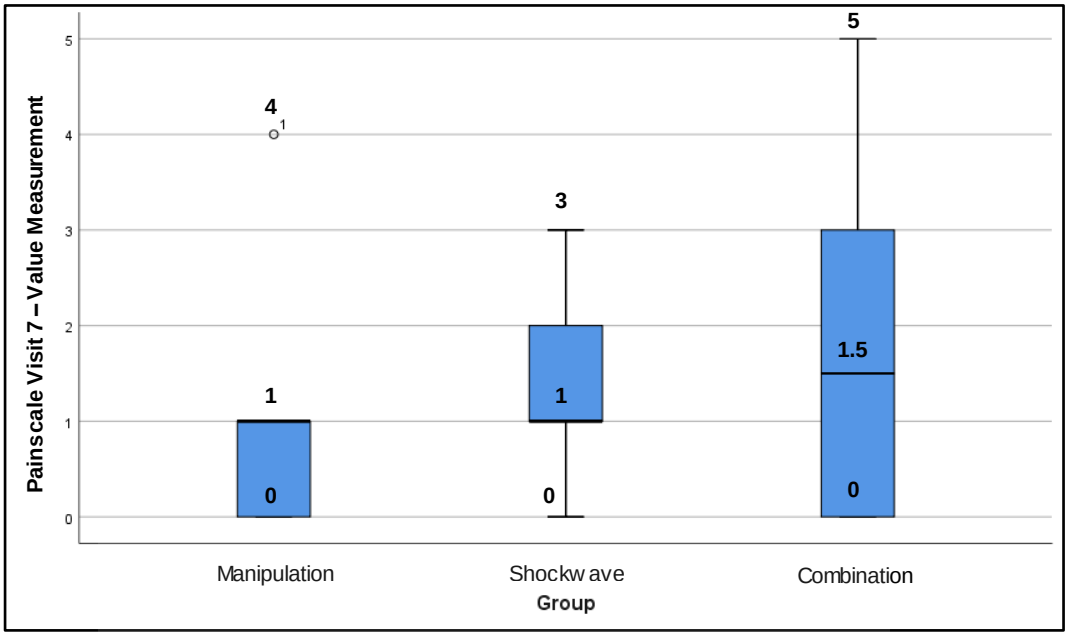


Figure 4.4. Boxplot comparing the distribution of scores between the three groups for the NPRS visit 7

NPRS clinical analysis

Figures 4.2., 4.3., and 4.4., illustrates the data that was collected from consultation visits 1, 4 and 7 respectively using the NPRS. Figure 4.2. illustrates the data that was collected at the beginning of the 1st consultation, the mean values for the SMT, shockwave and combination groups were **5.5**, **5.2**, and **6.3** with a standard deviation of **1.716**, **2.098**, and **1.567** respectively. Figure 4.3. illustrates the data that was collected at the beginning of the 4th consultation, the mean values for the SMT, shockwave, and combination groups were **3.1**, **3.3**, and **4.0** with a standard deviation of **1.197**, **1.567**, and **1.491** respectively. Figure 4.4. illustrates the data that was collected in 7th consultation, the mean values of the SMT, shockwave and combination groups were **0.9**, **1.3**, and **1.7** with a standard deviation of **1.197**, **0.949**, and **1.829** respectively.

Based on the mean values obtained in each consultation, a percentage which shows whether there was an improvement or not can be calculated in each of the three groups. These percentages were calculated over the overall clinical trial period of the study and the equation used is illustrated below. The percentage of overall clinical improvement in groups one, two and three were **83.63%**, **75.00%**, and **73.02%** respectively as shown in table 4.2.

$$Percentage\ improvement\ = \frac{Original\ mean\ value\ - New\ mean\ value}{Original\ mean\ value} \times 100$$

NPRS intragroup analysis

Table 4.2. Non-parametric Friedman Test of the NPRS

Group	Reading Number	Mean	Standard Deviation	Min	Max	p-value	Overall Clinical Improvement
Group one: SMT	Painscale1	5,50	1,716	3	8	**0.000** thus p<0.05	83.63%
	Painscale4	3,10	1,197	2	5		
	Painscale7	0,90	1,197	0	4		
Group two: ESWT	Painscale1	5,20	2,098	2	8	**0.000** thus p<0.05	75.00%
	Painscale4	3,30	1,567	1	6		
	Painscale7	1,30	0,949	0	3		
Group three: Combination	Painscale1	6,30	1,567	4	9	**0.000** thus p<0.05	73.02%
	Painscale4	4,00	1,491	2	6		
	Painscale7	1,70	1,829	0	5		

An intragroup analysis was done using the Friedman test to compare each group over the 4-week period of the clinical trials. Significant changes were shown in all three groups when the NPRS values were compared within each group. Table 4.2. illustrates that the p-values of groups one, two, and three were **0.000**, **0.000**, and **0.000** respectively.

If differences over time were picked up while using the Friedman test, the Wilcoxon Signed Ranks test was warranted for use. This test was used to show exactly where the differences occurred over the 4-week clinical trial period. The Wilcoxon Signed Ranks test is designed to pick up differences between the 1st and 4th consultations, and the 1st and 7th consultations shown below in table 4.3.

Table 4.3. Non-parametric Wilcoxon Signed Rank Test of the NPRS

Group	Consultation Number	p-value
Group one: SMT	Painscale1 - Painsacale4	**0.007** thus < 0.05

	Painscale1 - Painscale7	**0.005** thus < 0.05
Group two: ESWT	Painscale1 - Painsacale4	**0.007** thus < 0.05
	Painscale1 - Painscale7	**0.005** thus < 0.05
Group three: Combination	Painscale1 - Painsacale4	**0.005** thus < 0.05
	Painscale1 - Painscale7	**0.005** thus < 0.05

As illustrated in table 4.3., the NPRS data obtained from the 1st and 4th consultations of group one had a p-value of **0.007** and the 1st and 7th consultations had a p-value of **0.005**. These p-values indicate that there was a significant change that occurred in both intervals for group one. The 1st and 4th consultations of group two had a p-value of **0.007** and **0.005** between the 1st and 7th consultations. These p-values also indicate that there was a significant change that occurred in both intervals for group two. The 1st and 4th consultations of group three had a p-value of **0.005** and **0.005** between the 1st and 7th consultations. These p-values also indicate that there was a significant change that occurred in both intervals for group three.

NPRS intergroup analysis

The Kruskal-Wallis test is the non-parametric test that was used to conduct the intergroup analysis to compare the data obtained between the three groups in the 1st, 4th and 7th consultations of this study.

Table 4.4. Non-parametric Kruskal Wallis Test of the NPRS

Consultation Number	**Mean Rank/p-value**	**Group one: SMT**	**Group two: ESWT**	**Group three: Combination**
Painscale1	**Mean Rank**	14.65	13.75	18.10
	p-value	**0.495** thus > 0.05		
Painscale4	**Mean Rank**	13.40	14.50	18.60
	p-value	**0.362** thus > 0.05		
Painscale7	**Mean Rank**	12.80	16.85	16.85
	p-value	**0.465** thus > 0.05		

With regards to the NPRS, table 4.4. shows that the data obtained from the 1st, 4th and 7th consultations had a p-value of **0.495**, **0.362,** and **0.465**. These p-values showed that no significant changes occurred between all three groups.

4.3.2. Oswestry low back pain and disability questionnaire

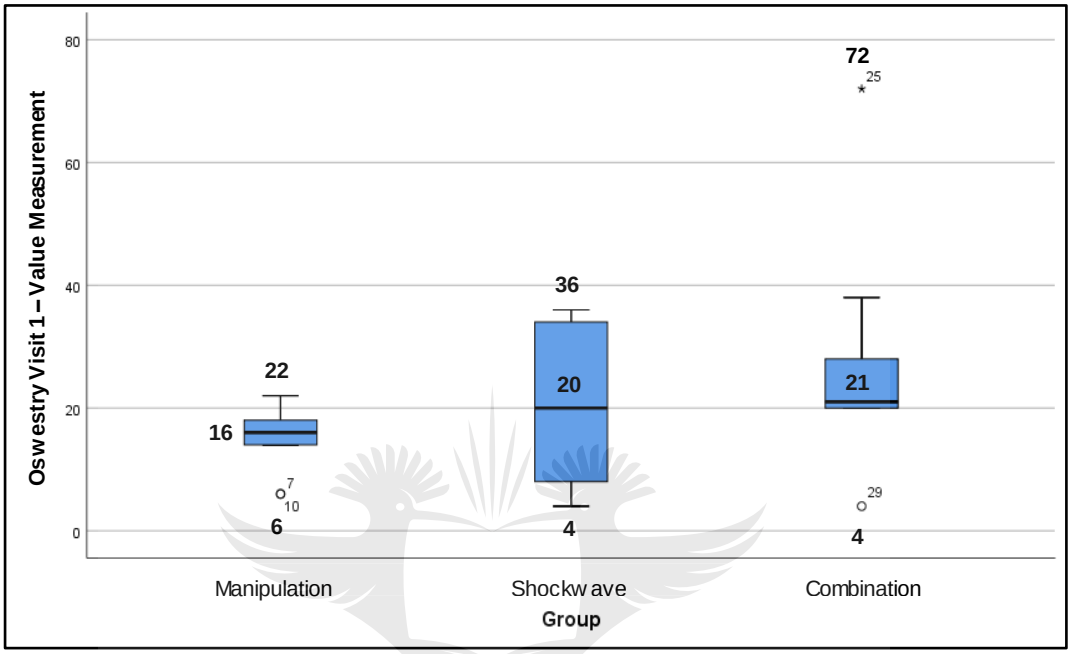


Figure 4.5. Boxplot comparing the distribution of scores between the three groups for the ODQ visit 1

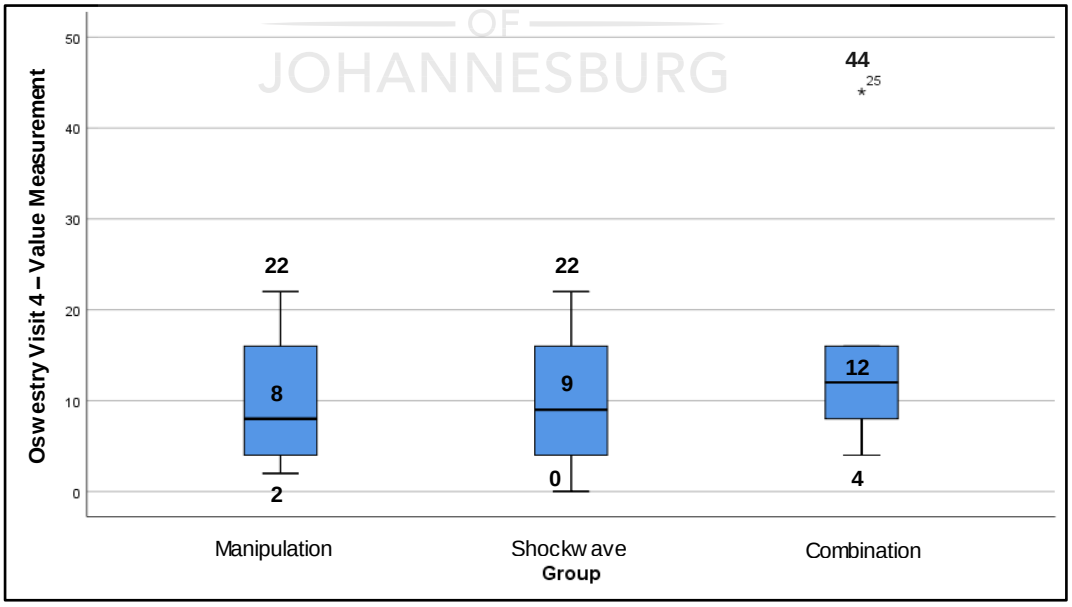


Figure 4.6. Boxplot comparing the distribution of scores between the three groups for the ODQ visit 4

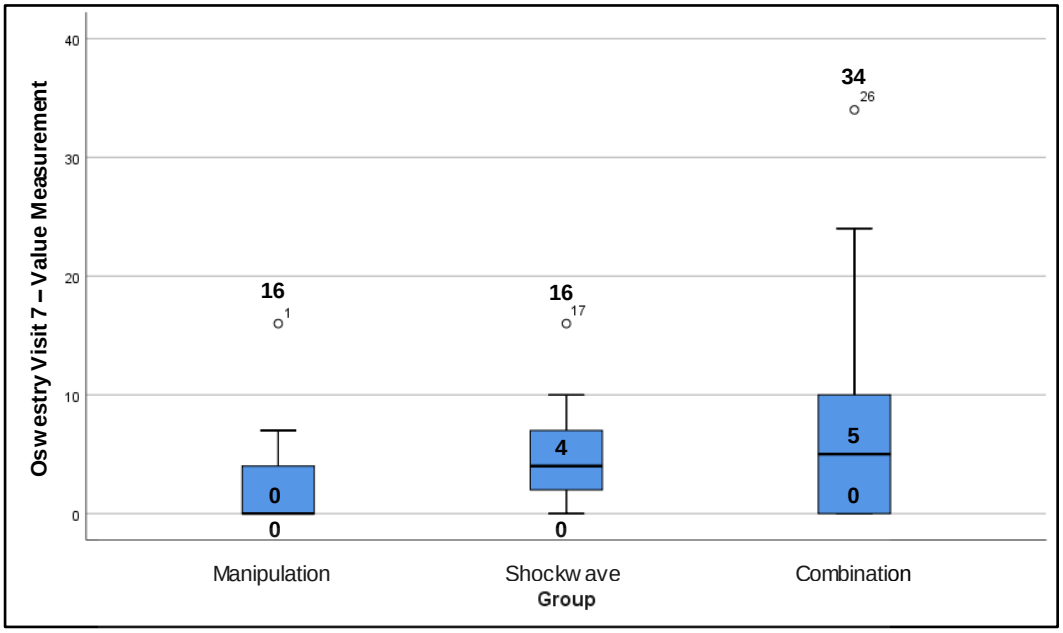


Figure 4.7. Boxplot comparing the distribution of scores between the three groups for the ODQ visit 7

ODQ clinical analysis

Figures 4.5., 4.6., and 4.7., illustrates the data that was collected from consultation visits 1, 4 and 7 respectively using the ODQ. Figure 4.5. illustrates the data that was collected at the beginning of the 1st consultation, the mean values for the SMT, shockwave and combination groups were **15**, **21.1**, and **27.2** with a standard deviation of **5.518**, **12.133**, and **17.943** respectively. Figure 4.6. illustrates the data that was collected at the beginning of the 4th consultation, the mean values for the SMT, shockwave, and combination groups were **10.4**, **10**, and **14.2** with a standard deviation of **6.653**, **7.483**, and **11.213** respectively. Figure 4.7. illustrates the data that was collected in the 7th consultation, the mean values of the SMT, shockwave and combination groups were **2.9**, **5.1**, and **8.8** with a standard deviation of **5.174**, **4.864**, and **11.361** respectively.

Based on the mean values obtained in each consultation, a percentage which shows whether there was an improvement or not can be calculated in each of the three groups. These percentages were calculated over the overall clinical trial period of the study and the equation used is illustrated below. The percentage of overall clinical improvement in groups one, two, and three were **80.67%**, **75.83%**, and **67.65%** respectively as shown in table 4.5.

$$Percentage\ improvement\ = \frac{Original\ mean\ value\ - New\ mean\ value}{Original\ mean\ value} \times 100$$

ODQ intragroup analysis

Table 4.5. Non-parametric Friedman Test of the ODQ Scores

Group	Reading Number	Mean	Std. Deviation	Min	Max	p-value	Overall Clinical Improvement
Group one: SMT	Oswestry1	15,00	5,518	6	22	**0.001** thus p<0.05	80.67%
	Oswestry4	10,40	6,653	2	22		
	Oswestry7	2,90	5,174	0	16		
Group two: ESWT	Oswestry1	21,10	12,133	4	36	**0.001** thus p<0.05	75.83%
	Oswestry4	10,00	7,483	0	22		
	Oswestry7	5,10	4,864	0	16		
Group three: Combination	Oswestry1	27,20	17,943	4	72	**0.003** thus p<0.05	67.65%
	Oswestry4	14,20	11,213	4	44		
	Oswestry7	8,80	11,361	0	34		

An intragroup analysis was done using the Friedman test to compare each group over the 4-week period of the clinical trials. Significant changes were shown in all three groups when the ODQ values were compared within the groups. The p-values of groups one, two, and three were **0.001**, **0.001**, and **0.003** respectively.

If differences over time were picked up while using the Friedman test, the Wilcoxon Signed Ranks test was warranted for use. This test was used to show exactly where the differences occurred over the 4-week clinical trial period. The Wilcoxon Signed Ranks test is designed to pick up differences between the 1st and 4th consultations, and the 1st and 7th consultations shown below in table 4.6.

Table 4.6. Non-parametric Wilcoxon Signed Rank Test of the ODQ Scores

Group	Consultation Number	p-value
Group one: SMT	Oswestry1 - Oswestry4	**0.045** thus < 0.05

	Oswestry1 - Oswestry7	**0.007** thus < 0.05
Group two: ESWT	Oswestry1 - Oswestry4	**0.013** thus < 0.05
	Oswestry1 - Oswestry7	**0.005** thus < 0.05
Group three: Combination	Oswestry1 - Oswestry4	**0.008** thus < 0.05
	Oswestry1 - Oswestry7	**0.011** thus < 0.05

As illustrated in table 4.6, the ODQ data obtained from the 1st and 4th consultations of group one had a p-value of **0.045** and the 1st and 7th consultations had a p-value of **0.007**. These p-values indicate that there was a significant change that occurred in both intervals for group one. The 1st and 4th consultations of group two had a p-value of **0.13** and **0.005** between the 1st and 7th consultations. These p-values also indicate that there was a significant change that occurred in both intervals for group two. The 1st and 4th consultations of group three had a p-value of **0.008** and **0.011** between the 1st and 7th consultations. These p-values also indicate that there was a significant change that occurred in both intervals for group three.

ODQ intergroup analysis

The Kruskal-Wallis test is the non-parametric test that was used to conduct the intergroup analysis to compare the data obtained between the three groups in the 1st, 4th and 7th consultations of this study.

Table 4.7. Non-parametric Kruskal Wallis test of the ODQ Scores

Consultation Number	Mean Rank/p-value	Group one: SMT	Group two: ESWT	Group three: Combination
Oswestry1	**Mean Rank**	10.80	16.30	19.40
	p-value	**0.085** thus > 0.05		
Oswestry4	**Mean Rank**	14.85	14.20	17.45
	p-value	**0.678** thus > 0.05		
Oswestry7	**Mean Rank**	11.65	16.90	17.95
	p-value	**0.208** thus > 0.05		

With regards to the ODQ, table 4.7. illustrates that the data obtained from the 1st, 4th and 7th consultations had a p-value of **0.085**, **0.678,** and **0.208** respectively. These p-values showed that no significant changes occurred between all three groups.

4.4. Objective Data

This data was obtained using one method which is the Digital Inclinometer for measuring lumbar ROM.

4.4.1. Digital inclinometer

4.4.1.1. Lumber spine flexion

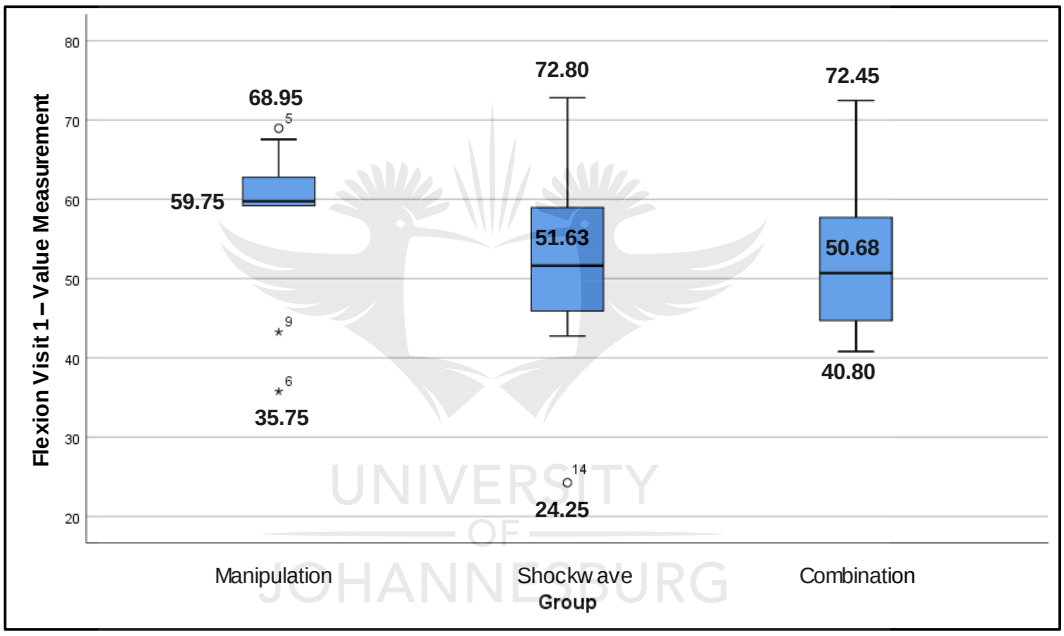


Figure 4.8. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in flexion visit 1

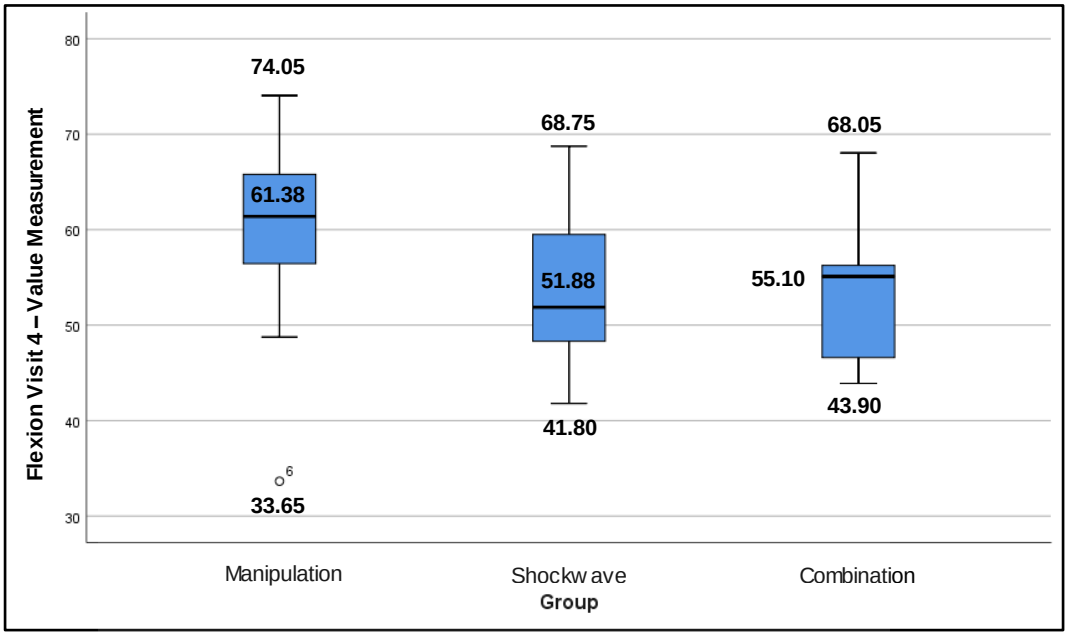


Figure 4.9. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in flexion visit 4

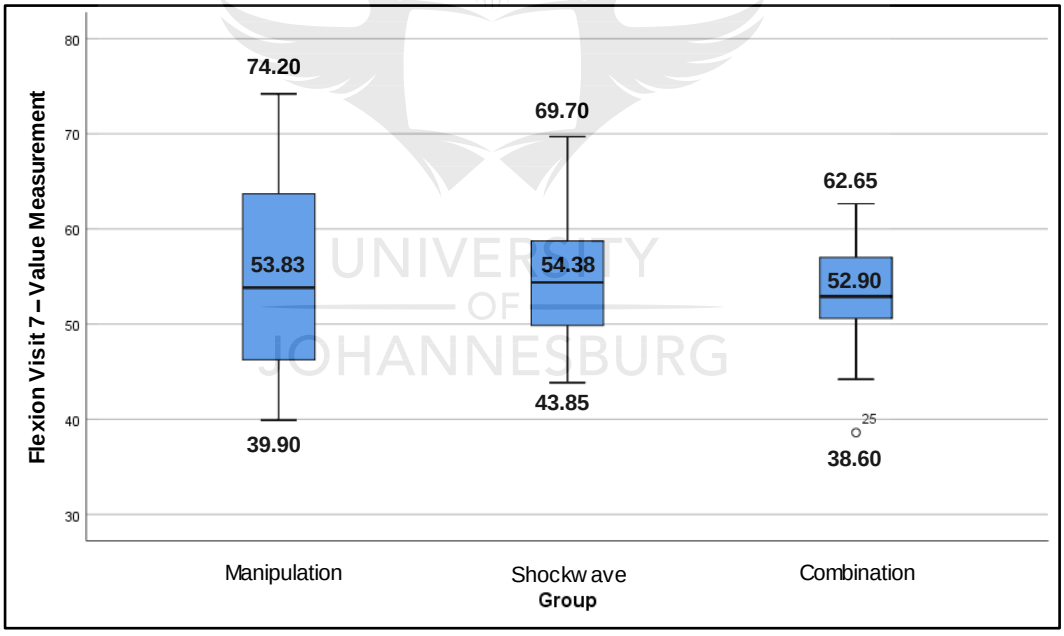


Figure 4.10. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in flexion visit 7

Clinical analysis

Figures 4.8., 4.9., and 4.10., illustrates the data that was collected from consultation visits 1, 4 and 7 respectively using the Digital Inclinometer to measure lumbar ROM in flexion. Figure 4.8. illustrates the data that was collected at the beginning of the 1st consultation, the mean

values for the SMT, shockwave and combination groups were **57.76**, **51.31**, and **53.10** with a standard deviation of **10.36**, **12.83**, and **10.43** respectively. Figure 4.9. illustrates the data that was collected at the beginning of the 4th consultation, the mean values for the SMT, shockwave, and combination groups were **59.49**, **53.89**, and **53.87** with a standard deviation of **11.54**, **8.45**, and **7.13** respectively. Figure 4.10. illustrates the data that was collected in the 7th consultation, the mean values of the SMT, shockwave and combination groups were **55**, **54.97**, and **52.51** with a standard deviation of **11.26**, **7.19**, and **7.07** respectively.

Based on the mean values obtained in each consultation, a percentage which shows whether there was an improvement or not can be calculated in each of the three groups. These percentages were calculated over the overall clinical trial period of the study and the equation used is illustrated below. The percentage of overall clinical improvement in groups one, two, and three were **4.78%** (decrease), **7.13%** (increase), and **1.11%** (decrease) respectively as shown in table 4.8.

$$Percentage\ improvement = \frac{Original\ mean\ value - New\ mean\ value}{Original\ mean\ value} \times 100$$

Intragroup analysis

Table 4.8. Non-parametric Friedman Test of the Digital Inclinometer for lumbar ROM in flexion

Group	Reading Number	Mean	Std. Deviation	Min	Max	p-value	Overall Clinical Improvement
Group one: SMT	Flexion1	57,76	10,363	36	69	**0.741** thus p>0.05	4.78% decrease
	Flexion4	59,49	11,535	34	74		
	Flexion7	55,00	11,257	40	74		
Group two: ESWT	Flexion1	51,31	12,825	24	73	**0.497** thus p>0.05	7.13% increase
	Flexion4	53,89	8,451	42	69		
	Flexion7	54,97	7,193	44	70		
Group three: Combination	Flexion1	53,10	10,428	41	72	**0.905** thus p>0.05	1.11% decrease
	Flexion4	53,87	7,126	44	68		
	Flexion7	52,51	7,070	39	63		

An intragroup analysis was done using the Friedman test to compare each group over the 4-week period of the clinical trials. Significant changes were not shown in all three groups when the Digital Inclinometer values were compared within the groups. The p-values of groups one, two, and three were **0.741**, **0.497**, and **0.905** respectively.

If differences over time were picked up while using the Friedman test, the Wilcoxon Signed Ranks test was warranted for use. This test was used to show exactly where the differences occurred over the 4-week clinical trial period. The Wilcoxon Signed Ranks test is designed to pick up differences between the 1st and 4th consultations, and the 1st and 7th consultations. Since the p-values of the Digital Inclinometer for lumbar ROM in flexion showed that there were no significant changes that occurred within each group over time, the Wilcoxon Signed Ranks test was not used.

Intergroup analysis

The Kruskal-Wallis test is the non-parametric test that was used to conduct the intergroup analysis to compare the data obtained between the three groups in the 1st, 4th and 7th consultations of this study.

Table 4.9. Non-parametric Kruskal Wallis test of the Digital Inclinometer for lumbar ROM in Flexion

Consultation Number	Mean Rank/p-value	Group one: SMT	Group two: ESWT	Group three: Combination
Flexion1	**Mean Rank**	19.35	13.55	13.60
	p-value	**0.238** thus > 0.05		
Flexion4	**Mean Rank**	20.20	13.40	12.90
	p-value	**0.117** thus > 0.05		
Flexion7	**Mean Rank**	15.50	16.50	14.50
	p-value	**0.879** thus > 0.05		

With regards to the Digital Inclinometer for lumbar ROM in Flexion, table 4.9. illustrates that the data obtained from the 1st, 4th and 7th consultations had a p-value of **0.238**, **0.117,** and **0.879** respectively. These p-values showed that no significant changes occurred between all three groups.

4.4.1.2. Lumbar spine extension

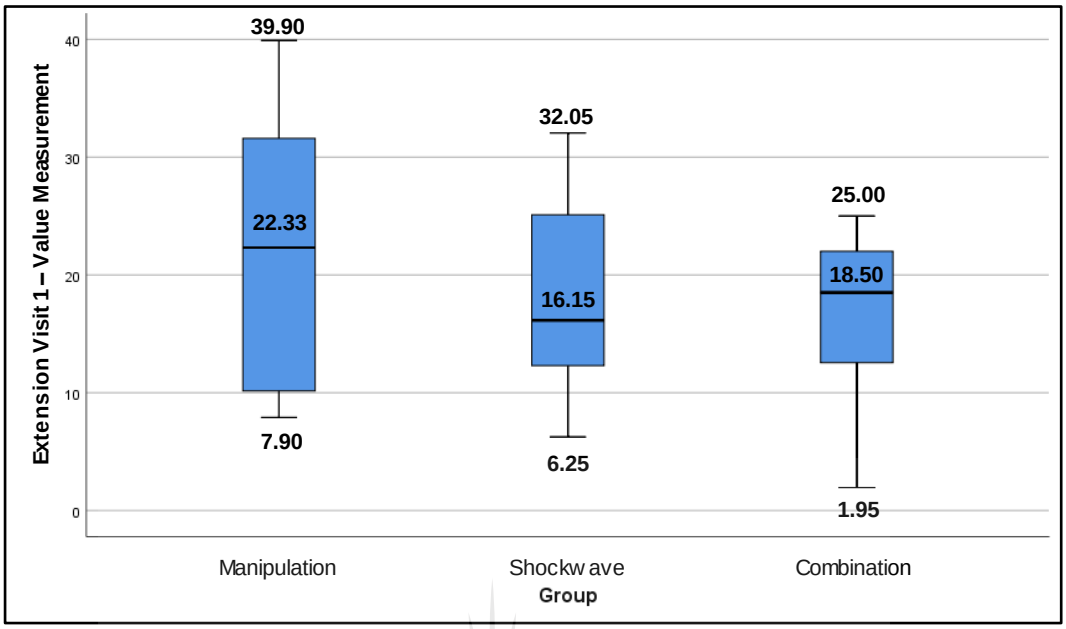


Figure 4.11. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in extension visit 1

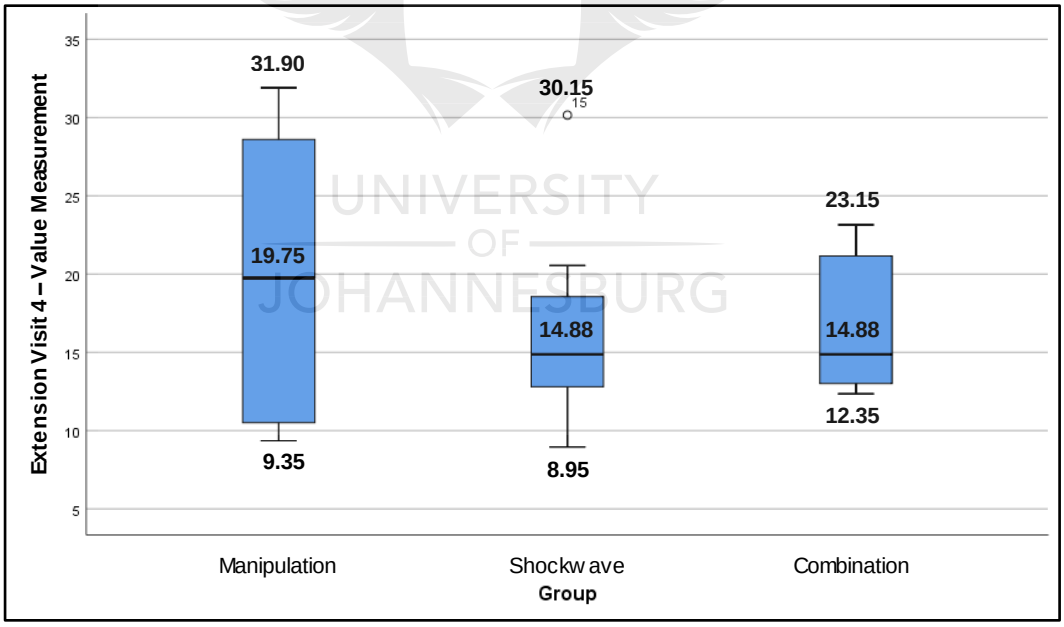


Figure 4.12. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in extension visit 4

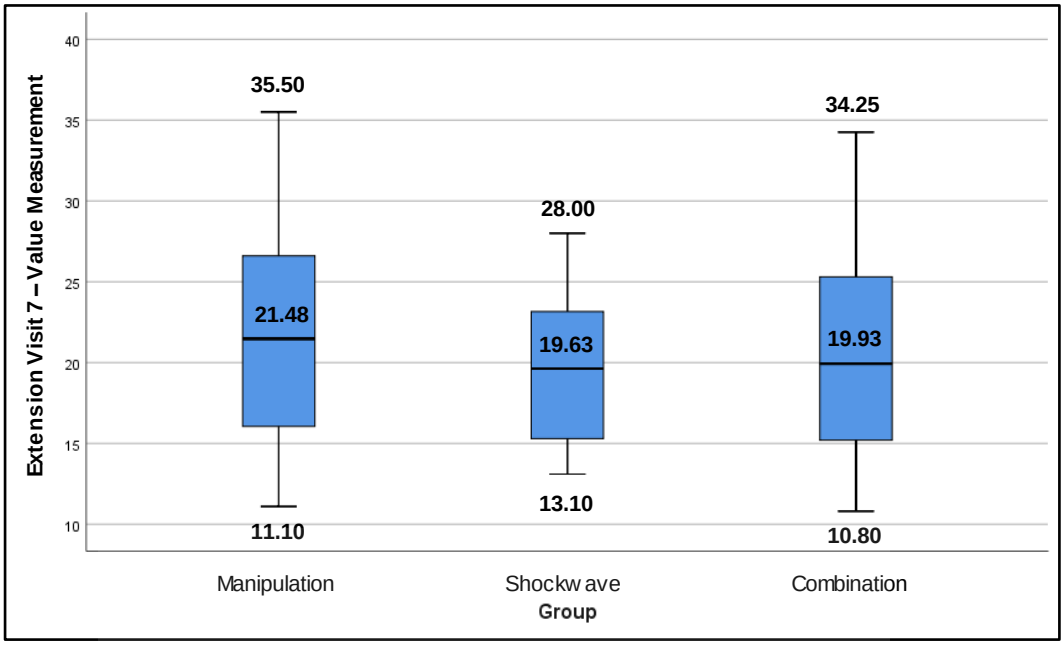


Figure 4.13. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in extension visit 7

Clinical analysis

Figures 4.11., 4.12., and 4.13., illustrates the data that was collected from consultation visits 1, 4 and 7 respectively using the Digital Inclinometer to measure lumbar ROM in extension. Figure 4.11. illustrates the data that was collected at the beginning of the 1st consultation, the mean values for the SMT, shockwave and combination groups were **21.75**, **17.81**, and **16.97** with a standard deviation of **11.199**, **8.586**, and **6.894** respectively. Figure 4.12. illustrates the data that was collected at the beginning of the 4th consultation, the mean values for the SMT, shockwave, and combination groups were **19.4**, **15.95**, and **16.42** with a standard deviation of **8.961**, **6.157**, and **3.965** respectively. Figure 4.13. illustrates the data that was collected in the 7th consultation, the mean values of the SMT, shockwave and combination groups were **21.43**, **19.5**, and **21.04** with a standard deviation of **7.344**, **4.7**, and **7.912** respectively.

Based on the mean values obtained in each consultation, a percentage which shows whether there was an improvement or not can be calculated in each of the three groups. These percentages were calculated over the overall clinical trial period of the study and the equation used is illustrated below. The percentage of overall clinical improvement in groups

one, two, and three were **1.47%** (decrease), **9.49%** (increase), and **23.98%** (increase) respectively as shown in table 4.10.

$$Percentage\ improvement\ = \frac{Original\ mean\ value\ - New\ mean\ value}{Original\ mean\ value} \times 100$$

Intragroup analysis

Table 4.10. Non-parametric Friedman Test of the Digital Inclinometer for Lumbar ROM in Extension

Group	Reading Number	Mean	Std. Deviation	Min	Max	p-value	Overall Clinical Improvement
Group one: SMT	Extension1	21,75	11,199	8	40	**0.301** thus p>0.05	1.47% (decrease)
	Extension4	19,40	8,961	9	32		
	Extension7	21,43	7,344	11	36		
Group two: ESWT	Extension1	17,81	8,586	6	32	**0.905** thus p>0.05	9.49% (increase)
	Extension4	15,95	6,157	9	30		
	Extension7	19,50	4,700	13	28		
Group three: Combination	Extension1	16,97	6,894	2	25	**0.020** thus p<0.05	23.98% (increase)
	Extension4	16,42	3,965	12	23		
	Extension7	21,04	7,912	11	34		

An intragroup analysis was done using the Friedman test to compare each group over the 4-week period of the clinical trials. Significant changes were only shown in group three when the Digital Inclinometer for ROM in extension values were compared within the groups. The p-values of groups one, two, and three were **0.301**, **0.905**, and **0.020** respectively.

If differences over time were picked up while using the Friedman test, the Wilcoxon Signed Ranks test was warranted for use. This test was used to show exactly where the differences occurred over the 4-week clinical trial period. The Wilcoxon Signed Ranks test is designed to pick up differences between the 1st and 4th consultations, and the 1st and 7th consultations shown below in table 4.11. Since only group three had significant changes, the test was only done with that groups data.

Table 4.11. Non-parametric Wilcoxon Signed Ranks Test of the Digital Inclinometer for Lumbar ROM in Extension

Group	Consultation Number	p-value
Group three: Combination	Extension1 - Extension4	**0.333** thus > 0.05
	Extension1 - Extension7	**0.059** thus > 0.05

As illustrated in table 4.11., the Digital Inclinometer for lumbar ROM in extension data obtained from the 1st and 4th consultations of group three had a p-value of **0.333** and the 1st and 7th consultations had a p-value of **0.059**. These p-values indicate that there was no significant change that occurred in both intervals for group three.

Intergroup analysis

The Kruskal-Wallis test is the non-parametric test that was used to conduct the intergroup analysis to compare the data obtained between the three groups in the 1st, 4th and 7th consultations of this study.

Table 4.12. Non-parametric Kruskal Wallis test of the Digital Inclinometer for Lumbar ROM in Extension

Consultation Number	Mean Rank/p-value	Group one: SMT	Group two: ESWT	Group three: Combination
Extension1	**Mean Rank**	17.65	14.80	14.05
	p-value	**0.628** thus > 0.05		
Extension4	**Mean Rank**	17.20	13.80	15.50
	p-value	**0.689** thus > 0.05		
Extension7	**Mean Rank**	16.55	14.05	15.90
	p-value	**0.805** thus > 0.05		

With regards to the Digital Inclinometer for lumbar ROM in extension, table 4.12. illustrates that the data obtained from the 1st, 4th and 7th consultations had a p-value of **0.628**, **0.689,** and **0.805** respectively. These p-values showed that no significant changes occurred between all three groups.

4.4.1.3. Left lumbar lateral flexion

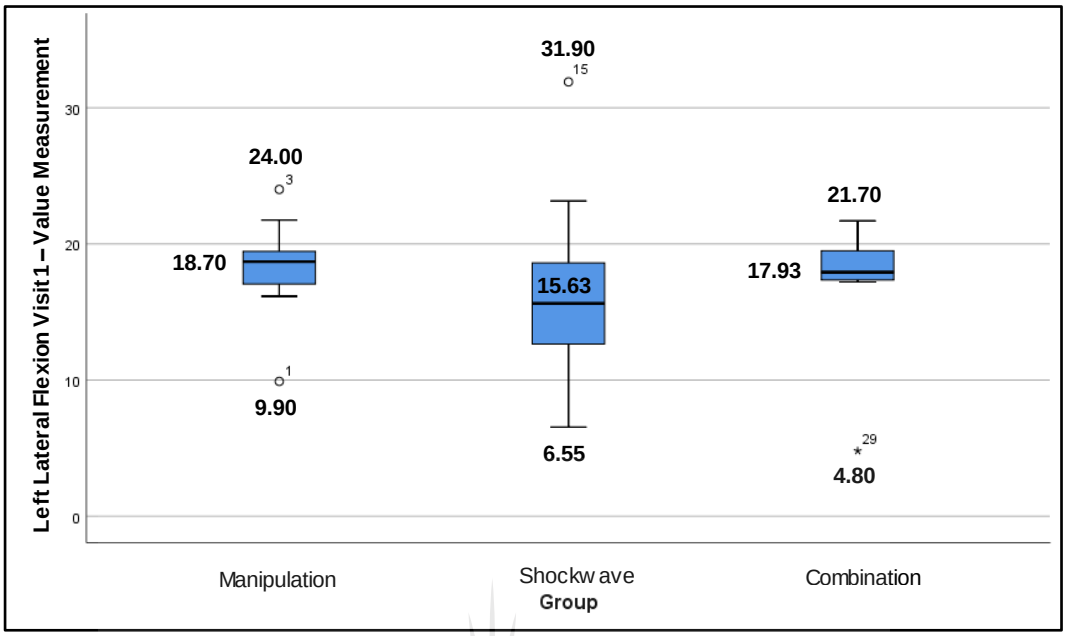


Figure 4.14. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in left lateral flexion visit 1

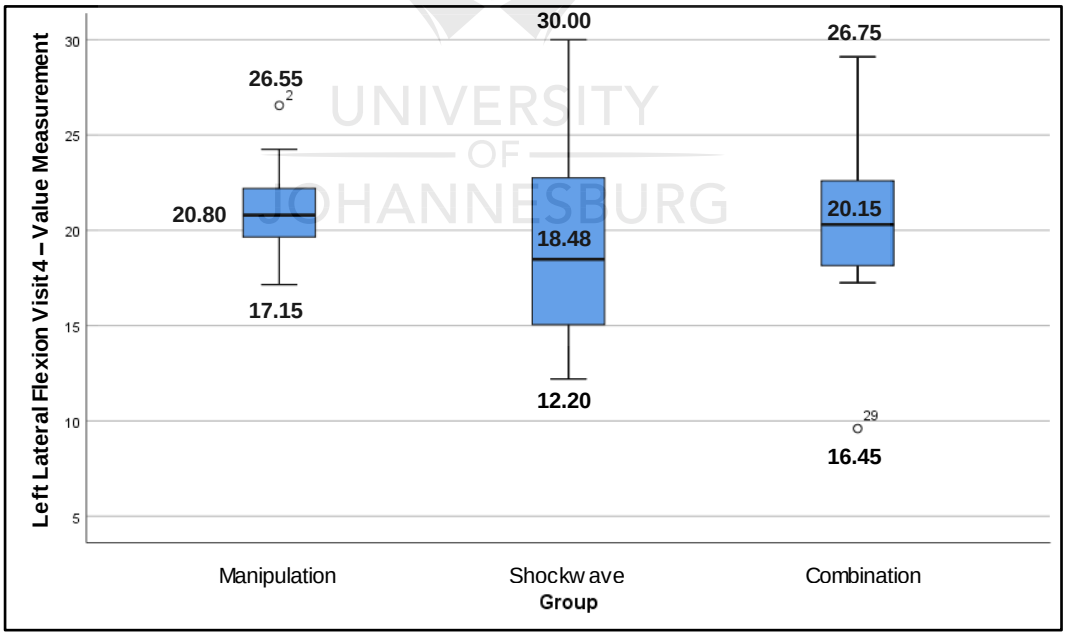


Figure 4.15. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in left lateral flexion visit 4

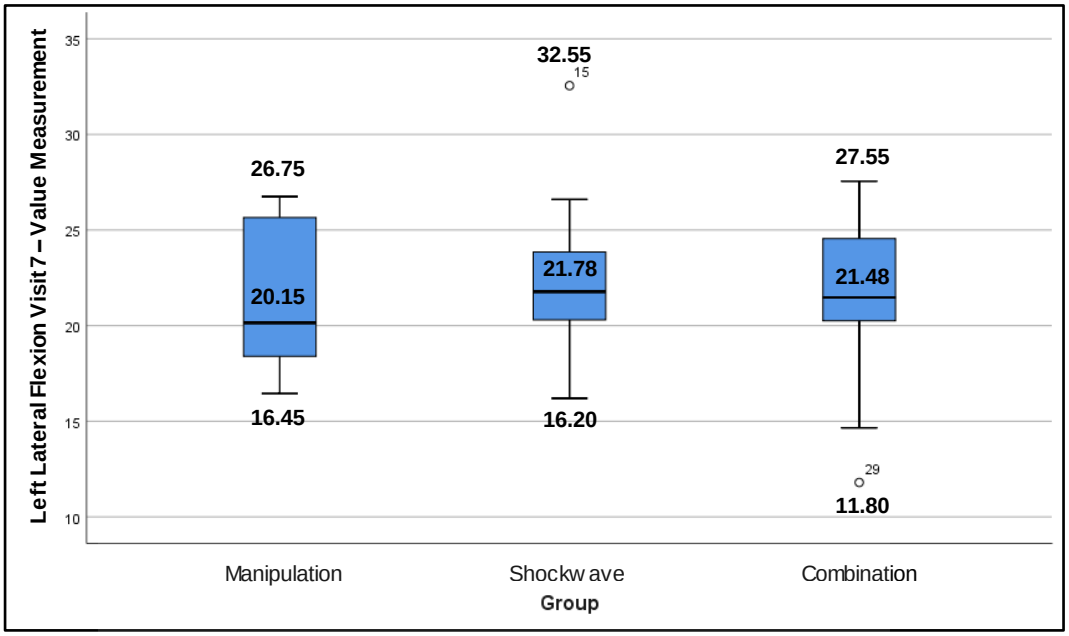


Figure 4.16. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in left lateral flexion visit 7

Clinical analysis

Figures 4.14., 4.15, and 4.16., illustrates the data that was collected from consultation visits 1, 4 and 7 respectively using the Digital Inclinometer for lumbar ROM in left lateral flexion. Figure 4.14. illustrates the data that was collected at the beginning of the 1st consultation, the mean values for the SMT, ESWT/shockwave and combination groups were **18.28**, **16.71**, and **17.41** with a standard deviation of **3.73**, **6.967**, and **4.73** respectively. Figure 4.15. illustrates the data that was collected at the beginning of the 4th consultation, the mean values for the SMT, ESWT/shockwave, and combination groups were **21.09**, **19.18**, and **20.13** with a standard deviation of **2.722**, **5.462**, and **5.008** respectively. Figure 4.16. illustrates the data that was collected in the 7th consultation, the mean values of the SMT, ESWT/shockwave and combination groups were **21.17**, **22.66**, and **20.95** with a standard deviation of **3.746**, **4.409**, and **4.667** respectively.

Based on the mean values obtained in each consultation, a percentage which shows whether there was an improvement or not can be calculated in each of the three groups. These percentages were calculated over the overall clinical trial period of the study and the equation used is illustrated below. The percentage of overall clinical improvement in groups

one, two, and three were **15.81%** (increase), **35.61%** (increase), and **20.33%** (increase) respectively as shown in table 4.13.

$$Percentage\ improvement\ = \frac{Original\ mean\ value\ - New\ mean\ value}{Original\ mean\ value} \times 100$$

Intragroup analysis

Table 4.13. Non-parametric Friedman Test of the Digital Inclinometer for Lumbar ROM in Left Lateral Flexion

Group	Reading Number	Mean	Std. Deviation	Min	Max	p-value	Overall clinical Improvement
Group one: SMT	LatFlex_L1	18,28	3,730	10	24	**0.045** thus p<0.05	15.81% (increase)
	LatFlex_L4	21,09	2,722	17	27		
	LatFlex_L7	21,17	3,746	16	27		
Group two: ESWT	LatFlex_L1	16,71	6,967	7	32	**0.020** thus p<0.05	25.61% (increase)
	LatFlex_L4	19,18	5,462	12	30		
	LatFlex_L7	22,67	4,409	16	33		
Group three: Combination	LatFlex_L1	17,41	4,730	5	22	**0.045** thus p<0.05	20.33% (increase)
	LatFlex_L4	20,13	5,008	10	29		
	LatFlex_L7	20,95	4,667	12	28		

An intragroup analysis was done using the Friedman test to compare each group over the 4-week period of the clinical trials. Significant changes were shown in all three groups when the Digital Inclinometer for lumbar ROM in left lateral flexion values were compared within the groups. The p-values of groups one, two, and three were **0.045**, **0.020**, and **0.045** respectively.

If differences over time were picked up while using the Friedman test, the Wilcoxon Signed Ranks test was warranted for use. This test was used to show exactly where the differences occurred over the 4-week clinical trial period. The Wilcoxon Signed Ranks test is designed to pick up differences between the 1st and 4th consultations, and the 1st and 7th consultations shown below in table 4.14.

Table 4.14. Non-parametric Wilcoxon Signed Rank Test of the Digital Inclinometer for Lumbar ROM in Left Lateral Flexion

Group	Consultation Number	p-value
Group one: SMT	LatFlex_L1 - LatFlex_L4	**0.022** thus < 0.05
	LatFlex_L1 - LatFlex_L7	**0.169** thus > 0.05
Group two: ESWT	LatFlex_L1 - LatFlex_L4	**0.333** thus > 0.05
	LatFlex_L1 - LatFlex_L7	**0.022** thus < 0.05
Group three: Combination	LatFlex_L1 - LatFlex_L4	**0.013** thus < 0.05
	LatFlex_L1 - LatFlex_L7	**0.022** thus < 0.05

As illustrated in table 4.14., the Digital Inclinometer for lumbar ROM in left lateral flexion data obtained from the 1st and 4th consultations of group one had a p-value of **0.022** and the 1st and 7th consultations had a p-value of **0.169**. The p-value of the 1st and 4th consultations indicates that there was a significant change that occurred in this interval while the p-value of the 1st and 7th consultations period showed no significant change for group one. The 1st and 4th consultations of group two had a p-value of **0.333** and **0.022** between the 1st and 7th consultations. The p-value of the 1st and 4th consultations period showed no significant change while the p-value of the 1st and 7th consultations indicates that there was a significant change that occurred in this interval for group two. The 1st and 4th consultations of group three had a p-value of **0.013** and **0.022** between the 1st and 7th consultations. These p-values indicate that there was a significant change that occurred in both intervals for group three.

Intergroup analysis

The Kruskal-Wallis test is the non-parametric test that was used to conduct the intergroup analysis to compare the data obtained between the three groups in the 1st, 4th and 7th consultations of this study.

Table 4.15. Non-parametric Kruskal Wallis test of the Digital Inclinometer for Lumbar ROM in Left Lateral Flexion

Consultation Number	Mean Rank/p-value	Group one: SMT	Group two: ESWT	Group three: Combination
LatFlex_L1	Mean Rank	17.60	12.45	16.45
	p-value	**0.389** thus > 0.05		
LatFlex_L4	Mean Rank	17.70	12.70	16.10
	p-value	**0.431** thus > 0.05		
LatFlex_L7	Mean Rank	13.80	17.25	15.45
	p-value	**0.681** thus > 0.05		

With regards to the Digital Inclinometer for lumbar ROM in left lateral flexion, table 4.15. illustrates that the data obtained from the 1st, 4th and 7th consultations had a p-value of **0.389**, **0.431,** and **0.681** respectively. These p-values showed that no significant changes occurred between all three groups.

4.4.1.4. Right lumbar lateral flexion

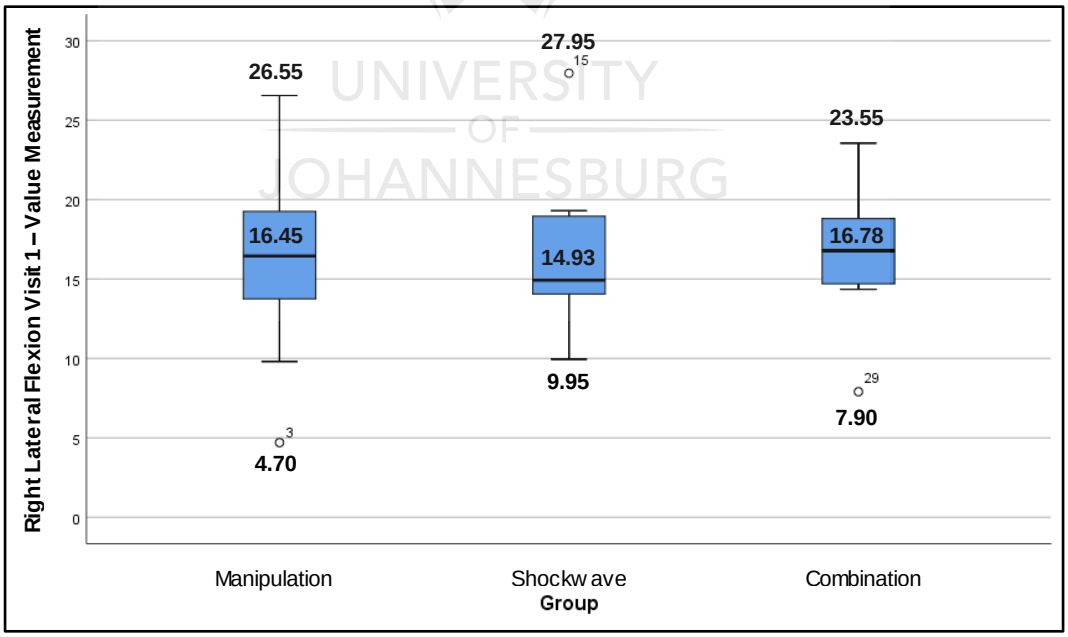


Figure 4.17. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in right lateral flexion visit 1

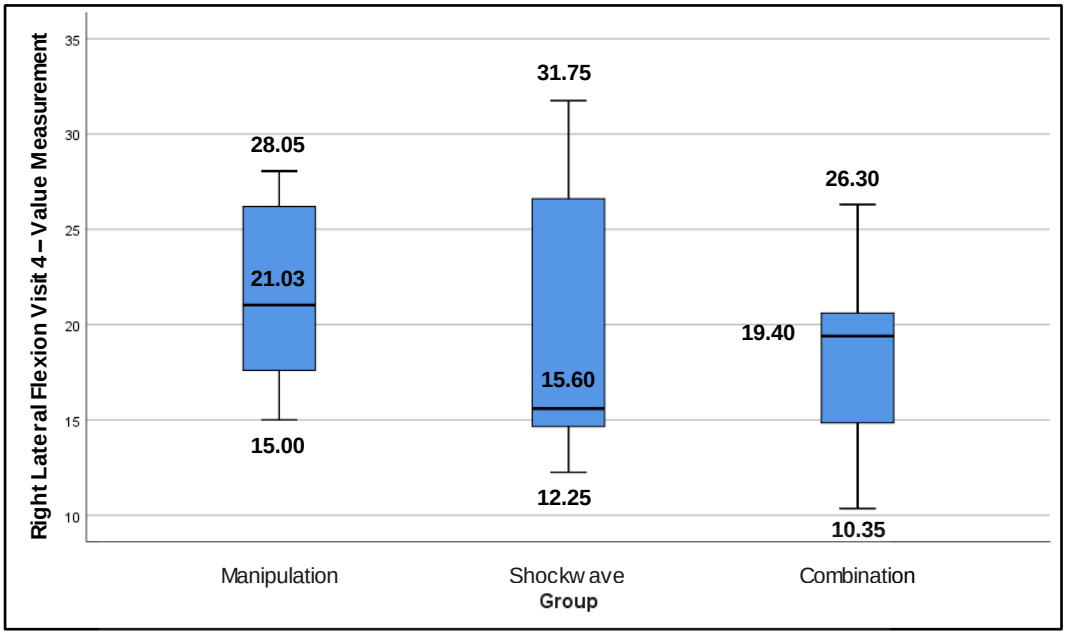


Figure 4.18. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in right lateral flexion visit 4

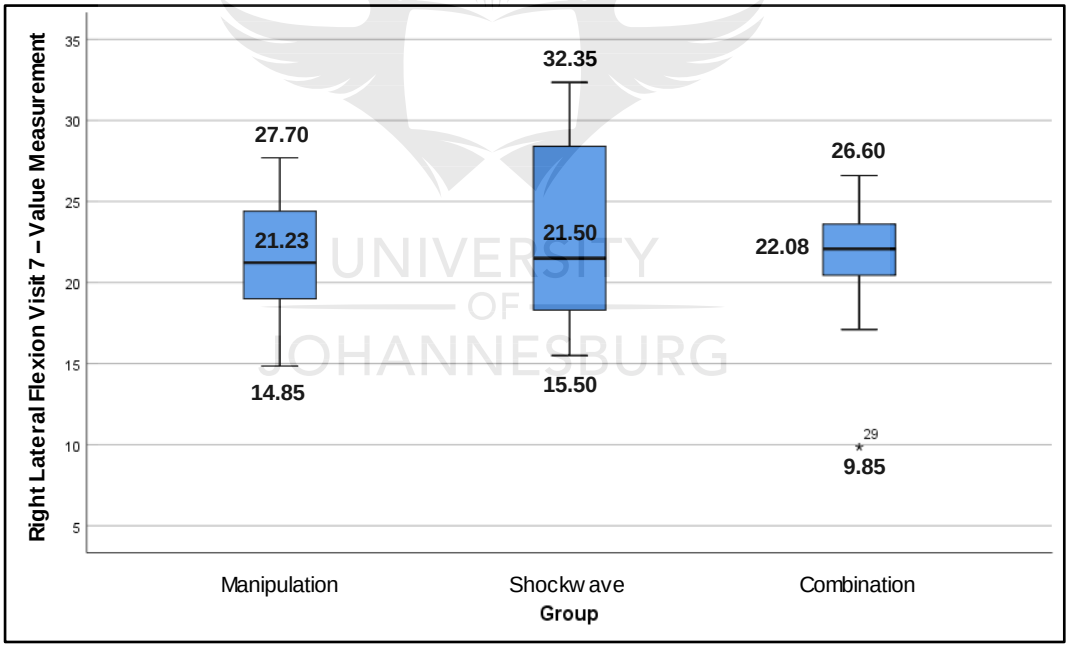


Figure 4.19. Boxplot comparing the distribution of scores between the three groups for the Digital Inclinometer ROM in right lateral flexion visit 7

Clinical analysis

Figures 4.17., 4.18, and 4.19., illustrates the data that was collected from consultation visits 1, 4 and 7 respectively using the Digital Inclinometer for lumbar ROM in right lateral flexion. Figure 4.17. illustrates the data that was collected at the beginning of the 1st consultation,

the mean values for the SMT, ESWT/shockwave and combination groups were **16.55**, **16.18**, and **16.62** with a standard deviation of **6.38**, **4.98**, and **4.10** respectively. Figure 4.18. illustrates the data that was collected at the beginning of the 4th consultation, the mean values for the SMT, ESWT/shockwave, and combination groups were **21.61**, **19.13**, and **18.57** with a standard deviation of **4.55**, **7.34**, and **4.57** respectively. Figure 4.19. illustrates the data that was collected in the 7th consultation, the mean values of the SMT, ESWT/shockwave and combination groups were **21.39**, **22.69**, and **21.02** with a standard deviation of **3.94**, **5.99**, and **4.69** respectively.

Based on the mean values obtained in each consultation, a percentage which shows whether there was improvement or not can be calculated in each of the three groups. These percentages were calculated over the overall clinical trial period of the study and the equation used is illustrated below. The percentage of overall clinical improvement in groups one, two, and three were **29.24%** (increase), **40.23%** (increase), and **26.47%** (increase) respectively as shown in table 4.16.

$$Percentage\ improvement = \frac{Original\ mean\ value - New\ mean\ value}{Original\ mean\ value} \times 100$$

Intragroup analysis

Table 4.16. Non-parametric Friedman Test of the Digital Inclinometer for Lumbar ROM in Right Lateral Flexion

Group		Mean	Std. Deviation	Min	Max	p-value	Overall Clinical Improvement
Group one: SMT	LatFlex_R1	16,55	6,383	5	27	**0.014** thus p<0.05	29.24% (increase)
	LatFlex_R4	21,61	4,551	15	28		
	LatFlex_R7	21,39	3,940	15	28		
Group two: ESWT	LatFlex_R1	16,19	4,979	10	28	**0.003** thus p<0.05	40.23% (increase)
	LatFlex_R4	19,13	7,344	12	32		
	LatFlex_R7	22,69	5,992	16	32		
Group three: Combination	LatFlex_R1	16,62	4,101	8	24		26.47% (increase)
	LatFlex_R4	18,57	4,567	10	26		

	LatFlex_R7	21,03	4,688	10	27	**0.001** thus p<0.05	

An intragroup analysis was done using the Friedman test to compare each group over the 4-week period of the clinical trials. Significant changes were shown in all three groups when the Digital Inclinometer for lumbar ROM in right lateral flexion values were compared within the groups. The p-values of groups one, two, and three were **0.014**, **0.003**, and **0.001** respectively.

If differences over time were picked up while using the Friedman test, the Wilcoxon Signed Ranks test was warranted for use. This test was used to show exactly where the differences occurred over the 4-week clinical trial period. The Wilcoxon Signed Ranks test is designed to pick up differences between the 1st and 4th consultations, and the 1st and 7th consultations shown below in table 4.17.

Table 4.17. Non-parametric Wilcoxon Signed Rank Test of the Digital Inclinometer for Lumbar ROM in Right Lateral Flexion

Group	Consultation Number	p-value
Group one: SMT	LatFlex_R1 - LatFlex_R4	**0.037** thus < 0.05
	LatFlex_R1 - LatFlex_R7	**0.074** thus > 0.05
Group two: ESWT	LatFlex_R1 - LatFlex_R4	**0.139** thus > 0.05
	LatFlex_R1 - LatFlex_R7	**0.009** thus < 0.05
Group three: Combination	LatFlex_R1 - LatFlex_R4	**0.053** thus > 0.05
	LatFlex_R1 - LatFlex_R7	**0.005** thus < 0.05

As illustrated in table 4.17., the Digital Inclinometer for lumbar ROM in right lateral flexion data obtained from the 1st and 4th consultations of group one had a p-value of **0.037** and the 1st and 7th consultations had a p-value of **0.074**. The p-value for group one of the 1st and 4th consultations indicates that there was a significant change that occurred in this interval while the p-value of the 1st and 7th consultations period showed no significant change occurred. The 1st and 4th consultations of group two had a p-value of **0.139** and **0.009** between the 1st

and 7th consultations. The p-value for group two of the 1st and 4th consultations period showed that no significant change occurred, while the p-value of the 1st and 7th consultations indicates that there was a significant change that occurred in this interval. The 1st and 4th consultations of group three had a p-value of **0.053** and **0.005** between the 1st and 7th consultations. The p-value for group three of the 1st and 4th consultations period showed no significant change occurred while the p-value of the 1st and 7th consultations indicates that there was a significant change that occurred in this interval.

Intergroup analysis

The Kruskal-Wallis test is the non-parametric test that was used to conduct the intergroup analysis to compare the data obtained between the three groups in the 1st, 4th and 7th consultations of this study.

Table 4.18. Non-parametric Kruskal Wallis test of the Digital Inclinometer for Lumbar ROM in Right Lateral Flexion

Consultation Number	Mean Rank/p-value	Group one: SMT	Group two: ESWT	Group three: Combination
LatFlex_R1	**Mean Rank**	16.10	13.80	16.60
	p-value	**0.750** thus > 0.05		
LatFlex_R4	**Mean Rank**	19.30	13.35	13.85
	p-value	**0.245** thus > 0.05		
LatFlex_R7	**Mean Rank**	15.05	16.10	15.35
	p-value	**0.963** thus > 0.05		

With regards to the Digital Inclinometer for lumbar ROM in right lateral flexion, table 4.18. illustrates that the data obtained from the 1st, 4th and 7th consultations had a p-value of **0.750**, **0.245,** and **0.963** respectively. These p-values showed that no significant changes occurred between all three groups.

4.4.1.5. Comparison between left and right within groups

Table 4.19. Non-parametric Wilcoxon Signed Ranks Test Paired Samples Statistics between left and right within groups

Group			Mean	N	Std. Deviation	Std. Error Mean	p-value
Group one: SMT	Pair 1	LatFlex_L1	18,28	10	3,730	1,179	**0.445** thus p>0.05
		LatFlex_R1	16,55	10	6,383	2,018	
	Pair 2	LatFlex_L4	21,09	10	2,722	0,861	**0.635** thus p>0.05
		LatFlex_R4	21,61	10	4,551	1,439	
	Pair 3	LatFlex_L7	21,17	10	3,746	1,185	**0.878** thus p>0.05
		LatFlex_R7	21,39	10	3,940	1,246	
Group two: ESWT	Pair 1	LatFlex_L1	16,71	10	6,967	2,203	**0.878** thus p>0.05
		LatFlex_R1	16,19	10	4,979	1,575	
	Pair 2	LatFlex_L4	19,18	10	5,462	1,727	**0.959** thus p>0.05
		LatFlex_R4	19,13	10	7,344	2,322	
	Pair 3	LatFlex_L7	22,67	10	4,409	1,394	**1.000** thus p>0.05
		LatFlex_R7	22,69	10	5,992	1,895	
Group three: Combination	Pair 1	LatFlex_L1	17,41	10	4,730	1,496	**0.285** thus p>0.05
		LatFlex_R1	16,62	10	4,101	1,297	
	Pair 2	LatFlex_L4	20,13	10	5,008	1,584	**0.046** thus p<0.05
		LatFlex_R4	18,57	10	4,567	1,444	
	Pair 3	LatFlex_L7	20,95	10	4,667	1,476	

		LatFlex_R7	21,03	10	4,688	1,482	**0.959** thus p>0.05

With reference to table 4.19. above, this is a table illustrating the data obtained using the Digital Inclinometer for lumbar ROM. The Wilcoxon Signed Ranks Test was used to draw up a table with a comparison within groups between the left and right measurements obtained during the clinical trial period. Based on the analysis of this data, all the obtained measurements showed no significant changes occurred when comparing each pair, except for pair 2 of the combination group. This pair had a p-value of **0.046** which shows that there was a significant change that occurred in the 4th consultation between the left and right measurements for group three.

CHAPTER FIVE: DISCUSSION

5.1. Introduction

This chapter serves to provide a summarised discussion of the statistical results obtained during the 4-week clinical trial period that were presented in chapter four. This discussion also aims to integrate the presented literature review in chapter two with the results of this study and previous studies to provide evidence-based explanations along with clinical reasoning.

The main two headlines of this chapter are statistical and clinical significance and thus these topics will be discussed in more depth. Statistical significance has to do with the likelihood of findings being due to chance while the clinical significance has to do with deciding on a particular treatment based on the practical value and/or relevance of that treatment. Statistical significance relies on the p-value whereas clinical significance does not. Clinical significance also does not rely on statistical significance as an initial criterion (Fethney, 2010).

5.2. Descriptive Data

This section included demographic data which encompasses an analysis of the age and gender distribution of the participants in this study. This study had a total of 30 participants who were split into three groups consisting of 10 participants each meaning that each group consisted of **33.3%** of the participants. The gender distribution between the groups was shown as a percentage.

5.2.1. Clinical analysis

According to table 4.1., the gender distribution of the participants who were recruited in this study were split into three groups as follows: group one consisted of **40.0%** males and **60.0%** females. Group two was made up of **50.0%** males and **50.0%** females. Group three was also comprised of **50.0%** males and **50.0%** females. Therefore, the overall gender distribution consisted of 14 males and 16 females. Thus, the total percentage of males and females were **46.7%** and **53.3%** respectively. This can also be seen in figure 4.1. The Pearson Chi-Square test showed a p-value of **0.875** for the gender distribution which is higher than 0.05 thus both males and females showed no significant changes.

The age distribution of the participants recruited in this study were as follows: the age range of group one was between the ages of **23** and **26** years with a mean age of **24.9** years. Group two had an age range of **24** to **27** years, with a mean age of **24.7** years. Group three had an age range of **23** to **27** years with a mean age of also **24.7** years.

5.2.2. Descriptive data discussion

Low back pain (LBP) is one of the leading causes of morbidity in the world, as an excess of 80% of the population will experience a LBP episode at some stage of their lives (Freburger, Holmes, Agans, Jackman, Darter, Wallace, Castel, Kalsbeek and Carey, 2009). As mentioned in chapter two of this study, it has been proven that low back pain, amongst other musculoskeletal disorders, is the leading reason why patients seek medical treatment and it is the number one cause of disability (Huang-Lionnet, Brummett and Cohen, 2018). Recurrent or chronic LBP is more likely to affect females more than males and generally have more severe LBP with a worse prognosis (Chenot, Becker, Leonhardt, Keller, Donner-Banzhoff, Hildebrandt, Baster, Baum, Kochen and Pfingsten, 2008).

The gender distribution of this study was mostly equally distributed amongst the three groups as group two and three both had an equal 50/50 percent split of males and females while group one had a 40/60 percent split of males and females respectively. The Pearson Chi-Square test showed a p-value of **0.875**, which indicated that no significant changes occurred between the two genders. This means that it is safe to assume that the gender differences within the groups had no role in the results obtained in the subjective and objective data measurements.

The age of the entire sample of this study ranged from a minimum of 23 years to a maximum of 27 years with a mean age of **24.77** years**.** As mentioned in chapter three, participants aged 18-35 years were allowed to participate in this study as this eliminates any possible degenerative changes that accompany increasing age (Kelly *et al.*, 2012). In chapter two, it was mentioned that a common cause of facetogenic pain is arthritis, so there is an increase in the prevalence rate of LBP with age (Van Kleef *et al.*, 2010). The facet joints in particular can be a potential source of back pain from the neck down to the lower back (Huang-Lionnet, Brummett and Cohen, 2018). Based on these studies, it is also safe to assume that the participants who were involved in this study were within the correct age group to not be

susceptible to degenerative changes therefore altering the outcome of the subjective and objective data measurements.

5.3. Subjective Data

This data was obtained using two methods which are the Numerical Pain Rating Scale (NPRS) and the Oswestry Low Back Pain and Disability Questionnaire (ODQ).

5.3.1. Numerical pain rating scale

The NPRS is a simple scale that is solely concerned with the individuals perceived pain intensity. In chapter three, it was mentioned that the participants were required to select a number on the scale which best represented the severity of the pain that they were experiencing at that moment in time. The scale was numbered from zero to ten where zero represented no pain at all and ten represented the worst pain that the participant had ever experienced. Therefore, the higher the rating, the higher the participants pain intensity and vice versa. According to literature, a change of 2-points or more over time on the NPRS is considered to be of clinical significance (Farrar *et al.*, 2001).

5.3.1.1. NPRS clinical analysis

In table 4.2., the mean values from the NPRS of all three groups indicated that all of the groups improved over the 4-week clinical trial period. Group one had the largest overall clinical improvement of **83.63%** followed by group two with **75.00%** and group three with **73.02%**. The p-values of all three groups using the Friedman test were **0.000** thus **$p < 0.05$**. Based on these results, this means that all three groups yielded statistically and clinically significant results with the NPRS.

5.3.1.2. NPRS intragroup analysis

Since all three groups yielded statistically significant results while using the Friedman test, the Wilcoxon Signed Ranks test was used. With reference to table 4.3., both treatment/clinical trial time intervals, being between the 1st and 4th as well as the 1st and 7th consultations, yielded p-values that were less than 0.05 in all three groups. This means that since **$p < 0.05$**, there was a statistically significant change that occurred with the NPRS data over time within each group. Therefore, changes started to occur from the 1st and 4th consultations and continued through to the 7th consultation within each group.

5.3.1.3. NPRS intergroup analysis

With reference to table 4.4., the p-values obtained using the Kruskal Wallis Test were more than 0.05 in the 1st, 4th and 7th consultations. Since **p > 0.05**, there was no statistically significant changes that occurred between the three groups. This means that all three treatment protocols worked similarly to one another in terms of the NPRS with subjective pain.

5.3.2. Oswestry low back pain and disability questionnaire

As explained in chapter three, the ODQ is a table of questions that has been designed to give the researcher information about how the participants low back pain is affecting their ability to manage in everyday life. The question table consists of 10 sections with 6 statements in each section which the participants were required to answer by checking one box in each section for the statement which best applied to them (Haneline, 2007). Each section had a total score of 5 in which the first statement was equal to 0 and the last statement was equal to 5. The higher the score, the higher the participants pain intensity and disability, and vice versa (Fairbank and Pynsent, 2000).

5.3.2.1. ODQ clinical analysis

In table 4.5., the mean values from the ODQ of all three groups indicated that all the groups improved over the 4-week clinical trial period. Group one had the largest overall clinical improvement of **80.67%** followed by group two with **75.83%** and group three with **67.65%**. The p-values of group one and two using the Friedman test were **0.001** and **0.003** for group three thus **p < 0.05** in all three groups. Based on these results, this means that all three groups yielded statistically and clinically significant results with the ODQ.

5.3.2.2. ODQ intragroup analysis

Since all three groups yielded statistically significant results while using the Friedman test, the Wilcoxon Signed Ranks test was used. With reference to table 4.6, both treatment/clinical trial intervals, being between the 1st and 4th as well as the 1st and 7th consultations, yielded p-values that were less than 0.05 in all three groups. This means that since **p < 0.05**, there was a statistically significant change that occurred with the ODQ data over time within each group. Therefore, changes started to occur from the 1st and 4th consultations and continued through to the 7th consultation within each group.

5.3.2.3. ODQ intergroup analysis

With reference to table 4.7., the p-values obtained using the Kruskal Wallis Test were more than 0.05 in the 1st, 4th and 7th consultations. Since **p > 0.05**, there was no statistically significant changes that occurred between the three groups. This means that all three treatment protocols worked similarly to one another in terms of the ODQ with subjective pain and disability.

5.3.3. Subjective data discussion

In chapter two of this study, it was discussed that shockwave therapy has effects on the body in three main ways. The cellular mechanotransduction effect which results in cell homeostasis being maintained via the conversion of mechanical forces within cells into biochemical signals (Frairia and Berta, 2011). The analgesic effect which results in the reduction of nociceptive chemicals such as substance P which stimulate pain receptors in the affected region and within the spinal cord (Schmitz *et al.*, 2010). Lastly, the tissue healing and regeneration effect which results from the stimulation of macrophages to produce anti-inflammatory interleukins and cytokines that are responsible for the promotion of cell regeneration, healing and further pain reduction (Sukubo *et al.*, 2015).

It is well recognised and clinically documented that spinal manipulative therapy has a positive effect on the reduction of pain and disability. It has been suggested in numerous studies that SMT can increase the levels of pain tolerance/threshold as it alters the central processing of noxious stimuli (Bergmann and Peterson, 2011). Neural stimulation has the ability to produce analgesia (Gatterman, 2005). A recent study discussed in chapter two where SMT was compared with other conservative treatments for low back pain concluded that SMT used with other conservative treatments is a safe and effective treatment strategy for acute or chronic low back pain (Bussières *et al.*, 2018).

During the early stages of injury and repair of soft tissue, the direction of manual therapy is towards pain reduction and decreasing inflammation thus preventing further injury and the promotion of flexible healing. Manual therapies are directed towards the restoration of joint mobility and function when contractures, stiffness, joint hypomobility, and chronic pain or disability result due to injury or degenerative changes. SMT helps with muscle spasm, temporary joint locking, and pain reduction (Bergmann and Peterson, 2011).

According to the analgesic hypothesis, SMT can potentially remove the source of inflammation and mechanical pain or it can potentially induce analgesia via the pain gate theory. This can be achieved as a result of the ability of SMT to induce enough force to activate both superficial and deep somatic mechanoreceptors, as well as the proprioceptors and nociceptors simultaneously. This stimulation is strong enough to create an afferent segmental barrage within the spinal cord sensory neurons that is capable of causing alterations in the patterns of afferent input to the central nervous system which results in the inhibition of the central pain transmission (Bergmann and Peterson, 2011).

Pain and paraesthesia's, changes in muscle tone and increased autonomic activity may be caused by nerve root compression within the intervertebral foramina (Gatterman, 2005). As discussed in chapter two, inflammation within the facet joints and the surrounding soft tissue may result in neurogenic inflammation and/or mechanical compression of the medial branch of the dorsal nerve root (Nedelka *et al.*, 2014). Fixed spinal subluxation positions and nerve root irritation can be reduced with SMT, as this may reduce nerve root traction, compression or inflammation (Bergmann and Peterson, 2011).

Somatic or joint dysfunction may induce a persistent altered proprioceptive and nociceptive input; this is a reflex paradigm known as reflex dysfunction (Bergmann and Peterson, 2011).

The pain gate theory, as mentioned above, is one of the major reasons why all three groups experienced such a great improvement with the treatment that was given. This theory, which was published by Ronald Melzack and Patrick Wall in 1965, is based on the transmission of sensory impulses from peripheral nerves to the central nervous system. It proposes that the flow of nerve impulses is modulated by a "gate" located in the dorsal horn of the spinal cord. The gate is influenced by the activity of peripheral fibres and by descending inhibitory pathways from the brain (Mendell, 2014). The stimulation of small C-fibres causes the activation of an excitatory system that increases the cells output. The activity of these latter cells is controlled by homeostasis between the small C-fibres and large A-delta fibres which is in turn controlled by the descending inhibitory pathways (Dickenson, 2002).

A previous study was done concerned with the effects of preventive SMT for chronic low back pain and related disabilities. Pain scales and disability questionnaires were used in this study to obtain subjective data. The study revealed and confirmed that spinal manipulation

causes a reduction in LBP and disability scores as reported in previous cases. It was also revealed that preventive chiropractic SMT has a positive effect on the maintenance of functional capacities and decreasing the frequency and intensity of LBP episodes after the treatment of an acute phase (Descarreaux, Blouin, Drolet, Papadimitriou and Teasdale, 2004).

Another study was done looking into the evidence-informed management of chronic LBP with spinal manipulation and mobilization. This study produced moderate to strong evidence about the efficacy of SMT in acute, subacute and chronic LBP cases. The study also showed that SMT has a similar effect as medical care that is combined with exercise and patient education when treating acute and chronic low back pain and disability (Bronfort *et al.*, 2008).

In a study concerned with the mechano-transduction effects of shockwaves in the treatment of lumbar facet joint pain, the ODQ and the PainDETECT validated questionnaire was used to obtain the subjective data. The study compared ESWT to invasive conventionally used treatments of corticosteroid injections and radiofrequency medial branch neurotomy. It was proven that ESWT is an effective, non-invasive modality to use to achieve pain reduction, tissue repair and increased joint function (Nedelka *et al.*, 2014).

The information provided in the articles above as well as chapter two explains the reasons why all three groups had significant clinical and statistical changes occur over the 4-week clinical trial period with regards to the NPRS and ODQ data. Clinically and statistically significant changes occurred in all three groups with Friedman test and statistically significant changes occurred with the Wilcoxon Signed Ranks test. The Kruskal Wallis test showed no statistically significant change between the three groups.

With regards to the Friedman test, group one had the highest overall clinical improvement/change with **83.63%** using the NPRS and **80.67%** using the ODQ. This suggests that chiropractic SMT used alone was the best treatment protocol for the reduction of pain and disability compared to the other treatments given in group two and three.

The Wilcoxon Signed Ranks test showed statistically significant changes over both time intervals for all three groups. This suggests that the treatment given in all three groups was effective in decreasing pain and disability from the 1st to the 4th consultations, right through to the 7th consultation. All the mechanisms of disability and pain reduction mentioned above

and in previous chapters and articles were effective with regards to the NPRS and ODQ data.

The Kruskal Wallis test showed that no statistically significant changes occurred between the three groups over time. This suggests that statistically all three groups improved over time with no one group standing out from the rest of the groups.

5.4. Objective Data

This data was obtained using one method which is the Digital Inclinometer for measuring lumbar ROM.

5.4.1. Digital inclinometer

As mentioned in chapter three, the Digital Inclinometer is a small hand-held device with an LCD screen that displays the participants' degrees of movement. The device was used to measure the participants' active lumbar ROM in flexion, extension and lateral flexion. The thoracolumbar (T12-L1) and lumbosacral (L5-S1) junctions were used as points of reference for the placement of the device to obtain measurements (Sadeghi *et al.*, 2015).

5.4.1.1. Lumbar spine flexion

5.4.1.1.1. Lumbar spine flexion clinical analysis

With reference to chapter four (table 4.8.), the mean values of the Digital Inclinometer measurements in group one increased from the 1st to the 4th consultations, but then decreased in the 7th consultation below the initial mean value. In group two, the mean values steadily increased throughout the 7 consultations. In group three, the mean values more or less stayed the same from the 1st to the 4th consultations with the slightest mean value increase but then decreased in the 7th consultation below the initial mean value. The overall clinical improvement/change for group one and three was a decrease of **4.78%** and **1.11%** respectively and for group two was an increase of **7.13%**. This means that group one and three yielded clinically insignificant results and group two was the only group to yield clinically significant results for the Digital Inclinometer in flexion.

The p-values for group one, two and three were **0.741**, **0.497** and **0.905** respectively. Thus, **p > 0.05** for all three groups. Based on these results, this means that all three groups yielded statistically insignificant results with the Digital Inclinometer in flexion.

5.4.1.1.2. Lumbar spine flexion intragroup analysis

Since all three groups yielded statistically insignificant results **(p > 0.05)** while using the Friedman test (refer to table 4.8.), the Wilcoxon Signed Ranks test was not used to test exactly where the differences lie over time.

5.4.1.1.3. Lumbar spine flexion intergroup analysis

With reference to table 4.9., the p-values obtained using the Kruskal Wallis Test were more than 0.05 in the 1st, 4th and 7th consultations. Since **p > 0.05**, there was no statistically significant changes that occurred between the three groups. This means that all three treatment protocols worked similarly to one another in terms of the Digital Inclinometer measurements for lumbar ROM in flexion.

5.4.1.2. Lumbar spine extension

5.4.1.2.1. Lumbar spine extension clinical analysis

With reference to chapter four (table 4.10.), the mean values of the Digital Inclinometer measurements in group one decreased between the 1st and 4th consultations, but then increased in the 7th consultation below the initial mean value. In group two, the mean value decreased between the 1st and 4th consultations, but then increased in the 7th consultation higher than the initial mean value. In group three, the mean value slightly decreased between the 1st and 4th consultations, but then increased in the 7th consultation higher than the initial mean value. The overall clinical improvement/change for group one was a decrease of **1.47%** and group two and three was an increase of **9.49%** and **23.98%** respectively. This means that group two and three yielded clinically significant results and group one was the only group to yield clinically insignificant results for the Digital Inclinometer for lumbar ROM in extension.

The p-values for group one, two and three were **0.301**, **0.905** and **0.020** respectively thus **p > 0.05** for group one and two, and **p < 0.05** for group three. Based on these results, this means that group one and two yielded statistically insignificant results and group three was the only group to yield statistically significant results with the Digital Inclinometer for lumbar ROM in extension.

5.4.1.2.2. Lumbar spine extension intragroup analysis

Since group three yielded statistically significant results while using the Friedman test, the Wilcoxon Signed Ranks test was used. With reference to table 4.11., both treatment/clinical trial intervals, being between the 1st and 4th as well as the 1st and 7th consultations, yielded p-values that were more than 0.05 in group three. This means that since **p > 0.05**, there was a statistically insignificant change that occurred with the Digital Inclinometer data for lumbar ROM in extension over time within group three. However, when looking at the p-value of 1st and 7th consultations interval **(p = 0.059)**, it is noted that the p-value is just over 0.05.

Since group one and two yielded statistically insignificant results **(p > 0.05)** while using the Friedman test (refer to table 4.11.), the Wilcoxon Signed Ranks test was not used to test exactly where the differences lie for these groups over time.

5.4.1.2.3. Lumbar spine extension intergroup analysis

With reference to table 4.12., the p-values obtained using the Kruskal Wallis Test were more than 0.05 in the 1st, 4th and 7th consultations. Since **p > 0.05**, there were no statistically significant changes that occurred between the three groups. This means that all three treatment protocols worked similarly to one another in terms of the Digital Inclinometer measurements for lumbar ROM in extension.

5.4.1.3. Left lateral lumbar flexion

5.4.1.3.1. Left lateral lumbar flexion clinical analysis

With reference to chapter four (table 4.13.), the mean values of the Digital Inclinometer measurements of all three groups steadily increased from the 1st to the 7th consultations over the 4-week clinical trial period. Group two had the largest overall clinical improvement/change with an increase of **25.61%** followed by group three with an increase of **20.33%** and group one with an increase of **15.81%**. The p-values of group one, two and three using the Friedman test were **0.045**, **0.020** and **0.045** respectively thus **p < 0.05**. Based on these results, all three groups yielded statistically and clinically significant results with the Digital Inclinometer for lumbar ROM in left lateral flexion.

5.4.1.3.2. Left lateral lumbar flexion intragroup analysis

Since all three groups yielded statistically significant results while using the Friedman test, the Wilcoxon Signed Ranks test was used. With reference to table 4.14., group one had statistically significant results **($p < 0.05$)** in the 1st and 4th consultation interval and statistically insignificant results **($p > 0.05$)** in the 1st and 7th consultation interval. Group two had statistically insignificant results **($p > 0.05$)** in the 1st and 4th consultation interval and statistically significant results **($p < 0.05$)** in the 1st and 7th consultation interval. Group three had statistically significant results **($p < 0.05$)** in both 1st and 4th as well as the 1st and 7th consultation intervals.

This means that group one had significant changes starting to occur in the 1st interval, group two had significant changes only starting to occur in the 2nd interval and group three had significant changes occurring from the 1st and 4th consultations (1st interval) and continued through to the 7th consultation (2nd interval).

5.4.1.3.3. Left lateral lumbar flexion intergroup analysis

With reference to table 4.15., the p-values obtained using the Kruskal Wallis Test were more than 0.05 in the 1st, 4th and 7th consultations. Since **$p > 0.05$**, there was no statistically significant changes that occurred between the three groups. This means that all three treatment protocols worked similarly to one another in terms of the Digital Inclinometer measurements for lumbar ROM in left lateral flexion.

5.4.1.4. Right lateral lumbar flexion

5.4.1.4.1. Right lateral lumbar flexion clinical analysis

With reference to chapter four (table 4.16.), the mean values of the Digital Inclinometer measurements in group one increased between the 1st and 4th consultations but then slightly decreased in the 7th consultation higher than the initial mean value. The mean values of group two and three steadily increased from the 1st to the 7th consultations over the 4-week clinical trial period. Group two had the largest overall clinical improvement/change with an increase of **40.23%** followed by group one with an increase of **29.24%** and then group three with an increase of **26.47%**.

The p-values of group one, two and three using the Friedman test were **0.014**, **0.003** and **0.001** respectively thus **p < 0.05**. Based on these results, all three groups yielded statistically and clinically significant results with the Digital Inclinometer for lumbar ROM in right lateral flexion.

5.4.1.4.2. Right lateral lumbar flexion intragroup analysis

Since all three groups yielded statistically significant results while using the Friedman test, the Wilcoxon Signed Ranks test was used. With reference to table 4.17., group one had a statistically significant result **(p < 0.05)** in the 1st and 4th consultation interval and a statistically insignificant result **(p > 0.05)** in the 1st and 7th consultation interval. Group two had a statistically insignificant result **(p > 0.05)** in the 1st and 4th consultation interval and a statistically significant result **(p < 0.05)** in the 1st and 7th consultation interval. Group three had a statistically insignificant result **(p > 0.05)** in the 1st and 4th consultation interval and a statistically significant result **(p < 0.05)** in the 1st and 7th consultation interval.

Statistically this means that for group one, the effects of the treatment that was being given (SMT) started working early in the clinical trial period and after the 4th consultation, there was no longer any significant changes occurring. Thus, we can assume that the effects had plateaued. For group two and three, the effects of the treatment only started working after the 4th consultation throughout to the 7th consultation.

5.4.1.4.3. Right lateral lumbar flexion intergroup analysis

With reference to table 4.18., the p-values obtained using the Kruskal Wallis Test were more than 0.05 in the 1st, 4th and 7th consultations. Since **p > 0.05**, there was no statistically significant changes that occurred between the three groups. This means that all three treatment protocols worked similarly to one another in terms of the Digital Inclinometer measurements for lumbar ROM in extension

5.4.1.5. Comparison between left and right within groups

With reference to table 4.19., the mean values for each pair within all three groups were more or less the same with the largest differences in values being observed in pair 1 of group one and pair 2 of group three. Pair 1 of group one had a mean value difference of **1.73** in the 1st consultation between the left and right Digital Inclinometer measurements. Pair 2 of

group three had a mean value difference of **1.56** in the 4th consultation between the left and right Digital Inclinometer measurements.

With use of the Wilcoxon Signed Ranks test, all the p-values were more than 0.05 except for pair 2 of group three which had a p-value that's less than 0.05. Since **p < 0.05** in pair 2 of group three, there was a statistically significant change that occurred within this group.

5.4.2. Objective data discussion

The ROM data obtained using the Digital Inclinometer mostly showed that there were no statistically significant changes that occurred in all three groups. This could possibly be due to the small sample size of the entire study and the even smaller sample size of the individual groups. The small sample size had a negative effect on the clinical trial which resulted in the inability of the true statistically significant changes to not be shown adequately. A total of 30 participants were recruited in this study thus the following statement is a true reflection of what has transpired with the results of the clinical trial of this study. The bigger the sample size of a study, the higher the statistical sensitivity and power, therefore increasing the chances of yielding statistically relevant outcomes (Murphy and Myors, 2004).

The treatment protocol was structured in such a way that all the participants of a certain group were meant to be seen on the same day. This was not always the case as some participants came to consultations twice a week as instructed but according to their availability. Therefore, the amount of time between consultations varied which could have influenced the results of the clinical trials of this study. Although the time frames between consultations did vary, all the participants recruited into this study completed the 4-week clinical trial period within the overall time frame.

In terms of the overall clinical improvement, the following motions increased: for group one, there was an increase in left lateral flexion (**15.81%**) and right lateral flexion (**29.24%**). For group two, there was an increase in flexion (**7.13%**), extension (**9.49%**), left lateral flexion (**25.61%**) and right lateral flexion (**40.23%**). For group three, there was an increase in extension (**23.98%**), left lateral flexion (**20.33%**) and right lateral flexion (**26.47%**).

In terms of the Friedman test, the following motions showed statistically significant changes: for group one, left lateral flexion (**0.045**) and right lateral flexion (**0.014**). For group two, left

lateral flexion (**0.020**) and right lateral flexion (**0.003**). For group three, extension (**0.020**), left lateral flexion (**0.045**) and right lateral flexion (**0.001**).

In terms of the Wilcoxon Signed Ranks test, interval 1 is from the 1st to the 4th consultation and interval 2 is from the 1st to the 7th consultation. With reference to table 4.14., the following left lateral flexion motions showed statistically significant changes: group one, interval 1 (**0.022**); group two, interval 2 (**0.022**); and group three, interval 1 (**0.013**) and 2 (**0.022**). With reference to table 4.17., the following right lateral flexion motions showed statistically significant changes: group one, interval 1 (**0.037**); group two, interval 2 (**0.009**); and group three, interval 2 (**0.005**).

Group one and three showed that no clinically significant changes occurred with the Digital Inclinometer measurements in flexion. This could be due to participants proceeding to do their normal daily activities which may have caused the LBP unknowingly in the first place resulting in muscle spasm, therefore limiting the given ROM. All three groups did however show that no statistically significant changes occurred in lumbar flexion ROM.

The overall clinical improvements for flexion and extension that have shown an increase above could be due to the lumbar spine being generally more flexible in flexion and extension than other lumbar ranges of motion. The lumbar spine accounts for approximately 75% of trunk flexion and extension and this increases significantly when flexion occurs from an extended position (Bergmann and Peterson, 2011). Lumbar spine flexion ranges from **40°-60°** whereas extension ranges from **20°-35°** (Magee, 2008). With reference to table 4.8., the mean values throughout the three groups for flexion ranged from **51.31°-59.49°** which were within the normal average ROM. With reference to table 4.10., the mean values throughout the three groups for extension ranged from **15.95°-21.75°** which was mostly below the normal average ROM.

Segmental lateral flexion averages approximately **6°** on either side. The lumbosacral junction has the least amount of motion with only half of the motion demonstrated on either side as compared to the other lumbar motion segments (Bergmann and Peterson, 2011). Tensile forces are created in the capsular ligaments as well as the intertransverse ligaments and ligamentum flavum on the contralateral side of lateral flexion. These tensile forces created within ligaments limit lateral flexion along with the anterior and posterior trunk

muscles (Levangie and Norkin, 2005). Lumbar spine lateral flexion ranges from **15°-20°** on either side (Magee, 2008). With reference to table 4.13., the mean values throughout the three groups for left lateral flexion ranged from **16.71°-22.67°** which were mostly within the normal average range. With reference to table 4.16., the mean values throughout the three groups for left and right lateral flexion ranged from **16.19°-22.69°** which were equally distributed below and within the normal average range. The values that were below the normal average range for both left and right lateral flexion were decreased due to pain.

The reason for the lower than average extension, left and right lateral flexion mean values was due to one of the main characteristics of low back pain discussed in chapter two and three. This characteristic is localised axial pain elicited by hyperextension and rotation with or without referred pain radiating to the buttocks and/or posterior or anterolateral thigh (Nedelka *et al.*, 2014). Another study (discussed in chapter two) mentions that the pain is made worse with lateral flexion, extension and rotation, and the pain is made better with forward flexion (Saravanakumar and Harvey, 2008).

Segmental muscle spasm present in areas of spinal dysfunction support the reflex connection theory to the anterior grey horn cells in the spinal cord (Gatterman, 2005). Chiropractic SMT can potentially normalise joint mechanics and cause the termination of the altered neurogenic reflexes that are commonly associated with joint dysfunction by blocking both the local and distal somatic and visceral effects. Adhesions are broken when the joint is gapped with SMT (Bergmann and Peterson, 2011).

A previous study suggests that LBP patients who will most likely respond to SMT can be identified accurately before receiving treatment (Flynn, Fritz, Whitman, Wainner, Magel and Renderio, 2002).

A clinical decrease was noted in flexion and extension but none of them were statistically significant changes. This may be partly or completely explained with the following statement: in terms of lumbar spine ROM, individual variability is considerable (Magee, 2008). Coupled motion is the notion that there is a consistent association of motion about one axis is linked to motion about another different axis therefore motions such as pure lateral flexion or rotation does not occur in isolation in the different spinal regions (Levangie and Norkin,

2005). Another possibility along with the reasons explained prior to this is that facet joint synovitis could have been a possible factor thus decreasing lumbar ROM.

An article concerned with SMT causing variable responses in the spinal kinematic and trunk muscle electromyography readings stated that an individual's response to SMT is variable and depends on the type of individual. It can range from no changes being experienced by some patients to the biggest changes experienced in other patients with highest pain levels. Researchers noticed that the largest changes happened in the sagittal plane where there was a change in ROM of more than 6° in patients who experienced the most amount of pain (Lehman and McGill, 2001).

Group three of this study had the most improvement in terms of the total ROM as it was the only group to have clinically and statistically significant (refer to table 4.10.) results in extension, left and right lateral flexion. However, the intra- and intergroup analysis of group three had no statistically significant changes occur although the interval 2 value (refer to table 4.11.) of group three came close. Perhaps with a longer clinical trial period, statistically significant results would have been produced. Group two had the most overall clinical improvement as the lumbar ROM increased in flexion, extension, left lateral flexion and right lateral flexion. However, group two only had statistically significant results for left and right lateral flexion. Left and right lateral flexion showed the most improvement as all three groups yielded clinically and statistically significant results. A possible explanation is that distractive adjustments are known to break adhesions, stretch tissues, restore mobility as well as the normal mechanoreceptive and proprioceptive input (Bergmann and Peterson, 2011). ESWT is known to cause the promotion of neovascularization as well as tissue repair and regeneration within bone, tendon and other soft tissues (Gruenwald *et al.*, 2013) and (Notarnicola and Moretti, 2012).

The outcome of the results of group three were the most interesting as this type of treatment would have led to thoughts of positive results as a combination of both treatments were given. It is well documented that SMT causes an increase in ROM and recently it was found that ESWT administered to the lumbar facet joints also played a role in increasing lumbar ROM (Nedelka *et al.*, 2014).

With reference to the Wilcoxon Signed Ranks test, the groups that had statistically significant results in interval 2 could be explained in the following manner: most dysfunction is usually self-limiting and/or minor, thus the individual is usually unaware of the issue and adapts via compensatory mechanisms to accommodate the structural or functional alteration (Bergmann and Peterson, 2011). Therefore, the period between the 1st and 7th consultations following the initial treatment could be enough to allow the body to correct the dysfunction.

This study was concerned with the treatment of LBP as a result of chronic lumbar facet syndrome. Considering the information above, the overall clinical trial period might have been too short to achieve desirable results.

Increased segmental muscle tone or spasm may result from restricted joint motion as muscles do not only create joint motion but can also prevent it. SMT as well as ESWT causes a reduction in muscle spasm and alters the sensory input towards the central nervous system (Bergmann and Peterson, 2011) and (Schmitz *et al.*, 2010).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The aim of this study was to determine whether a single treatment approach of extracorporeal shockwave therapy or chiropractic spinal manipulative therapy, compared to a combined treatment approach of chiropractic spinal manipulative therapy with extracorporeal shockwave therapy is effective with regards to pain, disability and lumbar range of motion in individuals with chronic lumbar facet syndrome. The results were based on the use of the Numerical Pain Rating Scale and the Oswestry Low Back Pain and Disability Questionnaire to assess subjective pain and disability as well as the Digital Inclinometer to assess objective lumbar range of motion. This study also aims to provide chiropractors and other health care practitioners with an alternative/additional modality in treating and managing chronic lumbar facet syndrome.

The intragroup analysis was done using the Friedman test and Wilcoxon Signed Ranks test. The intergroup analysis was done using the Kruskal Wallis test.

With regards to the Numerical Pain Rating Scale, it can be seen from the results obtained that all three groups showed improvement with regards to pain reduction. The intragroup analysis showed there was clinically and statistically significant changes that occurred in all three groups throughout the entire clinical trial period. Further analysis with the Kruskal Wallis test showed that there was no statistically significant change that occurred between the three groups. The results indicate that all three groups were effective with regards to the Numerical Pain Rating Scale, with group one showing the largest overall clinical improvement.

The results obtained using the Oswestry Low Back Pain and Disability Questionnaire also showed that all three groups had a reduction in their pain and disability. The intragroup analysis showed that there was a clinically and statistically significant change that occurred in all three groups throughout the entire clinical trial period. Further analysis using the Kruskal Wallis test revealed that there was no statistically significant change that occurred between the three groups. The results indicate that all three groups were effective with regards to the Oswestry Low Back Pain and Disability Questionnaire, with group one

showing the largest overall clinical improvement. Therefore, the participants of all three groups benefitted from the restoration of their ability to perform normal daily activities.

In terms of the Digital Inclinometer for lumbar ROM, the tested ranges of motion were lumbar flexion, extension, left lateral flexion and right lateral flexion. It was found that statistically significant changes were observed in only some ranges of lumbar spine motion in certain groups. Group one had clinically and statistically significant results in left and right lateral flexion only. Group two had clinically significant results in flexion, extension, left lateral flexion and right lateral flexion. Group two however, only had statistically significant results with left and right lateral flexion only. Group three had clinically and statistically significant results in extension, left lateral flexion and right lateral flexion.

With reference to chapter three and four, the Digital Inclinometer results for the three groups made it difficult to establish the best treatment protocol for the restoration of the lumbar spine ROM. This is due to the fact that most of the results were clinically significant and statistically insignificant. However, group two had the most clinically significant results, but group three demonstrated the most clinically and statistically significant results out of the three groups. This suggests that the combination treatment protocol was the most effective in the treatment of LBP due to chronic lumbar facet syndrome with regards to lumbar ROM.

Even though the combination treatment protocol was effective, it was not significantly better than the other two treatment protocols used in isolation.

6.2. Recommendations

It is recommended that the following should be considered for future research related to aspects of this study:

1. The overall sample size of this study was small, thus each group had a small number of participants. Therefore, a bigger overall sample size with more participants in each group could be more beneficial for the study in that the total population will be better represented and more information will be provided thus increasing the chances of yielding more statistically significant results.
2. A narrower age range could be used to determine whether the treatment protocols used in this study could work better for a specific age group.

3. A future study could be done utilizing an older age group looking into the effects of ESWT on degenerative joint disease in the spine.
4. The overall 4-week clinical trial period could be extended to either 6 or 8 weeks in the efforts of achieving more statistically significant results.
5. A control group could be utilized instead of a combination group to further analyse the effects of the SMT and ESWT on their own.
6. The objective data could include another method to even out the number of subjective and objective data recording methods.
7. One of the subjective data recording methods could be substituted with the pressure algometer which could be used directly on the facet joints to assess pain levels objectively.
8. The subjective and objective data could be recording before and after each treatment, thus more accurate readings will be recorded, and the study will have more information to analyse.
9. Consultation dates could be scheduled on specific dates so that all the participants of a certain group can receive treatment on the same day, thus ensuring that equal time frames between treatments will be kept, therefore valid and reliable outcomes will be ensured.
10. The same order of treatment in the combination group should be ensured by the researcher so either ESWT is administered first or SMT as this could alter the results of the study.
11. A following consultation one month after the clinical trial period could be included since this study was concerned with chronic lumbar facet syndrome so that the long-term effects of the treatment protocols could be analysed using the subjective and objective data recording methods.
12. Post-treatment protocols could be included and compared in future studies.

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APPENDIX A: Advertisement

RESEARCH

THE COMPARATIVE EFFICACY OF SPINAL MANIPULATIVE THERAPY AND EXTRACORPOREAL SHOCKWAVE THERAPY IN THE TREATMENT OF CHRONIC LUMBAR FACET SYNDROME

Chronic low back pain?

FREE Chiropractic treatment is what you need!

Do you have low back pain that has BEEN bothering you for the past few months?

If you are within the ages of 18 – 35 years old, please do not hesitate to come see me, *Lebogang Khesa*, at the University of Johannesburg Chiropractic Day Clinic and participate in a supervised chiropractic research study aimed at treating chronic low back pain.

The research study trials will take place between: June 2018 – July 2018

For more information, please contact Lebogang Khesa 0710483127

UJ Ethics Clearance Number: REC-01-73- 2018

Lebogang Khesa 0710483127	Lebogang Khesa 0710483127	Lebogang Khesa 0710483127	Lebogang Khesa 0710483127	Lebogang Khesa 0710483127	Lebogang Khesa 0710483127	Lebogang Khesa 0710483127

APPENDIX B: Case History

Research Copy

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

CASE HISTORY

Date: _____

Patient: _____ **File No:** _____

Occupation: _____ **Age:** _____ **Sex:** _____

Student: _____ **Signature:** _____

FOR CLINICIAN USE ONLY:

Initial visit clinician: _____ **Signature:** _____:

Case History: _____

_____

_____

_____

_____

_____

_____

_____

_____

Examination:

Previous: UJ Other Current: UJ Other

X-ray Studies:

Previous: UJ Other Current: UJ Other

Clinical Path. Lab:

Previous: UJ Other Current: UJ Other

Case status:

PTT: Conditional: Signed off: Final sign out:

Recommendations:

1

Students case history:

1. **Source of History:** _____

2. **Chief Complaint in patients own words:**

_____

_____

_____

_____

_____

3. PRESENT ILLNESS/PRIMARY COMPLAINT

Location	
Onset	
Duration	
Frequency	
Pain Character	
Progression	
Aggravating Factors	
Relieving Factors	
Ass Signs & Symptoms	
Previous Occurrence	
Past Tx and Outcomes	

4. PAST HISTORY

General Health Status	
Childhood Illnesses	
Adult Illnesses	
Psychiatric Illnesses	
Accidents	
Traumatic Injuries	
Surgeries	
Hospitalizations	

5. **ANY OTHER COMPLAINTS**

_____

_____

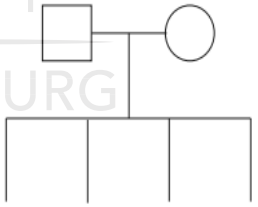
2

6. CURRENT HEALTH STATUS & LIFESTYLE

Allergies	
Immunizations	
Screening Tests	
Environmental Hazards	
Safety Measures	
Progression	
Exercise and Leisure	
Sleep Patterns	
Diet	
Current Mediation	
Tobacco	
Alcohol	
Social Drugs	
Other	

7. FAMILY HISTORY

Diabetes Mellitus	
Heart Disease	
TB	
HBP	
Stroke	
Kidney Disease	
Cancer	
Arthritis	
Anaemia	
Headaches	
Thyroid Diseases	
Epilepsy	
Mental Illness	
Alcoholism	
Drug Addiction	
Other	



8. PSYCHOSOCIAL HISTORY

Home Situation	
Daily Life	
Important Experiences	
Religious Beliefs	
Other	

9. REVIEW OF SYSTEMS

General	
Skin	
Head	
Eyes	
Ears	
Noses / Sinuses	
Mouth / Throat	
Neck	
Breasts	
Respiratory	
Cardiac	
Gastrointestinal	
Urinary	
Genital/Sexual Function	
Vascular	
Musculoskeletal	
Neurological	
Hematological	
Endocrine	
Psychiatric	
Other	

APPENDIX C: Physical Examination

Research Copy

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

PHYSICAL EXAMINATION

Underline abnormal findings in **RED**

Date: _____

Patient: _____ **File No:** _____

Clinician : _____ **Signature:** _____

Student: _____ **Signature:** _____

VITAL SIGNS

Height	
Weight	
Temperature	
Heart Rate	
Pulse	
Respiratory Rate	

BLOOD PRESSURE

	Left	Right
Arms		
Legs		

General Appearance

_____

_____

_____

STANDING EXAMINATION

Minor's Sign	
Skin Changes	
Posture • Erect • Adams	
Romberg's Sign	
Pronator Drift	
Trendelenburg Sign	
Gait • Rhythm • Balance • Pendulousness • On toes • On heels • Tandem	
Half Squat	
Scapular Winging	
Muscle Tone	
Spasticity / Rigidity	
Chest measurement • Inspiration • Expiration	_____ cm _____ cm
Visual Acuity	
Lumbar Spine ROM • Flexion (90º) • Extension (50º) • Lat. Flexion (30º) • Rotation (35º)	

1

SEATED EXAMINATION

Spinal Posture	
Head • Hair & Skin • Scalp • Skull • Face	
Eyes • Observation - Conjunctiva - Sclera - Eyebrows & Lids - Lacrimal Glands - Nasolacrimal Duct - Position - Alignment - Cornea / Lens • Corneal Reflex • Ocular Movements • Visual Fields • Accommodation • Ophthalmoscopy - Iris - Pupils - Red Reflex - Optic Disc - Macula - Vitreous - Lens	
Ears • Inspection - Auricle - Ear Canal - Drum • Auditory Acuity • Weber Test • Rinne Test	
Nose • External Inspection • Internal Inspection - Septum - Turbinate - Olfaction	
Sinuses • Tenderness • Transillumination	

SEATED EXAMINATION Cont.

Mouth & Pharynx • Lips • Buccal Mucosa • Gums & Teeth • Roof • Tongue - Inspection - Movements - Taste - Palpation • Pharynx – CN X	
TMJ • Inspection - ROM - Deviation • Palpation - Crepitus - Tenderness	
Neck • Posture • Size / Swellings • Scars • Discolorations • Hairline • Lymph Nodes • Tracheal Alignment • Thyroid & Carotids	
Cervical Spine ROM • Flexion (45°) • Extension (55°) • Lat. Flexion (40°) • Rotation (70°)	
Peripheral Vascular • Inspection - Pigmentation, Skin, Nailbeds, Hair loss • Palpation - Pulses, Lymph nodes, Skin Temp • Manual Compression • Retrograde Filling • Arterial Insufficiency • Allan's Test	

2

BREAST

Inspection • Skin • Size • Contour • Nipples • Arms Overhead • Hands Against Hips • Leaning Forward	
Palpation • Axillary Lymph Nodes • Breast • Breast tail	

THORAX – HEART AND LUNGS

Inspection • Skin • Shape • Respiratory Distress • Rhythm • Depth • Effort • Intercostal Retraction	
Palpation • Tenderness • Masses • Respiratory Expansion • Tactile Fremitus • JVP • PMI	
Percussion • Lungs (posterior) • Diaphgragmatic excursion • Kidney Punch	
Auscultation • Breath Sounds • Adventitious Sounds • Voice Sounds • Heart Auscultation • Heart Murmurs	

ABDOMINAL

Inspection • Skin • Umbilicus • Contour • Peristalsis • Pulsations • Hernias	
Auscultation • Bowel Sounds • Bruits	
Percussion • General • Liver • Spleen	
Palpation • Superficial Reflex • Cough • Light • Rebound Tenderness • Deep • Liver • Spleen • Kidneys • Aorta • Abdominal Masses • Shifting Dullness • Fluid Wave	
Acute Abdomen • Where pain began? • Moved to where? • Cough • Tenderness • Guarding / Rigidity • Rebound Tenderness	
Special Tests • Rovsing's Sign • Psoas Sign • Obturator Sign • Cutaneous Hyperaesthesia • Murphy's Sign • Rectal Examination	

MUSCULOSKELETAL

Shoulder • Observation - Skin - Symmetry • ROM - Glenohumeral - Scapulo-thoracic - Acromioclavicular - Elbow - Wrist		
Hip	Left	Right
• Flexion (90° / 120°)		
• Extension (15°)		
• Abduction (45°)		
• Adduction (30°)		
• Internal Rotation (40°)		
• External Rotation (45°)		
Knee	Left	Right
• Flexion (30°)		
• Extension (0° / 15°)		
Ankle	Left	Right
• Plantar Flexion (45°)		
• Dorsi Flexion (20°)		
• Inversion (30°)		
• Eversion (20°)		
Leg Length	Left	Right
• Apparent		
• Actual		

MENTAL STATUS

Appearance & Behavior • LOC • Posture • Motor Behavior • Dress, Grooming • Facial Expression • Affect	
Speed & Language • Quantity • Rate • Volume • Fluency • Aphasia (pm)	
Mood	
Memory • Orientation • Remote Memory • Recent Memory • New Learning Ability	
Higher Cognitive Function • Information • Vocabulary • Abstract Thinking	

CO-ORDINATION AND CEREBELLAR TESTING

Vertigo	
Ataxic Gait	
Nystagmus	
Intention Tremor	
Slurring/ Staccato Speech	
Hypotension	
Dysmetria (Point to point)	
Dysdiachokinesia	
Titubation	

CRANIAL NERVES

	Left	Right
CN I – Olfactory		
CN II – Optic		
CN III – Oculomotor		
CN IV - Trochlear		
CN V – Trigeminal • Motor • Sensory		
CN VI – Abducens		
CN VII – Facial • Motor • Sensory		
CN VIII - Vestibulocochlear		
CN IX – Glossopharyngeal		
CN X – Vagus		
CN XI – Spinal Accessory		
CN XII - Hypoglossal		

NEUROLOGICAL ASSESSMENT

DERMATOMES

	Left	Right
Cervical		
C2		
C3		
C4		
C5		
C6		
C7		
C8		
T1		
T2		
Lumbar		
T12		
L1		
L2		
L3		
L4		
L5		
S1		
S2		
S3		

REFLEXES

	Level	Left	Right
Cervical			
Biceps	C5		
Brachioradialis	C6		
Triceps	C7		
Lumbar			
Patella	L3 / L4		
Medial Hamstring	L5		
Lateral Hamstring	S1		
Tibialis Posterior	L4 / L5		
Achilles	S1 / S2		
Plantar Reflex			

NEUROLOGICAL ASSESSMENT

MYOTOMES

	Level	Left	Right
Cervical			
Neck Forward Flexion	C1 / C2		
Neck Lateral Flexion	C3		
Shoulder Elevation	C4		
Shoulder Abduction	C5		
Elbow Flexion	C5		
Elbow Extension	C7		
Elbow Flexion	C6		
Forearm Pronation	C6		
Forearm Supination	C6		
Wrist Extension	C6		
Wrist Flexion	C7		
Finger Flexion	C8		
Finger Abduction	T1		
Finger Adduction	T1		
Lumbar			
Hip Flexion	L1 / L2		
Knee Extension	L2 / L3 / L4		
Knee Flexion	L5 / S1		
Hip Internal Rotation	L4 / L5		
Hip External Rotation	L5 / S1		
Hip Adduction	L2 / L3 / L4		
Hip Abduction	L4 / L5		
Ankle Dorsiflexion	L4 / L5		
Ankle Plantar Flexion	S1 / S2		
Hallux Extension	L5		
Eversion	S1		
Inversion	L4		
Hip Extension	L5 / S1		

5

APPENDIX D: Lumbar Spine Regional Examination

Research Copy

UNIVERSITY OF JOHANNESBURG
CHIROPRACTIC DAY CLINIC

REGIONAL EXAMINATION
LUMBAR SPINE

Date: _____

Patient: _____ File No: _____

Clinician: _____ Signature: _____

Student: _____ Signature: _____

OBSERVATION

Body Type	
Posture	
Muscle Tone	
Bony Contours	
Soft Tissue Contours	
Skin	
Fasciculations	
Scars	
Discolourations	
Step Deformities	
Plumb lines • Frontal plane • Sagittal Plane	

MYOFASCIAL – ACTIVE TRIGGER POINTS

	Left	Right
Quadratus Lumborum		
Erector Spinae		
Gluteus Maximus		
Gluteus Medius		
Gluteus Minimus		
TFL		
Piriformis		
Hamstrings		
Iliopsoas		

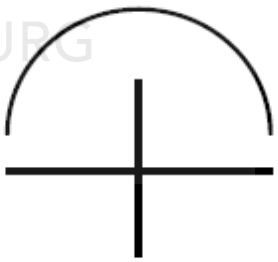
PALPATION

Iliac Crest	
Lumbar Spinous Process	
Muscle Bulk	
Sacro-iliac Joints	
Sacrum	

GAIT

Rhythm, Pendulousness	
On Toes (S1)	
On Heels (L4 / L5)	
Half Squat on One Leg	
Tandem Walking	

RANGE OF MOTION



1

NEUROLOGICAL ASSESSMENT

DERMATOMES

	Left	Right
T12		
L1		
L2		
L3		
L4		
L5		
S1		
S2		
S3		

NEUROLOGICAL ASSESSMENT

REFLEXES

	Level	Left	Right
Patella	L3 / L4		
Medial Hamstring	L5		
Lateral Hamstring	S1		
Tibialis Posterior	L4 / L5		
Achilles	S1 / S2		
Plantar Reflex			

REFLEX GRADING

- 4+ Very brisk, hyperactive. Perform ankle clonus.
- 2+ Average; normal
- 1+ Somewhat diminished; low normal.
- 0 No response

MUSCLE CIRCUMFERENCE

	Left	Right
Thigh	Cm	Cm
Calf	Cm	Cm

LEG LENGTH

	Left	Right
Actual	Cm	Cm
Apparent	Cm	Cm

NEUROLOGICAL ASSESSMENT

MYOTOMES

		Left	Right
Hip Flexion	L1 / L2		
Knee Extension	L2 / L3 / L4		
Knee Flexion	L5 / S1		
Hip Internal Rotation	L4 / L5		
Hip External Rotation	L5 / S1		
Hip Adduction	L2 / L3 / L4		
Hip Abduction	L4 / L5		
Ankle Dorsiflexion	L4 / L5		
Ankle Plantar Flexion	S1 / S2		
Hellux Extension	L5		
Eversion	S1		
Inversion	L4		
Hip Extension	L5 / S1		

MUSCLE GRADING

- 0 - No contraction detected
- 1 - Barely detectable flicker or trace of contraction
- 2 - Active movement with gravity eliminated
- 3 - Active movement against gravity
- 4 - Active movement against gravity and some resistance.

ABDOMINAL EXAMINATION

Observation	
Abdominal Reflexes	
Auscultation of Abdomen	
Auscultation of Groin	
Palpation of Abdomen	
Palpation of Groin	
Palpation of Abdominal Aorta	

PULSES

Femoral	
Popliteal	
Dorsalis Pedis	
Posterior Tibial	

ORTHOPAEDIC TESTS

	Left	Right
Standing		
Schober's Test		
Spinous Percussion		
Treadmill		
Minor's Sign		
Quick Test		
Trendelenburg's Test		
Seated		
Tripod Test		
Kemp's Test		
Valsalva Manoeuvre		
Supine		
SLR		
WLR		
Braggard's		
Bowstring's		
Sciatic Notch Pressure		
Sign of The Buttock		
Bilateral SLR		
Patrick Fabere's		
Gaenslen's Test		
'Squish' Test		
'Gapping' Test		
Gluteus Medius Stretch		
Thomas' Test		
Rectus Fem Contracture		
Hip Medial Rotation		
Psoas Test		
Lateral Recumbent		
Sacro-iliac Compression		
Ober's Test		
Femoral Nerve Stretch		
Prone		
Facet Joint Challenge		
Skin Rolling		
Erichsen's Test		
Sacro-iliac Tenderness		
Pheasant's Test		
Gluteal Skyline		

NON-ORGANIC TESTS

	Left	Right
Pin-Point pain		
Axial Compression		
Trunk Rotation		
Burn's Bench Test		
Flip Test		
Hoover's Test		
Ankle Dorsiflexion Test		
Pin-Point Pain		

MOTION PALPATION

	Left	Right
T7 / T8		
T8 / T9		
T9 / T10		
T10 / T11		
T11 / T12		
T12 / L1		
L1 / L2		
L2 / L3		
L3 / L4		
L4 / L5		
L5 / S1		
Sacro-iliac Joint		

GENERAL COMMENTS:

APPENDIX E: Information and Consent Form

DEPARTMENT OF CHIROPRACTIC

RESEARCH STUDY INFORMATION LETTER

Date: _____

Good Day

My name is Lebogang Khesa, **I WOULD LIKE TO INVITE YOU TO PARTICIPATE** in a research study on seeing whether a special machine called extracorporeal shockwave therapy will work in treating your back pain compared to traditional chiropractic treatment which involves the use of physical therapy/treatment to correct specific spinal dysfunction (chiropractic spinal manipulative therapy).

Before you decide on whether to participate, I would like to explain to you why the research is being done and what it will involve for you. **I will go through the information letter with you and answer any questions you have.** This should take about 10 to 20 minutes. The study is part of a research project being completed as a requirement for a Master's Degree in Chiropractic through the University of Johannesburg.

THE PURPOSE OF THIS STUDY is to determine whether extracorporeal shockwave therapy will work well for treating back pain compared to treatment with chiropractic spinal manipulative therapy to decrease pain and increase spinal range of motion (the amount of movement that can be achieved in the joints of the spine).

Below, I have compiled a set of questions and answers that I believe will assist you in understanding the relevant details of participation in this research study. Please read through these. If you have any further questions I will be happy to answer them for you.

DO I HAVE TO TAKE PART? No, you don't have to. It is up to you to decide to participate in the study. I will describe the study and go through this information sheet. If you agree to take part, I will then ask you to sign a consent form.

WHAT EXACTLY WILL I BE EXPECTED TO DO IF I AGREE TO PARTICIPATE? You will be required to go through a screening process whereby I will determine whether you qualify to participate in this study. If you qualify, you will then be put into one of the three groups by choosing a coloured file. Group one will receive chiropractic spinal manipulative therapy, group two will receive extracorporeal shockwave therapy, and group three will receive both treatments. The research study will last a total of four weeks per participant. Measurements/data will be collected before and after treatment on the first consultation. Measurements/data will then be collected again on the fourth and seventh consultations. The seventh consultation will be for collecting measurements/data only thus no treatment will occur in the fourth week.

WHAT WILL HAPPEN IF I WANT TO WITHDRAW FROM THE STUDY? If you decide to participate, you are free to withdraw your consent at any time without giving a reason and without any consequences. If you wish to withdraw your consent, you should inform me as soon as possible.

IF I CHOOSE TO PARTICIPATE, WILL THERE BE ANY EXPENSES FOR ME, OR PAYMENT DUE TO ME: If you participate in this research study, you will not be paid nor will you bear any expenses.

RISKS INVOLVED IN PARTICIPATION: There are minimal risks in participating in this study such as pain or discomfort lasting up to two days after receiving treatment, but this is normal due to the nature of the treatments. In the beginning of the treatment sessions, you may feel discomfort or pain during treatment with extracorporeal shockwave therapy, however I will

use the correct application techniques to minimise any pain caused by the machine. Muscle pain, redness or slight changes in skin colour may also occur over the area where extracorporeal shockwave therapy will be applied for up to two days after receiving treatment. Chiropractic spinal manipulative therapy may also be uncomfortable especially if your back pain is severe, but the manipulative techniques will be modified accordingly to reduce discomfort.

BENEFITS INVOLVED IN PARTICIPATION: You will benefit by receiving free chiropractic treatment for your back pain. Research has shown that chiropractic spinal manipulative therapy as well as extracorporeal shockwave therapy is beneficial for decreasing pain and increasing spinal range of motion, therefore you will benefit largely from these effects.

WILL MY PARTICIPATION IN THIS STUDY BE KEPT CONFIDENTIAL? Yes. Names on the questionnaire/data sheet will be removed once analysis starts. All data and back-ups thereof will be kept in password protected folders and/or locked away as applicable. Only I or my research supervisor will be authorised to use and/or disclose your anonymised information in connection with this research study. Any other person wishing to work with your anonymised information as part of the research process (e.g. an independent data coder) will be required to sign a confidentiality agreement before being allowed to do so.

WILL MY TAKING PART IN THIS STUDY BE ANONYMOUS? Yes. Anonymous means that your personal details will not be recorded anywhere by me. As a result, it will not be possible for me or anyone else to identify your responses once these have been submitted.

WHAT WILL HAPPEN TO THE RESULTS OF THE RESEARCH STUDY? The results will be written into a research report that will be assessed. In some cases, results may also be published in a scientific journal. In either case, you will not be identifiable in any documents, reports or publications. You will be given access to the study results if you would like to see them, by contacting me.

WHO IS ORGANISING AND FUNDING THE STUDY? The study is being organised by me, under the guidance of my research supervisor at the Department of Chiropractic in the

University of Johannesburg. This study will receive funding from the supervisor linked bursary.

WHO HAS REVIEWED AND APPROVED THIS STUDY? Before this study was allowed to start, it was reviewed in order to protect your interests. This review was done first by the Department of Chiropractic, and then secondly by the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg. In both cases, the study was approved.

WHAT IF THERE IS A PROBLEM? If you have any concerns or complaints about this research study, its procedures or risks and benefits, you should ask me. You should contact me at any time if you feel you have any concerns about being a part of this study. My contact details are:

Lebogang Khesa
0710483172
lebogangkhesa@gmail.com

You may also contact my research supervisor:

Dr M. Moodley
mmoodley@uj.ac.za

If you feel that any questions or complaints regarding your participation in this study have not been dealt with adequately, you may contact the Chairperson of the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg:

Prof. Christopher Stein
Tel: 011 559-6564
Email: cstein@uj.ac.za

FURTHER INFORMATION AND CONTACT DETAILS: Should you wish to have more specific information about this research project information, have any questions, concerns or complaints about this research study, its procedures, risks and benefits, you should communicate with me using any of the contact details given above.

Researcher:

Lebogang Khesa

Signature: _____

UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF CHIROPRACTIC

RESEARCH CONSENT FORM

THE COMPARATIVE EFFICACY OF SPINAL MANIPULATIVE THERAPY AND EXTRACORPOREAL SHOCKWAVE THERAPY IN THE TREATMENT OF CHRONIC LUMBAR FACET SYNDROME

Please initial each box below:

☐ I confirm that I have read and understand the information letter dated _____ for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

☐ I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving any reason and without any consequences to me.

☐ I agree to take part in the above study.

_____	_____	_____
Name of Participant	Signature of Participant	Date

_____	_____	_____
Name of Researcher	Signature of Researcher	Date

APPENDIX F: Chiropractic Spinal Manipulative Therapy Contra-indications (Bergmann and Peterson, 2011)

- Vascular complications
    - Vertebrobasilar insufficiency
    - Aneurysm
    - Atherosclerosis of major blood vessels
    - Clotting disorders
- Tumours
    - Primary to the bone
    - Secondary (metastasis to the bone)
- Space occupying lesions
- Uncarthrosis
- Osteoporosis (osteopenia)
- Bone infections
    - Tuberculosis of the spine
    - Osteomyelitis of the spine
- Traumatic injuries
    - Fractures
    - Severe sprains (instabilities)
    - Dislocation
    - Unstable spondylolisthesis
- Arthritis
    - Ankylosing spondylitis (acute)
    - Rheumatoid arthritis (acute)
    - Osteoarthritis (late stage)
- Psychological considerations
    - Malingering
    - Hysteria
    - Hypochondriasis
- Neurological complications
    - Diabetic neuropathy
    - Alzheimer disease

APPENDIX G: Extracorporeal Shockwave Therapy Contra-indications (Gerdesmeyer and Weil, 2007)

Absolute Contra-indications:

- Lung tissue in direction of sound fields
- Disturbances of coagulation
- Anti-coagulant therapies
- Circulatory disorders
- Tumour
- Local neurological disorders
- Pregnancy
- Infection
- Application to growth plates
- Pacemakers

APPENDIX H: Digital Inclinometer for Lumbar Range of Motion (Sadeghi *et al.*, 2015)

File No: _____

Lumbar ROM Readings:

Visit 1: **Date:** _____

	Flexion	Extension	L. Lateral Flexion	R. Lateral Flexion
T12				
S1				
True Lumbar ROM	_____ (65º)	_____ (30º)	_____ (25º)	_____ (25º)

Visit 4: **Date:** _____

	Flexion	Extension	L. Lateral Flexion	R. Lateral Flexion
T12				
S1				
True Lumbar ROM	_____ (65º)	_____ (30º)	_____ (25º)	_____ (25º)

Visit 7: **Date:** _____

	Flexion	Extension	L. Lateral Flexion	R. Lateral Flexion
T12				
S1				
True Lumbar ROM	_____ (65º)	_____ (30º)	_____ (25º)	_____ (25º)

APPENDIX I: Numerical Pain Rating Scale (Haefeli and Elfering, 2006)

File No: _____

Please indicate how much pain you have experienced since your last treatment.

Please mark in one of the boxes below to indicate the severity of your experienced pain.

0 being no pain at all and 10 being the worst pain you've ever experienced.

Visit 1: **Date:** _____

No pain Moderate pain Severe pain

0	1	2	3	4	5	6	7	8	9	10

Visit 4: **Date:** _____

No pain Moderate pain Severe pain

0	1	2	3	4	5	6	7	8	9	10

Visit 7: **Date:** _____

No pain Moderate pain Severe pain

0	1	2	3	4	5	6	7	8	9	10

APPENDIX J: Oswestry Low Back Pain and Disability Questionnaire (Fairbank and Pynsent, 2000)

File No: _____ **Visit No:** _____ **Date:** _____

This questionnaire has been designed to give us information as to how your back pain is affecting your ability to manage in everyday life. Please answer by checking **ONE** box in each section for the statement which best applies to you. We realise you may consider that two or more statements in any one section apply but please just shade out the spot that indicates the statement which most clearly describes your problem.

Section 1: Pain intensity	**Section 2: Personal care (washing, dressing, etc.)**
⌗ I have no pain at the moment ⌗ The pain is very mild at the moment ⌗ The pain is moderate at the moment ⌗ The pain is fairly severe at the moment ⌗ The pain is very severe at the moment ⌗ The pain is the worst imaginable at the moment	⌗ I can look after myself normally without causing extra pain ⌗ I can look after myself normally, but it causes extra pain ⌗ It is painful to look after myself and I am slow and careful ⌗ I need some help but manage most of my personal care ⌗ I need help every day in most aspects of self-care ⌗ I do not get dressed, I wash with difficulty and stay in bed
Section 3: Lifting	**Section 4: Walking**
⌗ I can lift heavy weights without extra pain ⌗ I can lift heavy weights, but it gives extra pain ⌗ Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently placed e.g. on a table	⌗ Pain does not prevent me walking any distance ⌗ Pain prevents me from walking more than 1 mile (1.6 kilometres) ⌗ Pain prevents me from walking more than 1/2 mile (800 meters) ⌗ Pain prevents me from walking more than 100 yards (91.4 meters)

⌗ Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned ⌗ I can lift very light weights ⌗ I cannot lift or carry anything at all	⌗ I can only walk using a stick or crutches ⌗ I am in bed most of the time
Section 5: Sitting	**Section 6: Standing**
⌗ I can sit in any chair as long as I like ⌗ I can only sit in my favourite chair as long as I like ⌗ Pain prevents me sitting more than one hour ⌗ Pain prevents me from sitting more than 30 minutes ⌗ Pain prevents me from sitting more than 10 minutes ⌗ Pain prevents me from sitting at all	⌗ I can stand as long as I want without extra pain ⌗ I can stand as long as I want but it gives me extra pain ⌗ Pain prevents me from standing for more than 1 hour ⌗ Pain prevents me from standing for more than 30 minutes ⌗ Pain prevents me from standing for more than 10 minutes ⌗ Pain prevents me from standing at all
Section 7: Sleeping	**Section 8: Sex life (if applicable)**
⌗ My sleep is never disturbed by pain ⌗ My sleep is occasionally disturbed by pain ⌗ Because of pain I have less than 6 hours sleep ⌗ Because of pain I have less than 4 hours sleep ⌗ Because of pain I have less than 2 hours sleep ⌗ Pain prevents me from sleeping at all	⌗ My sex life is normal and causes no extra pain ⌗ My sex life is normal but causes some extra pain ⌗ My sex life is nearly normal but is very painful ⌗ My sex life is severely restricted by pain ⌗ My sex life is nearly absent because of pain ⌗ Pain prevents any sex life at all
Section 9: Social life	**Section 10: Travelling**

⌗ My social life is normal and gives me no extra pain ⌗ My social life is normal but increases the degree of pain ⌗ Pain has no significant effect on my social life apart from limiting my more energetic interests e.g. sport ⌗ Pain has restricted my social life and I do not go out as often ⌗ Pain has restricted my social life to my home ⌗ I have no social life because of pain	⌗ I can travel anywhere without pain ⌗ I can travel anywhere but it gives me extra pain ⌗ Pain is bad, but I manage journeys over two hours ⌗ Pain restricts me to journeys of less than one hour ⌗ Pain restricts me to short necessary journeys under 30 minutes ⌗ Pain prevents me from travelling except to receive treatment

APPENDIX K: Institutional Research and Planning, Evaluation and Monitoring (IPEM) consent form

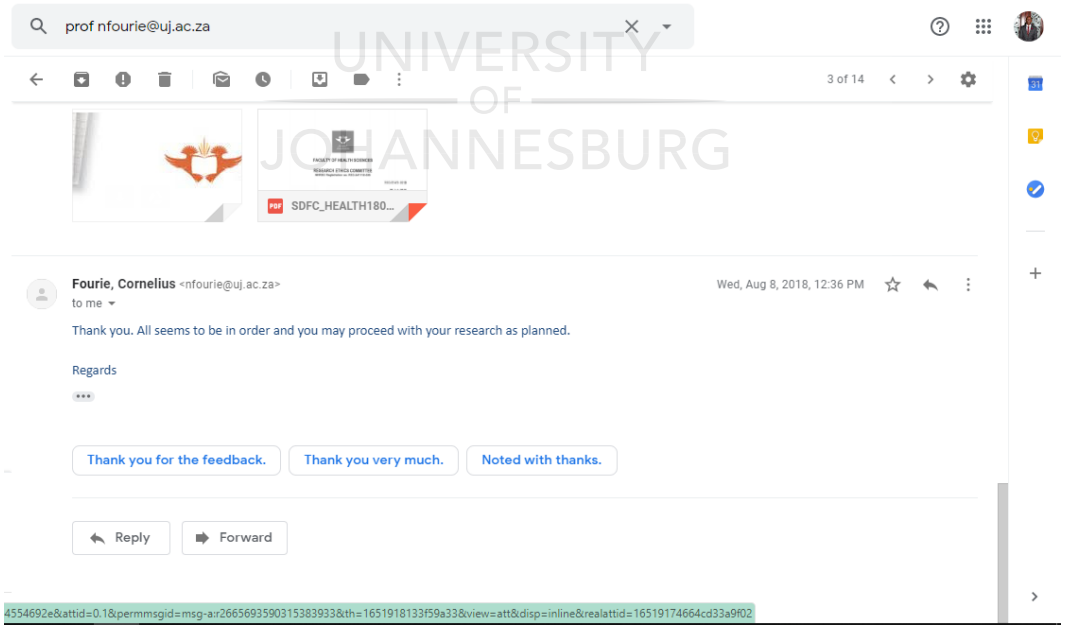
Dear Prof C.M Fourie

This letter is to serve as a consent from you as the director of IPEM to allow me, Lebogang Khesa 6th year Chiropractic student intern at the University of Johannesburg Doornfontein Campus, to conduct my research on possible student participants that are enrolled with the University of Johannesburg. My research trials will be conducted in the Chiropractic Clinic at the University of Johannesburg Doornfontein Campus.

The name of my research is *The Comparative Efficacy of Spinal Manipulative Therapy and Extracorporeal Shockwave Therapy in the Treatment of Chronic Lumbar Facet Syndrome*. A copy of my research proposal is attached for your perusal. Please read through it and let me know if I may proceed with my research trials. This letter will serve as proof of consent from IPEM.

Kind Regards

Lebogang Khesa 201214319



APPENDIX L: Research Ethics Committee Clearance Letter

FACULTY OF HEALTH SCIENCES

RESEARCH ETHICS COMMITTEE
NHREC Registration no: REC-241112-035

REC-01-73- 2018

30 July 2018

TO WHOM IT MAY CONCERN:

STUDENT: KHESA, LS
STUDENT NUMBER: 201214319

TITLE OF RESEARCH PROJECT: The Efficacy of Spinal Manipulative Therapy and Extracorporeal Shockwave Therapy in the Treatment of Chronic Lumbar Facet Syndrome

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr M Moodley **CO-SUPERVISOR:** -

The Faculty Research Ethics Committee has scrutinised your research proposal and confirm that it complies with the approved ethical standards of the Faculty of Health Sciences; University of Johannesburg.

The REC would like to extend their best wishes to you with your postgraduate studies.

Yours sincerely,

Prof C Stein
Chair : Faculty of Health Sciences REC
Tel: 011 559 6564
Email: cstein@uj.ac.za

APPENDIX M: Higher Degrees Committee Clearance Letter

FACULTY OF HEALTH SCIENCES

HIGHER DEGREES COMMITTEE

HDC-01-38- 2018

18 June 2018

TO WHOM IT MAY CONCERN:

STUDENT: KHESA, L
STUDENT NUMBER: 201214319

TITLE OF RESEARCH PROJECT: The Efficacy of Spinal Manipulative Therapy and Extracorporeal Shockwave Therapy in the Treatment of Chronic Lumbar Facet Syndrome

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr M Moodley CO-SUPERVISOR: -

The Faculty Higher Degrees Committee has scrutinised your research proposal and concluded that it complies with the approved research standards of the Faculty of Health Sciences; University of Johannesburg.

The HDC would like to extend their best wishes to you with your postgraduate studies

Yours sincerely,

Prof Y Coopoo
Chair: Faculty of Health Sciences HDC
Tel: 011 559 6944
Email: yogac@uj.ac.za

APPENDIX N: Plagiarism Tunit-in Report

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