The immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators.

By

Stefan le Roux

Dissertation submitted in partial compliance with the requirements for the Master's Degree in Technology: Chiropractic at the Durban University of Technology (DUT).

I, Stefan le Roux, do declare that this dissertation is representative of my own work in both conception and execution.

Stefan le Roux Date:

APPROVED FOR FINAL SUBMISSION BY:

Supervisor Date:
Dr C. Korporaal
Head of Department (HOD)-Chiropractic
M.Tech: Chiropractic (SA), CCFC (SA), CCSP (USA), ICCSD (USA)

DEDICATION

To my Lord and Savior, without whose grace, knowledge and guidance I could not have completed this.

To my parents, Johan and Cynthia. Your patience, commitment, support and unconditional love during the course of this journey have meant more to me than you will ever know. I am eternally grateful!

And to Jan, thank you is not enough!

"Healing is a matter of time, but it is sometimes also a matter of opportunity."

"Natural forces within us are the true healers of disease."

Hippocrates (460-377 B.C.*)-Greek Physician*

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The immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators.

Abstract

Literature overview:

Golfing literature today recommends to both the amateur and professional golfers to try and achieve maximum performance with each golf club (Seaman, 1998 and Bulbulian, Ball and Seaman, 2001). This encourages golfers to use a state of maximum spinal rotation in their golf swing in order to achieve optimal performance (Seaman, 1998), thus resulting in back pain becoming endemic in the golfing population.

Thus if it is considered that performance, in terms of the golf swing, is mainly influenced by;

- the strength and power of the torso, i.e. the low back and abdominal muscles (Chek, 2003),
- as well as muscle balance and flexibility, i.e. those muscles which are responsible for the static and dynamic postural stability of the golf swing (Chek, 2003).

It then stands to reason that any decrease in the range of motion of the lumbar or thoracic spine of the amateur golfer, in terms of biomechanics, could affect their performance (Nordin and Frankel, 2001). In this regard it is hypothesised that altered biomechanics could be that of asymptomatic segmental joint dysfunction[1].

In terms of interventions Kirkaldy-Willis and Burton (1992) explained the effect of SMT in the treatment of low back pain, similarly Bergmann et al. (1993) and Vernon and Mrozek (2005) further proposed the following effects of spinal manipulative therapy (SMT):

- SMT may stretch or break intra-articular adhesions that form from immobilised facet joints due to acute synovial reactions.

[1] For the purpose of this study segmental joint dysfunction will be classified as: hypomobility within a joint, which, by definition, is the clinically important status of the joint. If it is the purpose of manipulation to address dysfunction by improving mobility, then by definition, manipulation must be delivered to a joint with less-than-normal mobility (Vernon and Mrozek, 2005).

- SMT allows entrapped menisci to exit the facet joint in which it became entrapped.
- If the capsule of the facet gets lodged between two adjacent articular surfaces, the process of SMT could allow this to be freed.
- SMT re-aligns misaligned spinal segments to conform to the centre of gravity.

It was thus assumed that if these mechanical and reflex mechanisms occur in the symptomatic amateur golfer, they should also occur in the asymptomatic amateur golfer. Currently however very little is known about the effects of spinal manipulative therapy (SMT) on asymptomatic segmental joint dysfunction.

Objective:

Therefore, the purpose of this study was to evaluate the immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators.

Methods:

Forty three asymptomatic participants were randomized to four equal groups consisting of ten participants each (and three drop outs). Three of the groups received a single intervention, i.e. spinal manipulative therapy (SMT) while the last group acted as a placebo control group and received no intervention. Objective measurements were taken using the EDH Sports-FlightScope Pro Electronic Swing Analyser. All objective data collection took place pre and post SMT. Statistical analysis included various statistical methods and correlation analyses, by means of the latest version of SPSS.

Results and conclusions:

The main findings were that certain outcomes seem to be better with lumbar manipulation alone (smash, horizontal azimuth) and others better with thoracic manipulation alone (CHV, vertical azimuth, distance), but none are better with both lumbar and thoracic manipulation. Therefore in terms of future studies of this nature the treatment groups should be analysed separately and the research powered for such analyses (e.g. larger sample sizes).

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GLOSSARY:

Club Head Velocity (CHV)

CHV is the speed at which the golf club head makes contact with the golf ball (i.e. swing speed) and measured in miles per hour.

Vertical Azimuth (VA)

VA is the launch angle, measured in degrees (°), of the golf ball immediately after impact in the vertical plane.

Horizontal Azimuth (HA)

HA is the launch angle, measured in degrees (°), of the golf ball immediately after impact in the horizontal plane. It indicates the degree to which the ball was hit to the left or right of the target from the point of origin.

Smash

The smash ratio is the relationship between club head velocity (CHV) and ball velocity. This is a good indication of how solidly the ball was struck.

Smash ratio	**Strike**
1.30-1.35	Poor strike
1.35-1.45	Good strike
1.45-1.55	Great strike
1.55-1.65	Hit like a Pro

Distance

Defined as the distance in meters (m) to which the golf ball travels and is limited to air travel only.

Appendix A: Case History

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CHAPTER 1

1.1 Introduction

Back pain concomitant with a decrease in range of motion, is considered endemic in the golfing population as a result of the adoption of the "modern" golf swing. Notwithstanding this, golfing literature recommends to both the amateur and professional golfer to try and achieve maximum performance with each golf club (Seaman, 1998 and Bulbulian, Ball and Seaman, 2001). This therefore, encourages golfers to use a state of maximum spinal rotation in their golf swing in order to achieve optimal performance (Seaman, 1998).

In this regard Chek (2003) has shown that optimal performance, in terms of the golf swing, is mainly influenced by:

- the strength and power of the torso, i.e. the low back and abdominal muscles,
- as well as muscle balance and flexibility (Chek, 2003).

It then stands to reason that any decrease in the range of motion of the lumbar or thoracic (back) spine of the golfer, in terms of biomechanics, could adversely affect their performance. This is congruent with Nordin and Frankel (2001) who state that, in terms of lumbar and thoracic spinal biomechanics, range of motion differs at various levels of the spine depending on the orientation of the relevant zygapophyseal or facet joints within an anatomical motion segment. Thus it could be hypothesised that altered biomechanics / range of motion within an anatomical motion segment, could result in segmental joint dysfunction[1], presenting either symptomatically or asymptomatically.

[1] For the purpose of this study segmental joint dysfunction will be classified as: hypomobility within a joint, which, by definition, is the clinically important status of the joint. If it is the purpose of manipulation to address dysfunction by improving mobility, then by definition, manipulation must be delivered to a joint with less-than-normal mobility (Vernon and Mrozek, 2005).

In this regard, Kirkaldy-Willis and Burton (1992) explained the effect of spinal manipulative therapy (SMT) on a restricted motion segment in the treatment of low back pain on the grounds of certain mechanical and reflex mechanisms, which are known to be present in symptomatic golfers and may or may not be present in the asymptomatic golfer.

In addition Bergmann et al., (1993) and Vernon and Mrozek (2005) proposed the following effects of SMT, which are congruent with the findings of Kirkaldy-Willis and Burton (1992):

- SMT may stretch or break intra-articular adhesions that form from immobilised facet joints due to acute synovial reactions.
- SMT allows entrapped menisci to be freed within the facet joint in which was it became jammed.
- If the capsule of the facet gets lodged between two adjacent articular surfaces, the process of SMT could allow this to be freed.
- SMT re-aligns misaligned spinal segments to conform to the centre of gravity.

It is therefore assumed that if these mechanical and reflex mechanisms occur in the symptomatic amateur golfer, they should also occur in the asymptomatic amateur golfer. Currently however very little is known about the effects of SMT on asymptomatic segmental joint dysfunction.

Therefore this research aimed at evaluating the immediate and short term effect of SMT on asymptomatic amateur golfers in terms of performance indicators.

1.2 Aims and objectives of this study

The aim of this study was to evaluate the immediate and short term effect of SMT on asymptomatic amateur golfers in terms of performance indicators.

The Objectives

1.2.1 Objective One

Was to assess the significance of the change from pre to post treatment (immediate effects) and from pre to final treatment (short term effects) in the combined treatment groups (n=30).

Hypothesis 1:

SMT would show no significant immediate or short term effect on the performance indicators of asymptomatic amateur golfers.

1.2.2 Objective Two

Was to compare the short term treatment effect between the pooled treated groups (n=30) and the control group (n=10) (2 group comparison).

Hypothesis 2:

SMT would show no significant difference (in the short term) in treatment effect between the two groups, i.e. the pooled treated group and the control group.

1.2.3. Objective Three

Was to compare the treatment effect between all three treatment groups (n=10) and the control group (n=10) (4 group comparison).

Hypothesis 3:

SMT would show no significant difference in terms of treatment effect between all four groups, i.e. the three treatment groups and the control group.

1.3 Rationale and benefits of the study

Literature encourages golfers to use a state of maximum spinal rotation in their golf swing to achieve optimal performance, particularly related to club head velocity (CHV) (measurement of the speed at which the club head hits the golf ball prior to imparting the energy to the ball) and distance (measurement of the ball flight distance) (Seaman, 1998; Bulbulian, Ball and Seaman, 2001).

Therefore, it is assumed that a decrease in range of motion in the lumbar and thoracic spinal segments would essentially lead to altered swing mechanics and a decrease in overall swing performance. To overcome this, SMT has been shown to have a therapeutic effect on patients suffering from mechanical low back pain (Kirkaldy-Willis and Burton, 1992) on the grounds of certain mechanical and reflex mechanisms. However, the effect of SMT on the asymptomatic golfer is relatively unknown (Jermyn, 2004). It could however be assumed that these same mechanisms would be present in the asymptomatic golfer when SMT is applied. This could result from increased lumbar and thoracic segmental range of motion and its related mechanical and reflex mechanisms, which produces better swing mechanics as well as improved muscle flexibility (Seaman, 1998). This will then lead to an increase in overall performance indicators related to the golf swing, which would be measurable.

1.4 Benefits of the study

The results of this study would be twofold as it will show the efficacy of SMT on asymptomatic amateur golfers, but it may also show to have positive effects on the professional golfer who has to perform more consistently at optimal levels.

1.5 Limitations

For statistical purposes and reporting, this study did not include the analysis of the mechanical aspects of the golf swing.

It also did not include any other objective measurements with regards to lumbar and thoracic range of motion, and it did not take into account the effects or factors related to golf ball travel (distance) such as wind factors.

1.6 Conclusion

With respect to the above introduction, Chapter Two will discuss the literature in greater detail, followed by Chapter Three which highlights the methodology relevant to this study. Chapter Four reports the findings. Chapter Five discusses the results of this study, and presents the conclusions and recommendations based on the outcomes of this study.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter contains the literature related to the core of the research. It is concerned with the anatomy and biomechanics of the thoracic spine, lumbar spine as well as the pelvis, and how this relates to the biomechanics of the golf swing.

This chapter also covers asymptomatic joint dysfunction, its treatment, and its possible effect on the performance indicators of asymptomatic amateur golfers.

2.1 The Anatomy and Biomechanics of the Thoracic spine

According to Bergmann et al., (1993); Moore (1992); Edmondston and Singer (1997); Moore and Dalley (1999) the thoracic spine's primary function is protection of the vital organs (heart, lungs and those organs in the upper abdomen). In order to achieve this, the thoracic cage consists of 12 pairs of ribs and costal cartilages, 12 thoracic vertebrae and intervertebral discs (IVD) as well as the sternum (Moore, 1992; Moore and Dalley, 1999). These structures and their interaction with each other provide a great amount of stability to the thoracic spine (Moore and Dalley, 1999; Edmondston and Singer, 1997). Another contributing factor to the stability of the thoracic spine is the complex nature in which the ribs attach to the thoracic vertebrae and IVD via the radiate ligament and strong intercostal fascia (Edmondston and Singer, 1997). These arrangements not only provide considerable stiffness in terms of motion, but it also allows for a transition between the more mobile cervical and lumbar spines (Willems et al., 1996). Thus this emphasis on the stability function of the thoracic spine is of such importance that it takes precedence even over intersegmental mobility (Bergmann et al., 1993), and thus predisposes to the increased likelihood for decreased functional ability (segmental dysfunction), which may affect the golf swing adversely.

The above is further complicated by the transition from the cervical to thoracic to lumbar spine, which is not only associated with specific changes in the zygapophyseal or facet joint orientation but also with respect to vertebral body dimensions. These changes regionalize the thoracic spine into upper, middle and lower divisions which is also reflected in the distribution of primary movements (Willems et al., 1996). Willems et al., (1996) goes on to state that it may be possible to regard the upper thoracic spine as part of the cervical spine because this area usually allows for the same sided coupling characteristics of the cervical region, especially in rotation and lateral flexion. Similarly the same can be said of the lower thoracic spine and its relationship to the lumbar spine. This was further noted in a study done by Willems et al., (1996) where sixty healthy participants 30 male and 30 female aged between 18-24 were measured for primary and combined movements in the upper, middle and lower thoracic areas, i.e. T1-4, T5-8 and T9-12. Using an external, three-dimensional measurement devise and it was found that rotation was the dominant motion of the upper thoracic region followed by flexion/extension and lateral flexion motion. The middle thoracic region (T5-8) accounted for half of the total thoracic rotation range with the lower thoracic region (T9-12) exhibiting the least rotation, which is more in keeping with the range of motion displayed in the lumbar spine (Bergmann et al., 1993). These ranges of motion are enhanced by the “mortise” type morphology of the facet joints as well as the near sagittal alignment of the upper lumbar articulations which facilitate further torsional stiffness on the thoracolumbar junction region (Edmondston and Singer, 1997).

The findings of Willems et al., (1996), where substantiated by Edmondston and Singer (1997), who found that the thoracic spine posture is likely to have an important influence on the range and pattern of movement, yet very little is known of the relative influence of the factors which determine the resting spinal curvature. They also noted that normal variations in skeletal anatomy and joint morphology exist in the thoracic spine, especially where facet joint asymmetry of greater than 20º has been reported. This was the case in greater than 30% of examined individuals at the thoracolumbar junction. However, the extent to which these features of degeneration and pathoanatomy are related to symptoms in the thoracic spine are unclear; even though studies of the cervical and lumbar regions indicate that structural changes do influence the range and patterns of spinal movement as well as patient symptomatology (Edmondston and Singer, 1997). Thus it should at the very least be considered that postural abnormalities could play a part in the development of spinal pain, even though most quantitative studies have been unable to establish such a relationship (Edmondston and Singer, 1997).

To complicate the above movement parameters, often the innervation of the thoracic spine, which according to Moore and Dalley (1999) constitutes twelve (12) pairs of spinal nerves that divide into both a dorsal and ventral rami as soon as it exits the intervertebral foramina, is responsible for the pain that symptomatic golfers feel. This pain, may radiate along the length of the ventral rami of the first eleven (11) pairs of nerves form the intercostal nerves that run along the extent of the intercostal spaces or that of the T12 ventral ramus which runs inferior to the 12th ribs (subcostal nerve) (Moore and Dalley, 1999). This innervation is seen as a referred pain, as the principle originator of pain is the dorsal rami of the thoracic spinal nerves, which passes posteriorly and immediately lateral to the articular processes and zygopophyseal joints (Edmondston and Singer, 1997; Moore and Dalley, 1999). In asymptomatic golfers however, this portion of the clinical picture is absent as the acute inflammatory phase which is often associated with the pain has resolved (Leach, 1994; Vernon and Mrozek, 2005).

2.2 The Thoracolumbar junction

With respect to the golfer, the thoracolumbar junction is of greater importance, as Bergmann et al., (1993) noted that the thoracolumbar region was primarily characterized by the change from a more restricted primary kyphotic curve in the thoracic spine to the more mobile secondary lordotic curve of the lumbar spine.

In line with Cramer and Darby (2005) and in accordance with Bergmann et al., (1993) the most significant structural characteristics in the thoracolumbar region of the spine is the change in the facet orientation from the semi-coronal plane in the thoracic spine to the sagittal plane in the lumbar spine. Bergmann et al., (1993) as mentioned in Delgado (2005) stated that this transition could occur anywhere between T10 and L1. According to Giles and Singer (1997) this transition area can be seen as a potential “weak spot” in the spine, especially when placed under combined axial and torsional stress. The undue placement of external stressors on this part of the spine is magnified further by the fact that the thoracolumbar junction also plays an important role as a site of muscle attachment [i.e. the thoracolumbar paraspinals (erector spinae, transversospinalis and intersegmental muscles as well as the lattisimus dorsi, quadratus lumborum, psoas major as well as transverse abdominus muscles also attach to the area (Luttgens et al., 1992; Moore and Dalley, 1999)].

Table 1: Muscles of the spine with local action (Thoracic and Lumbar)

Muscle name	Muscle action	Innervation	Action related to the golf swing
Erector spinae			
Iliocostalis Longissimus Spinalis	Acting bilaterally they extend the vertebral column and control movement during flexion. Unilaterally they laterally bend the vertebral column.	Dorsal rami of spinal nerves.	Right and left muscles contract nearly symmetrically during the downswing to help with spinal stabilization. These muscles have a spinal protective role (Seaman, 1998).
Transversospinalis			
Multifidus	Stabilize movements of the vertebral column and assist with local extension and rotary movements.	Dorsal rami of spinal nerves.	Opposes flexion of the abdominal muscles as they produce rotation (Seaman, 1998).
Rotatores	Stabilize movements of the vertebral column and assist with local extension and rotary movements.	Dorsal rami of spinal nerves.	Opposes flexion of the abdominal muscles as they produce rotation (Seaman, 1998).
Intersegmental			
Interspinalis	Aid in extension and rotation in the vertebral column.	Dorsal rami of spinal nerves.	
Intertranversari	Aid in lateral bending of the vertebral column. Bilaterally they stabilize the	Dorsal and ventral rami of spinal nerves.	

	vertebral column.		

(Moore and Dalley, 1999; Travell and Simons, 1999)

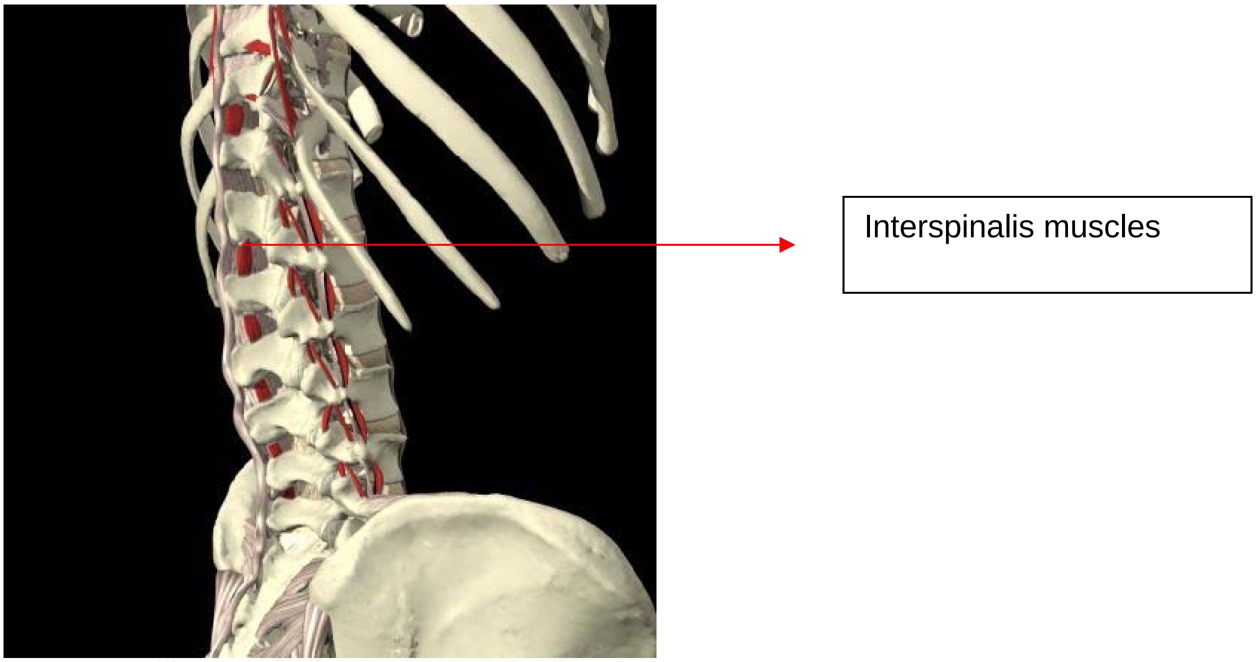

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Figure 1: Interspinalis muscles

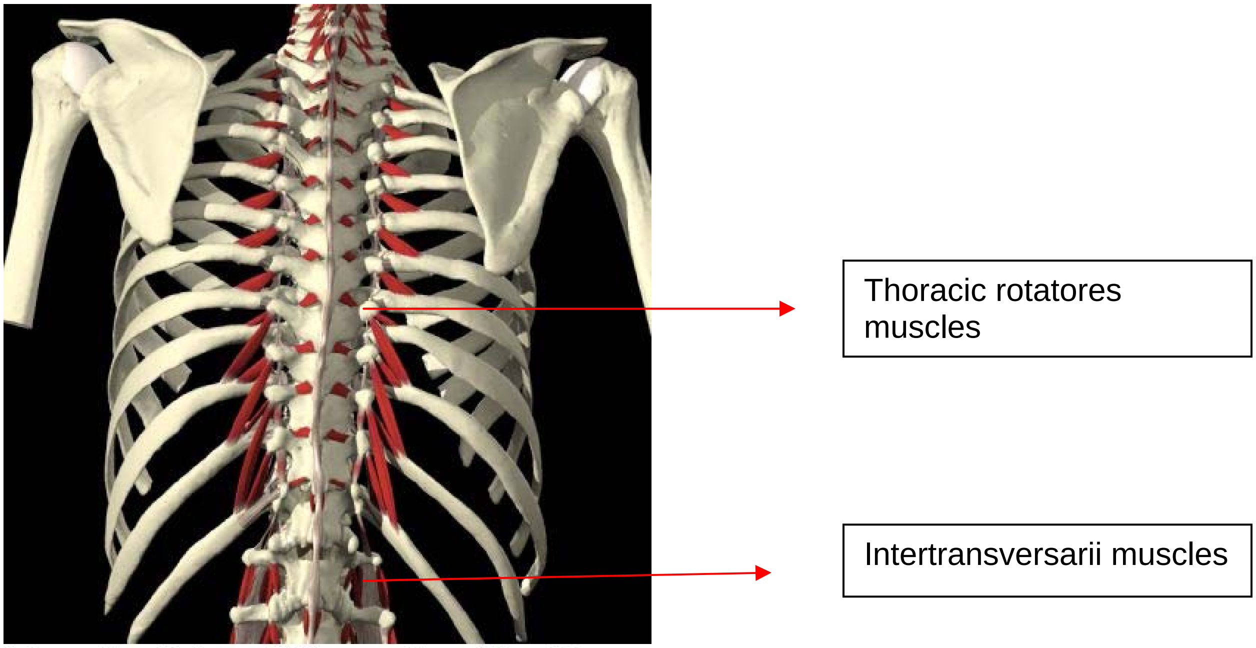

Figure 2: Thoracic rotatores and intertransversarii muscles

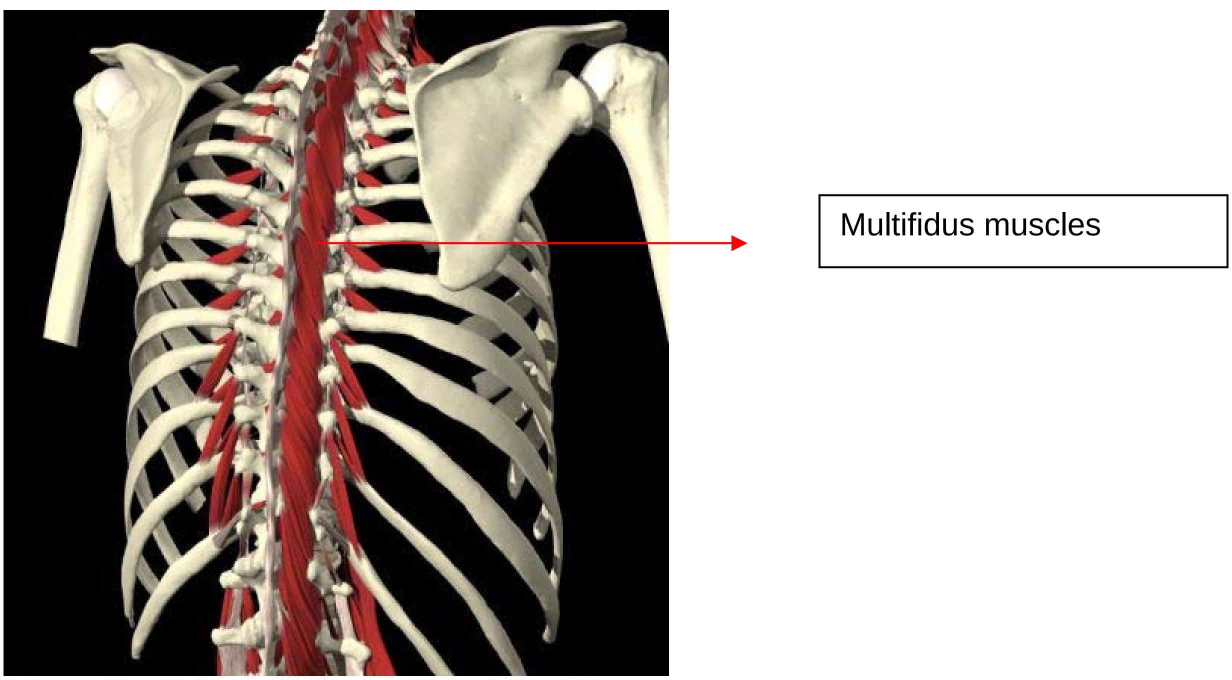

Figure 3: Multifidus muscles

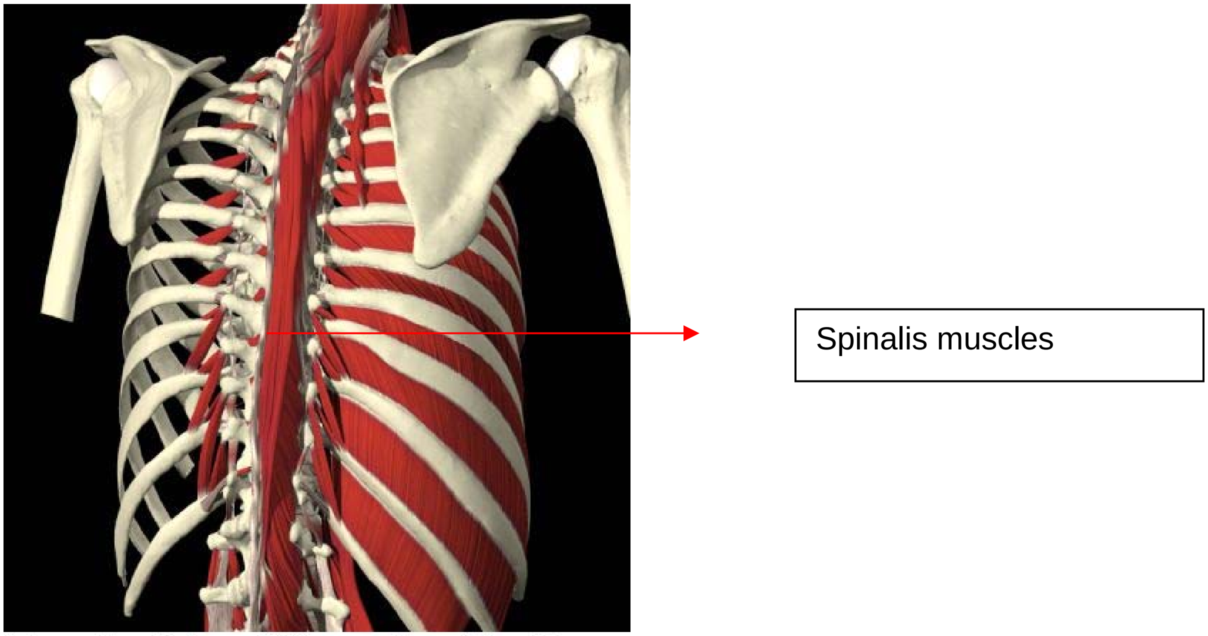

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Figure 4: Spinalis muscles

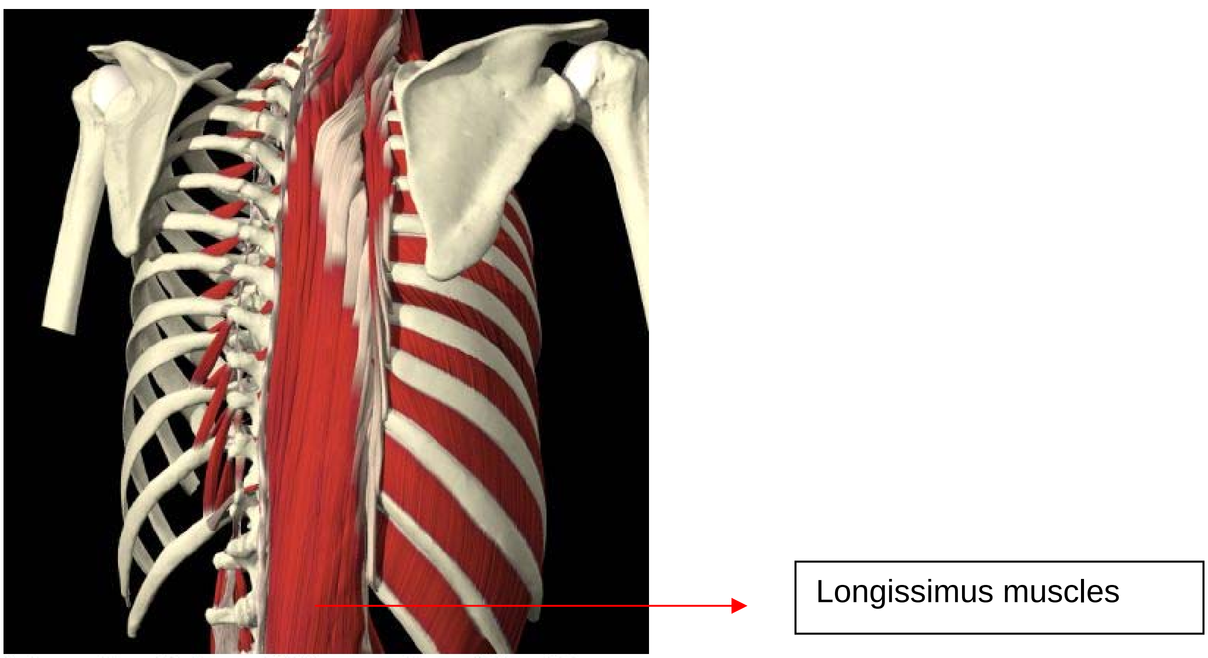

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Figure 5: Longissimus muscles

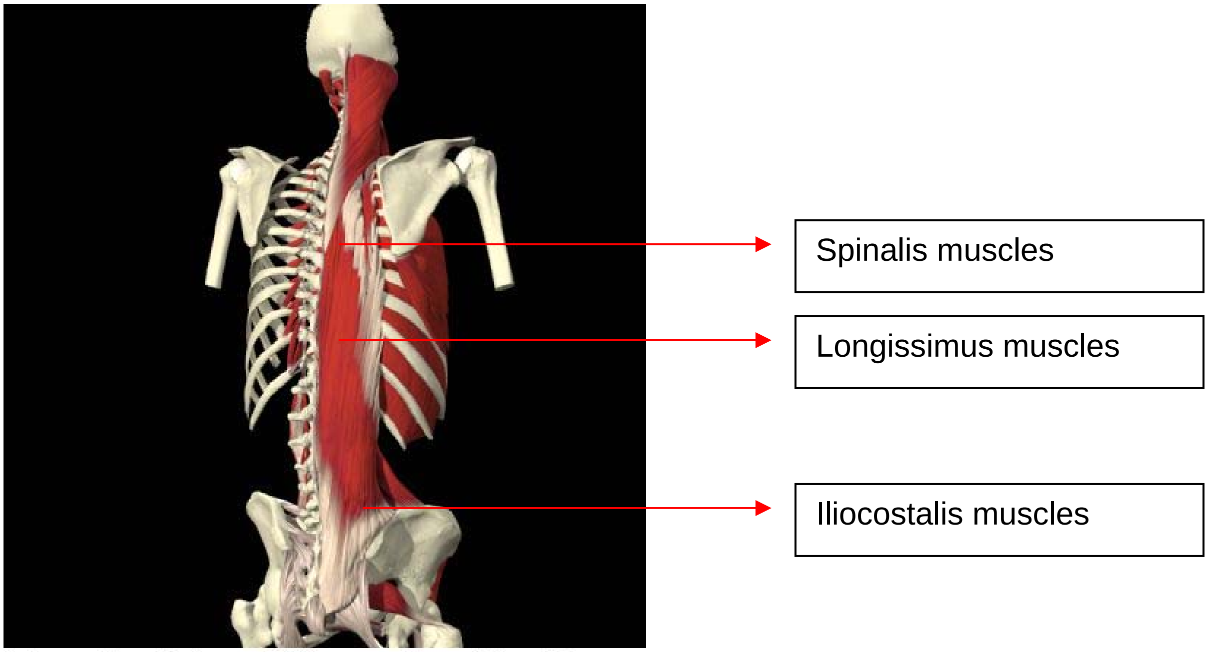

Figure 6: Spinal musculature

In addition it should be further remembered that the thoracolumbar fascia (ThLF), although not a muscle, it functions primarily as a low back stabilizer by keeping the deep muscles of the spine and erector spinae muscles close to the skeletal structure as well as a structure that transfers energy / forces through the lower back from the lower extremity to the upper extremity and vice versa (Luttgens et al., 1992). In this respect Lattisimus dorsi is one of the principle muscle used to transfer force between the upper and lower extremity (Seaman, 1998). According to Mould (2003) an imbalance between the lattisimus dorsi and its antagonists, the gluteus medius and maximus on the contralateral side of the thoracolumbar fascia, could lead to decreased range of motion in the sacro-iliac joints. Harrison et al., (1997) confirmed this by stating that one of the functions of the thoracolumbar fascia is that of sacro-iliac joint compression as an aid for energy transfer.

The above is further supported by the ligamentous structures of the lumbar spine and sacroiliac joints, as these merge with the ThLF and as well as provide primary attachment sites for the main movers and stabilizers of the lower extremities. These include muscles like gluteus maximus, gluteus medius, multifidus, biceps femoris, psoas and piriformis muscles respectively (Harrison et al., 1997; Seaman, 1998; Mould, 2003).

These functions of the muscles, fascia, ligaments and joints play a role in the attainment of the optimal golf swing (Mackey, 1995).

2.3 The Anatomy and Biomechanics of the Lumbar spine

The lumbar spine makes up 25% of the total length of the vertebral column and consists of five lumbar vertebrae (Mackey, 1995). In terms of the difference between the thoracic spine and the lumbar spine, is that the lumbar vertebrae are distinguished by the size of their vertebral bodies, their sturdy and stocky laminae and then also the absence of costal facets (Moore and Dalley, 1999). However, similarly to the thoracic spine the lumbar spine has two posterior spinal articulations known as zygapophyseal or facet joints between each of the successive vertebrae. In addition each facet joint surface is lined with hyaline cartilage and has an intracapsular fibrocartilagenous disc that separates the joint surfaces (Bergmann et al., 1993). As a result the facet joints of the lumbar spine are classified as “diarthrodial” (Moore and Dalley, 1999), thus the superior articulating processes of the lumbar spine are concave and face posterior and medial, where the inferior articulating processes are convex and face anterior and lateral (Gatterman, 1990). Shafer and Faye (1990) described the plane of these lumbar facets as being near parallel to the vertical plane in the upper lumber spine and change from this sagittal plane orientation to a more coronal plane orientation in the lower lumbar region (Gatterman, 1990). Because of the slightly more horizontal lumbosacral facet plane angle in relation to the lumbar vertebral segments above, greater antero-posterior (A-P), postero-anterior (P-A) and lateral motion are allowed and therefore less joint locking occurs at this level (Schafer and Faye, 1990). Also of importance is the horizontal and anterior inclination of L5 that becomes progressively more vertical as we move up the lumbar spine, i.e. L4 to L1 (Schafer and Faye, 1990), resulting in decreased / altered motion parameters. These changes within the lumbar spine articulations are unique to each individual and therefore the application of a particular technique for all golfers may not allow for optimal performance for a particular golfer. This may also result from the fact that certain golfers with a particular anatomical constitution may be more predisposed to motion restrictions more readily than others (Leach, 1994) impeding their optimal performance.

Also in similarity to the thoracic spine and according to Souza (1997), facet joints are innervated by the medial branch of the dorsal ramus. The origin of this branch in turn arise from the lumbar nerves at each respective level, with each facet joint receiving innervation from both the nerve exiting at that level and the adjacent superior nerves bilaterally (Moore and Dalley, 1999).

Facet joints of the lumbar spine make up two of the three joints of the three joint complex with the center of motion being near the center of the third joint-the intervertebral disc (IVD) (Mackey, 1995).

The intervertebral disc (IVD), which in total constitutes 22 to 33% of the entire vertebral column, is composed of the inner nucleus pulposis, the surrounding annulus fibrosis as well as the superior and inferior cartilaginous endplates (Mackey, 1995). According to Bergmann et al., (1993) the unique and resilient structure of the IVD allows for its function in weight bearing and motion. The nucleus pulposis is the central core of the IVD and is located more posteriorly than centrally (Nordin and Frankel, 2001). Because of its high water content it adds mobility to the spine as well as an even dispersion of forces in all directions (Gatterman, 1990). This structure also acts like a semi fluid ball bearing during flexion (moving posteriorly), extension (moving anteriorly), rotation and lateral flexion (moving laterally in the opposite direction) of the vertebral column (Moore and Dalley, 1999). The annulus fibrosis as described by Moore and Dalley (1999) has a ring-like structure consisting of concentric lamella of fibrocartilage forming the circumference of the IVD. The fibers forming each lamella run obliquely from one vertebra to another, and typically run at right angles to those of the adjacent ones. This arrangement, although allowing some movement between adjacent vertebrae, provides a strong cohesiveness between them (Moore and Dalley, 1999). Cartilaginous endplates consist of hyaline cartilage and it separates the IVD from the vertebral endplate (Mackey 1995).

Thus as we can see from the abovementioned literature flexion and extension (in the sagittal plane) is the most common movement of the lumbar spine, followed by lateral flexion in the coronal plane. It should be noted that these three movements are those in which the greatest likelihood is of disc injury and therefore also the movements in which muscular, ligamentous and fascial support is required to prevent injury.

Table 2: Muscles of the spine with global action (Thoracic and Lumbar)

Muscle name	Muscle action	Innervation	Action related to the golf swing
Deep Lateral muscles			
Quadratus Lumborum	Assists with inspiration by fixing the twelve ribs. Unilateral action: laterally flexes the spine ipsilaterally. Bilateral action: extends the spine.	Branches of the lumbar plexus from spinal nerves T12/L1 to L4.	Assists with lateral flexion and extension during the golf swing.
Psoas Major	Flexes the spine when sitting up from supine position.	Branches of the lumbar plexus L2 to L4.	Contributes to flexion of the spine and has a protective role resisting torsional forces (Mallare, 1996).
Latissimus Dorsi	Extends and rotates the humerus medially. Powerful adductor in conjunction with Pectoralis major.	Thoracodorsal nerve.	Contracts bilaterally during the acceleration phase of the golf swing (Tibone et al., 1994).
External Oblique	Compress and support abdominal viscera. Flexion and rotation of the trunk.	Thoraco-abdominal nerves (Inferior 6 thoracic	In right handed golfers the left external oblique is primarily responsible for initial rotation of the spine and torso in the take away

		nerves) and subcostal nerve.	phase. The right external oblique contracts maximally during the downswing phase (Seaman, 1998).

(Moore and Dalley, 1999; Travell and Simons, 1999)

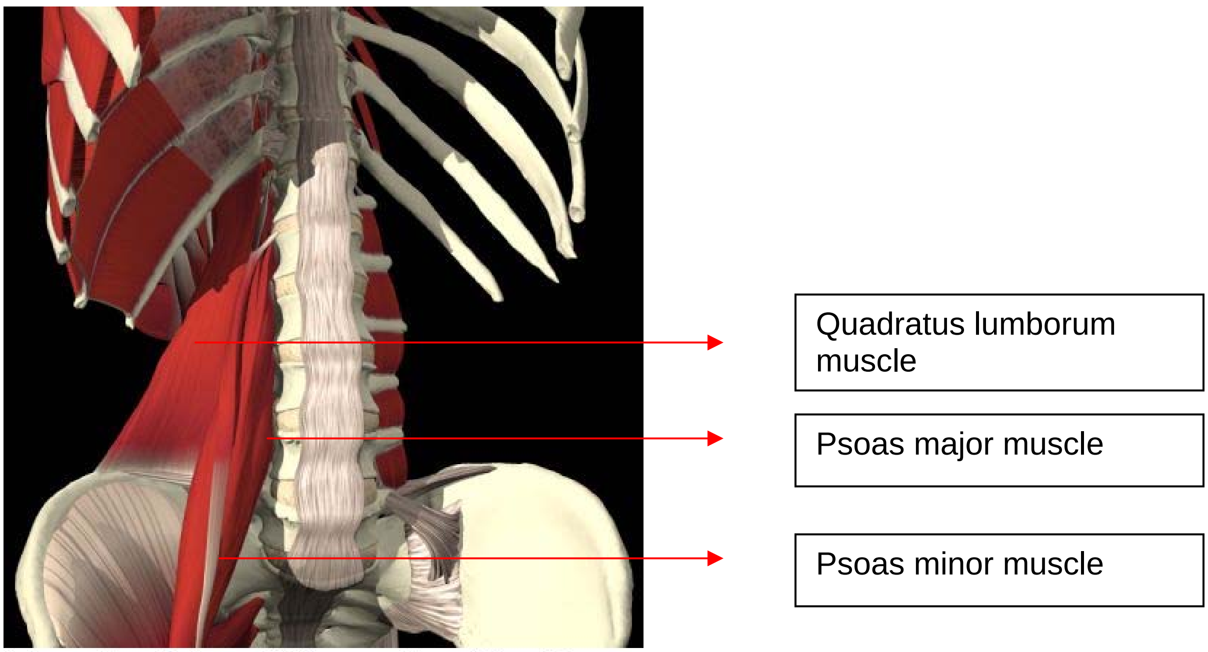

Figure 7: Anterior lumbar spine musculature

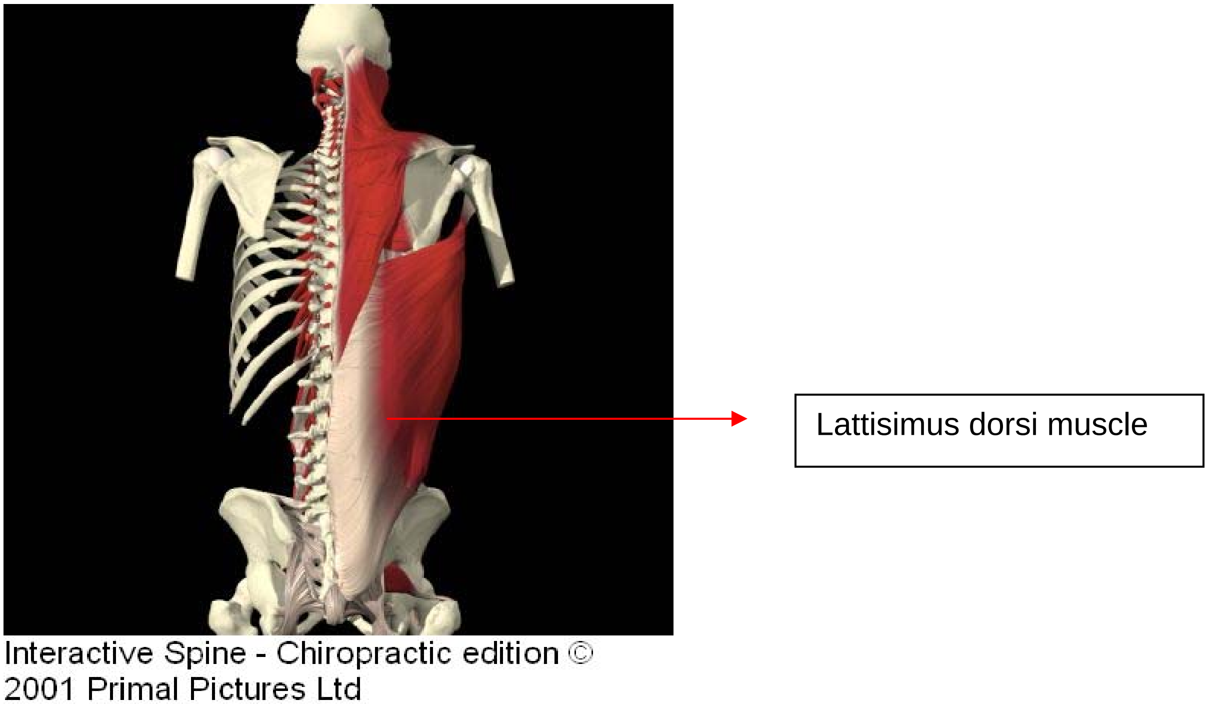

Figure 8: Posterior lumbar spine musculature

In addition, the movements that are least possible are also those that are most easily restricted, [e.g. the most restricted of movement is axial rotation which takes place in the transverse plane (Moore and Dalley, 1999)]. Both of these instances would be restrictive in achieving optimal golf performance.

2.4 The Anatomy and Biomechanics of the Sacro-iliac joint

Unlike the joints of the thoracic and lumbar spines, the sacro-iliac joint is composed of an auricular or C-shaped joint, which is a strong articulation between the surfaces of the sacrum and the ilium. Partial interlocking of these surfaces is caused by irregular bony surface elevations and depressions (Moore, 1992) with the convex contour facing anteriorly and slightly inferiorly (Cassidy and Mierau, 1992). According to individual uniqueness, various shapes, sizes and contours exist within the sacro-iliac (SI) joint with the vertically orientated joint surfaces lying at an oblique angle to the sagittal plane (Cassidy and Mierau, 1992). Male sacroiliac (SI) joints have extra- and intra-articular tubercles for strength and weight bearing, whereas the female articulation is built for mobility and parturition (Walters, 1993).

According to Schafer and Faye (1990) the SI joints are both diarthrotic and amphiarthrotic where the inferior two thirds of each joint are a true synovial articulation and the superior third of the joint a fibrocartilagenous amphiarthrosis. A synovial membrane lines the inner surface of the joint capsule and produces synovial fluid for lubrication of the joint cavity (Walters, 1993). Based on this configuration, the sacro-iliac joints are prone to restriction and / or external (asymmetrical) force induced locking (Cramer and Darby, 2005).

To complicate this picture, a strong series of ligaments help with weight bearing in the SI joint (Cassidy and Mierau, 1992). Haldeman (1992) stated that the interosseous ligament unites the iliac and sacral tuberosities and allow for the interlocking mechanism of the SI joint. The posterior ligament on the other hand prevents flaring of the joint and counter-nutation of the sacrum with respect to the ilium (Bogduk and Twomey 1987, Cramer and Darby, 2005). The anterior ligament prevents anterior separation of the joint and assists with binding the joint together (Haldeman, 1992). Abovementioned ligaments surround the SI joint so thoroughly that the joint capsule is said to merge with these ligaments (Walters, 1993; Bogduk, 1999).

It is generally accepted in literature that the innervation of the posterior aspect of the SI joint is derived from the lateral branches of the posterior lateral rami of L4 to S3 and the anterior innervation from L2 to S2 (Bogduk, 1999). In more recent years mechanosensitive afferent units have also been identified in the SI joint and adjacent tissues (Sakamoto et al., 2001) and most of these units are nociceptive in nature (Cassidy and Mierau, 1992; Sakamoto et al., 2001).

The biomechanics of the SI joint allow for a small amount of anterior to posterior rotary movement in the sagittal plane while at the same time providing stability to take the weight of the body (Hendler et al., 1995). According to Bogduk (1999) full range of motion in the SI joint is less than 4 degrees and this small movement is vital for the joint to be distorted in all dimensions, i.e. in the sagittal, coronal and transverse planes. Without the SI joints torsional stress in the pelvis would otherwise be transmitted to the sacrum resulting in fractures.

Finally, it has also to be remember that some of the largest and most powerful muscles in the body, (viz. erector spinae, psoas, quadratus lumborum, piriformis, rectus femoris as well as gluteus maximus, minimus and medius muscles) surround the SI joint, however none of these cross the joint or are known to directly influence joint movement (Bergmann et al., 1993). It must also be remembered that the hamstring and quadriceps muscles also play an important role in normal SI movements (Walters, 1993). These muscles however will not be tabulated as they do not pertain to the focus of this study.

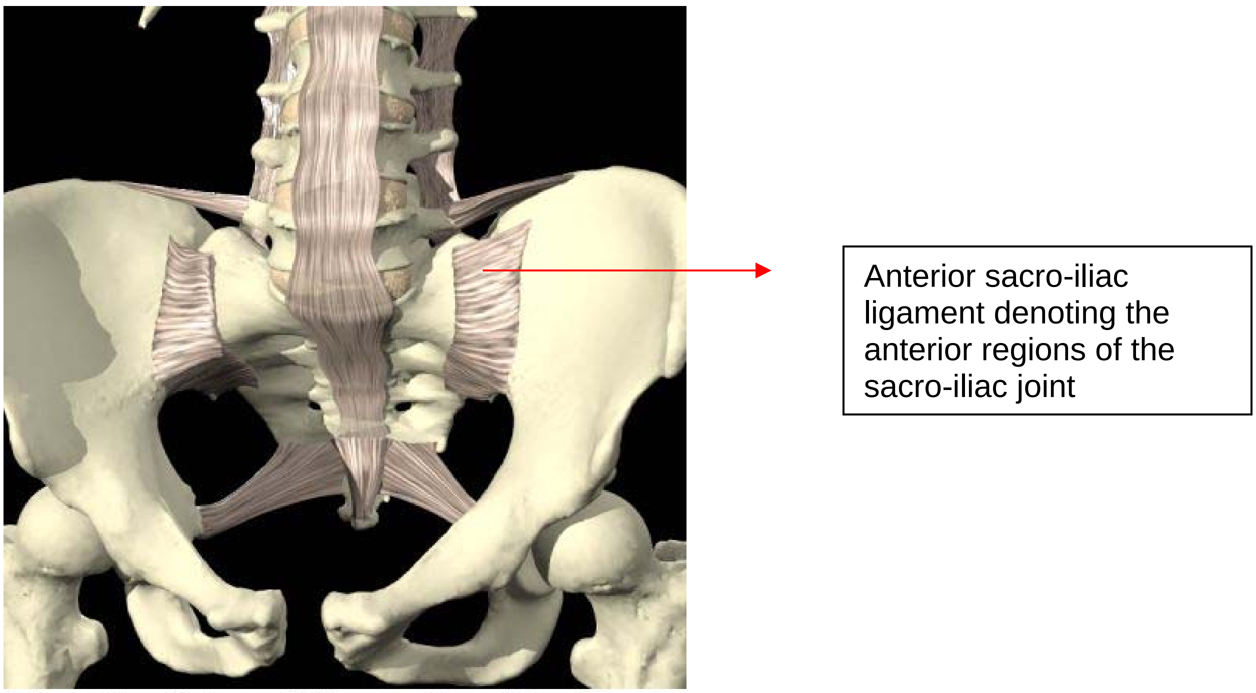

Figure 9: Sacro-iliac joint

In summary, it should be noted that Gatterman (1990) suggests that if one area of the spine/pelvis becomes hypomobile an area of hypermobility has to develop elsewhere. Therefore if the sacro-iliac joints show decreased range of motion, it is likely that the lumbar spine has to compensate for this to sustain relative full range of motion (Mackey, 1995). Altered biomechanics as a result of this could then lead to lumbar spine dysfunction and later symptoms like facet syndromes or sacro-iliac syndromes (Mackey, 1995). These dysfunctions and syndromes could then interfere with the ability of the golfer in terms of performance on the golf course. This will be discussed in the following section.

2.5 Golf related literature

2.5.1 Introduction

It is of vital importance to the clinical practitioner to understand normal golf swing biomechanics and how it relates to the injury profile in amateur golfers.

Research has found that the general profile for golf is relatively problematic as elite golfers differ from recreational golfers, male golfers differ from female golfers and senior golfers need their own special considerations (Jermyn, 2004). Age, ability, amount of play, physical conditioning and individual swing mechanics are but a few considerations that need to be taken into account when dealing with the general golfing population (Batt, 1992; Mackey, 1995; Grimshaw et al., 2002).

The Classic Golf Swing vs. the Modern Golf Swing

Seaman (1998) describes two types of golf swings:

The Classic Golf Swing of the past

> This golf swing was characterized by considerable pelvic rotation during the backswing. This was done by lifting the heel of the front foot almost to the point where only the toes

made contact with the ground and thereby reducing the chance of injury by generating significantly less torsion (torque) around the lumbar spine. This is almost in direct contrast to the more modern golf swing that is in use today.

The Modern Golf Swing

This golf swing is characterized by limited pelvic rotation with maximal thoracic rotation, thereby generating significantly more injury-promoting forces within the relevant spinal structures of both amateur and professional golfers alike.

2.5.2 The Biomechanics of the Modern Golf Swing[1]

The modern golf swing is an integrated movement composed of several phases with no set system to classify each phase (Seaman, 1998). Generally these phases include:

- Phase One: The backswing phase (or take away phase),
- Phase Two: The down swing phase (or impact phase) and
- Phase Three: The follow-through phase.

Initially, the golf swing normally begins after the golfer has gripped his club and has taken his aligned stance over the golf ball, also known as the address position.

2.5.2.1 Phase one: The backswing

Immediately after the address position, the player then begins his backswing and moves the club to the top of his swing by rotating his shoulders, hips, knees, lumbar and cervical spine while keeping his head fixed in space (Mackey, 1995). Seaman (1998) explains that during this phase the shoulders, arms and golf club should move together as a unit and that this is accomplished by shifting weight and rotating the pelvis minimally to the right while maintaining

[1] Please note that this discussion is relevant to the modern golf swing only as it is the swing used by the majority of golfers throughout the world today, both amateurs and professionals. Also for the sake of this discussion the literature is relevant to right-hand golfers only.

a slightly flexed right knee. This also prevents a lateral shift of the body to the right according to Seaman (1998).

At the most extreme (top) end of the backswing the left arm will be perpendicular to the ground, the left thumb hyperabducted, the left wrist radially deviated, the right wrist extended, the right shoulder hyperabducted and the cervical and lumbar spines hyper-rotated (i.e. the upper thoracic spine, back of the shoulders and the golf club will point towards the target) (Mackey, 1995). It is at this point in the backswing / take-away phase that the golfer will have achieved maximal spinal rotation to the right (Mackey, 1995). Seaman (1998) also recommends that at this point weight transfer from the right to the left hand side of the body begins. As this weight transfer is initiated the arms and the golf club will continue to lift slightly because of momentum created by the arms and shoulders during this first phase (Seaman, 1998).

During this phase from the address position to the top of the backswing it is mainly the left external oblique muscle that is responsible for the initial rotation of the trunk (Mackey, 1995). From this rotated position the player will strongly contract his right external oblique muscle, both rotator cuff muscles (supra- and infraspinatus, teres minor and subscapularis muscles) as well as other shoulder muscles (lattisimus dorsi, pectoralis major and deltoid muscles) to start the next phase of the golf swing (i.e. the downswing phase) (Seaman, 1998).

2.5.2.2 Phase two: The downswing

The downswing phase consists of two sections:

The pre-impact phase

> This starts from the extreme end (top) of the backswing to impact, where the muscles on the right side of the trunk (right external oblique) contract to lead the swing (Mackey, 1995). The right external oblique fires maximally during this phase to produce rotation and simultaneously cause flexion of the lumbar spine (Moore and Dalley, 1999). During

the downswing phase the left and right paraspinal muscles (especially multifidus muscle) contract almost symmetrically reflecting their spinal stabilizing action, but also to oppose the lumbar flexion movement of the downswing (Hosea, Gatt and Gertner, 1994).

During this phase the player begins contact with the ball by keeping his right wrist maximally extended, his left thumb hyperabducted, his left hip rotated and his right knee in a position of valgus stress (Mackey, 1995).

The impact phase (viz. impact is when the player strikes the ball)

According to Mackey (1995) at impact the players' left wrist ulnar deviates, while the right wrist undergoes compression, the right knee is under valgus stress, and the left hip is rotated.

As mentioned earlier it is during this phase that the lumbar spine is subject to maximum muscle activity from the right external oblique and opposing paraspinal (i.e. multifidus) muscle.

The lumbar spine has thus moved from a point of maximal rotation to the right, to a relatively neutral position in terms of spinal rotation at the impact phase.

2.5.2.3 Phase three: The follow-through

During this phase the players' left elbow supinates, the right elbow pronates, the right hip internally rotates and completes hip rotation, the knees rotate to the left and the left ankle inverts. The left shoulder hyperabducts while the cervical and lumbar spine rotate and hyperextend (Mackey, 1995). Seaman (1998) also mentions that the body weight should at this point be completely shifted to the left and that the torso should be resting over a slightly flexed left knee.

The end product of the follow-through or finish position is characterized by a right shoulder that points toward the target (i.e. a position of maximal spinal rotation to the left). This position is referred to in golf as the reverse “C” position and is often characterized by hyperextension of the spine (Seaman, 1998).

2.6 Asymptomatic Segmental Joint Dysfunction and the Golf swing

Back pain among the golfing population is considered endemic as a result of the repetitive nature of the game, poor swing mechanics as well as the adoption of the “modern” golf swing (Seaman, 1998; Bulbulian et al., 2001). The modern golf swing calls for limited pelvic rotation and maximum trunk rotation, which results in the generation of significant injury-promoting forces within spinal structures of the lumbar and thoracic spines (Seaman, 1998).

Nevertheless golfing literature today recommends to both the amateur and professional golfer to try and achieve maximum performance with each golf club (Delgado, 2005). This encourages golfers to use a state of maximum spinal rotation in their golf swing in order to achieve optimal performance, particularly related to club head velocity (CHV) and distance (Seaman, 1998; Bulbulian et al., 2001).

Hosea, Gatt and Gertner (1994), supported by Lindsey and Horton (2002), feel that the downswing, as opposed to the backswing, is that part of the golf swing during which most stress and injury occur. They also believe the downswing to be the most likely cause of joint complex dysfunction.

Bergmann et al., (1993); supported Haldeman (1992), when he defined the joint complex dysfunction (joint dysfunction) as subtle changes affecting not only the quality of the joint, but also its range of motion. Bergmann et al., (1993) goes further on to say that the diagnosis of early joint complex dysfunction can be made by means of stress and motion radiography, but also more importantly to the chiropractor by means of motion palpation (Schafer and Faye, 1990). Vernon and Mrozek (2005) in their theoretical discussion of joint complex dysfunction also state that this phenomenon can present itself in the asymptomatic individual, showing decreased range of motion without the presence of any clinical indicators (e.g. pain). They termed the above phenomenon asymptomatic segmental joint dysfunction (Vernon and Mrozek, 2005).

It therefore stands to reason that due to the inherent nature of the golf swing any altered biomechanics as a result of asymptomatic segmental joint dysfunction of the lumbar and / or thoracic spine could influence the performance indicators of amateur golfers. Currently knowledge pertaining to altered biomechanics in relation to the performance indicators of asymptomatic amateur golfers is scarcely mentioned in the literature.

Nordin and Frankel (2001) state that in terms of lumbar and thoracic spinal biomechanics, range of motion differs at various levels of the spine depending on the orientation of the facet joints. An example in the thoracic spine is the coronal orientation of the facets allowing for rotation and limited lateral flexion (Moore and Dalley, 1999). In addition certain skeletal structures decrease movement in the thoracic spine while other structures compliment it (i.e. the rib cage and pelvis respectively) (Nordin and Frankel, 2001).

In contrast to this Moore and Dalley (1999) found that in the lumbar spine the sagittal orientation of the facets allow flexion and extension as the primary movement in those segments. Thus rotation and lateral flexion are more limited (Moore and Dalley, 1999).

Furthermore it should be remembered that simple motion (i.e. about one plane or axis of motion) between two vertebrae never occur independently and that all spinal movements involve the combined action of several motion segments in order to achieve the desired outcome in a co-ordinated and synchronised manner (Bergmann et al., 1993). This is especially true for the biomechanics and complex motor task involved in the golf swing today (Lehman and McGill, 1999).

Vernon and Mrozek (2005) claim that asymptomatic segmental joint dysfunction could be one of the causes of altered biomechanics in the spine, but currently no clinical knowledge as to the affects of this and the influence of spinal manipulative therapy (SMT) on this phenomenon exists.

2.7 Asymptomatic Segmental Joint Dysfunction and its Treatment

Spinal manipulative therapy (SMT) can be described as a manual therapy making use of specific short levers to which a high velocity thrust of controlled amplitude are applied with the aim of restoring joint mobility (Gatterman, 1990; Gatterman, 1995; Cooperstein et al., 2001).

Currently very little is known about the specific effects of SMT on asymptomatic segmental joint dysfunction. In contrast to this, SMT with the emphasis on restoring joint mobility in individuals suffering from mechanical low back pain is not only one of the most effective, but also the most cost effective approach to management (Di Fabio, 1992; Cooperstein et al., 2001).

This is acknowledged by the work of Kirkaldy-Willis and Bernard (1999), and in congruence with Kirkaldy-Willis and Burton (1992) and Bergmann et al., (1993), who explained the mechanical effects of SMT in the treatment of low back pain on the grounds of the following mechanisms:

- SMT may stretch or break intra-articular adhesions that form from immobilised facet joints due to acute synovial reactions (Bergmann et al., 1993; Leach, 1994; Vernon and Mrozek, 2005).
- SMT allows entrapped menisci to exit the facet joint (Bergmann et al., 1993; Leach, 1994).
- If the capsule of the facet gets lodged between two adjacent articular surfaces, the SMT process could allow this to be freed (Bergmann et al., 1993; Leach, 1994).
- SMT re-aligns misaligned spinal segments to conform to the centre of gravity (Gatterman, 1990; Bergmann et al., 1993; Gatterman, 1995; Cooperstein et al., 2001).

Kirkaldy-Willis and Burton (1992) and Kirkaldy-Willis and Bernard (1999) also proposed certain reflex mechanisms in the treatment of low back pain. These include:

- SMT causes an increase in proprioceptive input, which has a reflex inhibition on the transmission of pain (Dvorak, 1985; Kirkaldy-Willis and Burton, 1992; Leach, 1994; Kirkaldy-Willis and Bernard, 1999).
- SMT can reflexly inhibit facilitated motor neuron pools which are responsible for increased muscle excitability (Kirkaldy-Willis and Burton, 1992; Leach, 1994; Gatterman and Goe, 1995; Kirkaldy-Willis and Bernard, 1999; Suter et al., 2000; Hillerman et al., 2005).
- SMT could influence vasomotor tone of neuromuscular structures via the autonomic nervous system (Dvorak, 1985; Kirkaldy-Willis and Burton, 1992; Leach, 1994; Cooperstein et al., 2001).

Further assessment on the influence of manipulation on lumbar kinematics in symptomatic golfers by Lehman and McGill (1999), found that after single rotary manipulations (at the relevant level), the golf swing increased in all total ranges of motion for each plane of movement, with associated muscle relaxation. This is supported by the results achieved by Jermyn (2004), who applied SMT to the sacro-iliac and lumbar facet joints in symptomatic golfers in order to determine the effect SMT would have on CHV. It was found that for some parameters, i.e. CHV and distance, the effects were statistically significant, indicating that the mechanisms suggested above have merit (Jermyn, 2004).

From the research it can therefore be deducted that by means of SMT, one could predictably increase the biomechanical range of motion in restricted spinal segments and attain reflex muscle relaxation within those segments (Lehman and McGill, 1999). According to Herzog et al., (1999) and Nansel et al., (1993) SMT should lead to increased trunk rotation, increased muscle flexibility, decreased strain on the relative spinal structures and essentially increased performance.

As one or all of the lesions noted by Kirkaldy-Willis and Burton (1992), Bergmann et al., (1993) as well as Kirkaldy-Willis and Bernard (1999) could be present in an asymptomatic individual, limiting full potential and yet not presenting with any clinically measurable markers (Daum, 1995; Vernon and Mrozek, 2005). It is therefore possible to assume that if several or all of the abovementioned mechanisms occur in the symptomatic amateur golfer, they should also occur in the asymptomatic amateur golfer. However, this has never been assessed in a pragmatic study before.

Therefore this study aims to evaluate the immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators. Should the results of this study reveal no clinical or statistical significant difference between the control and experimental groups; a recommendation accordingly will be made that although assessment of the lumbar and thoracic spine is necessary in an asymptomatic amateur golfer, it by no means will ensure a difference in patient outcome with or without treatment of the relevant spinal segments.

2.8 Summary

We could therefore summarise the literature as follows:

- Mechanical low back pain in amateur golfers is a result of joint complex dysfunction (Seaman, 1998; Horton et al., 2001).
- Joint complex dysfunction causes reduced/decreased spinal range of motion (Gatterman and Goe, 1990; Gatterman, 1990; Batt, 1992; Leach, 1994; Gatterman, 1995; Grimshaw et al., 2002).
- Decreased range of motion may also be present in asymptomatic individuals (Gatterman and Goe, 1990; Leach, 1994; Vernon and Mrozek, 2005).
- Decreased range of motion may or may not have an effect on performance indicators, especially CHV (Bulbulian et al., 2001; Horton et al., 2001).
- SMT has shown to be effective in the treatment of low back pain (Leach, 1994; Cooperstein et al., 2001), however the immediate and short term effect of SMT on

asymptomatic amateur golfers in terms of performance indicators have not been investigated.

CHAPTER 3

Material and Methods

3.1 Introduction

This chapter contains an overview of how the study was carried out. Included in this chapter is information concerning the study design, the participants involved and the intervention (treatment) they received. A brief explanation of the statistical methods used for interpretation of the data is also provided in this chapter.

3.2 Study Design

This study was a pre and post experimental investigation with clinical intervention that focussed on the immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators.

The study in its current format was ethically approved by the Faculty of Health Sciences Research Committee on 05/10/2004 and was in line with the Declaration of Helsinki 1975.

3.3 Advertisements and participant recruitment

Potential participants for this study were referred from advertisements placed mainly at golf clubs and driving ranges in the Durban Metropolitan area. Potential participants that responded to the advertisement (Appendix H) then underwent a brief telephonic interview with the researcher to establish suitability for the study.

3.4 Telephonic procedure

The following questions were asked during the telephonic interview:

- Are you male and between the ages of 25 and 45 years old?
  This was to improve homogeneity of the sample (Mouton, 1996).
- Are you an amateur golfer? (Participants had to be amateur golfers, i.e. a person who takes part in golf without receiving any money for it and therefore not a professional (Oxford Advanced Learner's Dictionary, 1995)).
- Do you have an official handicap? This was done on the argument that participants with handicaps had to play golf on a more regular basis to sustain those handicaps. This was to improve homogeneity of the sample (Mouton, 1996).
- Are you pain free before, during and after a round of golf?
- Have you ever had surgery or are you currently on any medication / treatment related to your low back or mid back (between the shoulder blades) areas?
- Can you commit to two consultations within a seven day period?

Once the likelihood of potential participant suitability had been ascertained, the researcher then proceeded to schedule an initial consultation with the participant. During this consultation, all potential participants underwent a case history (Appendix A), physical examination (Appendix B) as well as a thoracic and lumbar regional examination (Appendix C). This was done to further ensure participant suitability.

3.5 Sampling procedure

3.5.1 Sample method

All potential participants that responded to the advert were assessed for study compliance and were then initially accepted based on the principles of consecutive convenience sampling (Mouton, 1996).

Once accepted into the study all participants where then randomly (Mouton, 1996) allocated into either group A or group B.

Thereafter participants in group A were purposively (Mouton, 1996) allocated to subgroups A1, A2 or A3 based on the requirements for each of these subgroups.

3.5.2 Sample allocation

Consecutive convenience sampling (Mouton, 1996) occurred at the outset of this study as a result of the manner in which potential participants responded to adverts recruiting the general public.

Random (Mouton, 1996) allocation was then utilised to assign participants to their respective groups, with the participants drawing a letter (A or B) out of an envelope. Participants were then assigned to either group A or B depending on which letter was drawn.

Those participants who fell into group A were then further divided into their respective groups (A1/A2/A3) utilising purposive sampling (Mouton, 1996), depending on the presence of asymptomatic segmental joint dysfunction in the relevant spinal segments. This was done by means of motion palpation as described by the Liekens-Gillet method and set out in Bergmann's Chiropractic Technique (1993).

Those participants who fell into group A1 (n=10) received lumbar manipulation only, those in group A2 (n=10) received thoracic manipulation only and those participants who fell into group A3 (n=10) received both lumbar and thoracic manipulations.

Group B consisted of 10 participants that would act as the control group in this study. By means of motion palpation, they too were assessed in order to assure the presence of asymptomatic segmental joint dysfunction in the relevant spinal segments.

Table 3.5.2.1 shows the sample allocation into the relevant sub groups.

Table 3.5.2.1: Sample allocation

	Group A			**Group B**
Sub group (if relevant)	**A1 (Lumbar manipulation only)**	**A2 (Thoracic manipulation only)**	**A3 (Lumbar and Thoracic manipulation)**	**Not applicable**
Sample size (minimum)	10	10	10	10

3.5.3 Sample size

A sample group of forty golfers was required as this would ensure better statistical viability with regards to the parameters in question (Nienaber, 2005), and as shown in the above table (Table 3.5.2.1)

3.5.4 Sample characteristics

A case history (Appendix A), physical exam (Appendix B), thoracic and lumbar regional examinations (Appendix C) were performed by the researcher to assess for any conditions that may have excluded a participant from the study.

3.5.4.1 Inclusion criteria

- All participants had to be right handed, amateur, male golfers in order to create homogeneity within the study sample (Mouton, 1996).
- All participants had to be between the ages of 25 and 45, and had to be asymptomatic with regards to low back and thoracic spine pain. Kirkaldy-Willis and Burton (1992) stated that age is an important risk factor in low back pathology which tends to begin during the third decade of life and reaches maximal frequency during middle age. The researcher also wanted to exclude degenerative changes as much as possible and according to Brandt (2002) these changes do not usually occur before the age of 45.
- Participants selected from the above-mentioned group all had to have an official handicap. This was done on the argument that handicap golfers should have a more consistent swing related to biomechanics in order to sustain those handicaps. This also contributed in an indirect way to assure a certain degree of sample homogeneity (Mouton, 1996).

- All participants were required to show segmental spinal dysfunction in their lumbar and / or thoracic spines, as detected by motion palpation (Schafer and Faye, 1990 and Bergmann et al., 1993).

3.5.4.2 Exclusion criteria

- Participants who received medical, surgical or additional manual interventions prior to the study as this could possibly have interfered with the results of the study were excluded (Poul et al., 1993; Seth, 1999).
- Participants who presented with any contra-indications to spinal manipulation, which included but was not limited to osteomyelitis, TB of the spine, infectious arthritis, disc prolapse, haemangioma, vertebral malignancy and advanced spondylolysthesis (Gattermann, 1990).
- Illiterate participants were excluded as they would not have been able to read the necessary paperwork. They would also not be able to follow the instructions given by the researcher during the execution of the study.
- Any participant who did not sign the informed consent form was immediately withdrawn from the study.

For purposes of homogeneity (Mouton, 1996):

- Females were excluded.
- Participants younger than 25 years and older than 45 years of age were excluded.
- Professional golfers were excluded.

3.5.5 Diagnostic criteria for inclusion

At the initial consultation the following assessments were performed under the relevant regional examinations in order to assure that potential participants were asymptomatic.

For the purpose of this study as well as clinical standardisation, potential participants had to be pain free with regards to the following tests:

- Kemp's test (Schafer and Faye, 1990)
- Facet joint challenge test (Bergmann et al., 1993)
- Erichson's / Yeoman's test (Schafer and Faye, 1990)
- Sacro-iliac percussion / compression test (Bergmann et al., 1993)

According to Kirkaldy-Willis and Burton (1992) true positive results obtained when applying the above tests were utilized in the diagnosis of low back pain of mechanical origin. For this study however the participants were required to have a true negative for each of these tests, indicating that they did not have low back pain of mechanical origin.

This means that participants were required to show asymptomatic joint dysfunction with decreased range of motion in the relevant spinal segments. This was done by means of motion palpation and in accordance with Schafer and Faye (1990) and Bergmann et al., (1993).

It was possible that local para-spinal spot tenderness around the areas of dysfunction was present provided that this was not noted as pain by the patient (Gerard and Kleinfeld, 1993 and Plaugher, 1993). There may also have been latent myofascial trigger points in the surrounding musculature; however these would not have been able to induce pain as perceived by the patient. Both of these clinical entities could have been present even though the patient regarded themselves as pain free and it stands to reason that these subclinical findings may be present as a result of altered spinal biomechanics in the relevant segments (Travell and Simons, 1999).

3.6 Clinical procedure

After the initial consultation and evaluation against the inclusion and exclusion criteria, potential participants were given a Letter of Information (Appendix D). They then had the opportunity to ask any questions related to this study after which they were requested to sign an Informed Consent Form (Appendix E). This allowed potential participants to officially take part in the study.

Those forty participants that met the inclusion and exclusion criteria then underwent an initial performance assessment using the EDH Sports-FlightScope Pro Electronic Swing Analyser (Appendix G) at the Pro Shop, Springfield Park, in order to determine the following performance indicators (i.e. Club Head Velocity, Vertical and Horizontal Azimuth, Smash and Distance). Participants were asked to bring their own seven iron golf club (to minimise the effect of incorrect club size for the participant) and to use the same club for the duration of the study. In addition this was done to ensure player comfort and confidence. All participants used Topflight practice balls which were supplied by the Pro Shop in order to ensure that there were no changes in the ball dynamics.

All this was done under the supervision of a research supervisor from the Durban University of Technology (DUT) Chiropractic Day Clinic and as required by the Faculty of Health Sciences Research Committee as well as the Allied Health Professions Council of South Africa (Act 63 of 1982 as amended).

3.7 Intervention type

The researcher then administered the first and only SMT intervention related to the participants’ individual sub groups (related to the associated segmental joint dysfunction). This was then followed by a second set of performance indicator measurements. This was done to establish the immediate effect of SMT on the performance indicators of asymptomatic amateur golfers (i.e. pre – post measurements).

A second and last consultation, no less than three and no more than seven days later, was then arranged by the researcher. During this consultation, participants received no SMT intervention, but were required to supply the researcher with a final set of performance measurements. This was to establish the short term effect of SMT on the performance indicators of asymptomatic amateur golfers.

3.8 Clinical intervention and frequency

Clinical intervention (i.e. SMT) followed the techniques set out by Shafer and Faye, (1990) and Bergmann et al., (1993) and was judged successful following a grade 5 mobilization with an audible cavitation (Vernon and Mrozek, 2005).

Group A

- Participants in group A received SMT (including the sacro-iliac joints) in accordance with the treatment protocol of Thompson (2002). This involved a right-to-left or a left-to-right lateral recumbent (Lehman and McGill, 1999) or seated manipulation to the lumbar spine. Additional procedures as named in Schafer and Faye (1990) were also utilized if previous manipulations were unsuccessful.
- The sacro-iliac manipulation was also done in the lateral recumbent position but differs to the lumbar manipulation by emphasizing traction and tension on the sacro-iliac joint through the contact hand (Bergmann et al., 1993).
- The thoracic manipulation was done with the participant in the supine position over the contact hand with special emphasis being placed on the posterior joints of the spine. Long axis traction, as well as an anterior to

- In group A, SMT involved a single spinal intervention during the initial consultation, with a follow up consultation no less than three and no more than seven days later (short term). The second consultation was used to take a final set of performance measurements only, so no SMT intervention took place.

Group B

- Participants in group B received no spinal intervention for the duration of the study but were also required to come back for a follow-up consultation no less than three and no more than seven days later. This second consultation was used to take a final set of performance measurements in accordance with those participants falling in group A of the study.

3.9 Measurements

3.9.1 Subjective data

No Subjective data was collected as all participants were asymptomatic with regard to pain.

3.9.2 Objective data

EDH Sports-FlightScope Pro Electronic Swing Analyser

“The EDH Sports-FlightScope Pro Electronic Swing Analyser is a 3D tracking radar system that measures performance indicators in golfers.”

(http://www.edh.co.za/, 2005). The device is based on "phased array technology" to enable it to measure the flight path of projectiles (i.e. golf ball). As a result this analyser has a launch velocity range of 1.2 to 250 miles per hour within 0.5 % accuracy and can give the landing position of the golf ball with a standard error of 5 % of actual flight distance. In addition the CHV strike is accurate to 2 %.

In terms of testing, the EDH Sports-FlightScope Pro Electronic Swing Analyser has been tested and approved for use by the All England Lawn Tennis Club and the Association of Tennis Professionals (ATP), based on its accuracy (http://www.edh.co.za/, 2005).

This device measures many aspects of the golfers swing including; ball speed, vertical and horizontal azimuth (club head angle), distance and swing paths. For the purpose of this study, club head velocity and ball distance were the main performance indicators of concern. Ball distance was recorded for statistical analysis only as Stude and Gullickson (2000) stated that there was a 1:3 relationship between CHV and distance which suggests that for every 1 mph increase in CHV there is a subsequent 3 yard increase in air travel distance.

3.10 Patient and Testing procedure

At The ProShop, participants were instructed to hit five golf balls from an artificial indoor "tee-off mat" into a suspended net using the participant's own 7-iron. They were then instructed to warm-up the way they would under normal playing conditions. No other suggestions were made regarding specific stretching and warm-up exercises and therefore this non-intervention approach to the warm-up would allow for more accurate and specific simulation of the participants' golfing habits. It would also show any subtle changes in the participant's performance after the clinical intervention.

At least 3 minutes were allowed for recovery before actual measurements related to the study were taken. This was done to minimise the effect of fatigue from affecting the outcome of the study (MacIntosh et al., 2002).

Participants were then instructed to hit another five (5) golf balls, for which an average of the performance indicators was calculated and which would serve as a baseline measurement. Participants then underwent clinical intervention in the form of SMT. A second set of performance measurements were taken immediately after the clinical intervention, for which an average was then also calculated.

3.11 Measurement frequency

Objective measurements, i.e. EDH Sports-FlightScope Pro Electronic Swing Analyser readings were recorded at the initial consultation both pre and post clinical intervention. This was done to determine the immediate effect of SMT on asymptomatic amateur golfers in terms of performance indicators.

A third and final objective reading was taken during the second consultation three to seven days later. No clinical intervention took place at this time, as this was done to determine the short term effect of SMT on asymptomatic amateur golfers in terms of performance indicators.

All performance measurements/analyses were done at the Pro Shop in Springfield Park, Durban.

3.12 Statistical Analysis of Data

Statistical analysis was performed using the latest version of the SPSS statistical package and consisted of a combination of parametric and non-parametric testing.

- Intra-group analysis would make use of the Wilcoxin signed rank test for the control group and the paired T-test for the experimental group.
- Inter-group analysis would involve the Mann-Whitney U test.

The above tests were applied to all objective measurements and this was done at a 95% level of confidence.

CHAPTER 4

4.0 Introduction

This chapter contains the statistical analysis of all subjective and objective data obtained from the participants for the duration of the study. The participants in group A received SMT in accordance to the protocol set out by Kirkaldy-Willis and Burton (1992), while the participants in group B received no intervention and acted as the control/placebo group for this study. Information was obtained from a case history, physical examination, thoracic spine regional as well as lumbar spine and pelvis regional examinations. All the relevant paperwork was explained to each participant prior to completion and the researcher executed all the necessary interventions.

4.1 The Data

The data used in this study was both primary and secondary in nature.

4.1.1 The Primary Data

The primary data was obtained directly from the participants and consisted of:

- A Case History (Appendix A)
- Physical Examination (Appendix B)
- Thoracic Spine Regional Examination (Appendix C1)
- Low Back and Pelvis Regional Examination (Appendix C2)
- Objective data was collected from The EDH Sports-FlightScope Pro-Electronic Swing Analyser in terms of CHV, Vertical and Horizontal Azimuth, Smash and Distance (Appendix G)
- No Subjective data was collected as all participants were asymptomatic with regard to pain

4.1.2 The Secondary Data

Secondary data was obtained from various sources of related literature, journal articles, textbooks and the Internet.

4.1.3 Key terms and abbreviations:

º	- degrees
CHV	- club head velocity
HA	- horizontal azimuth
L	- lumbar vertebra
mph	- miles per hour
m	- meters
SI	- sacro-iliac
SD	- standard deviation
T	- thoracic vertebra
VA	- vertical azimuth

4.2 Results

All of the data collected for this research took place over a period of six months. Forty participants were allocated to four equal groups consisting of ten participants each (see section 3.5.2). Three of the groups received a single intervention, i.e. SMT while the last group acted as a placebo control group and received no intervention.

Of the total amount of participants involved in this study three had to be withdrawn, one due to unforeseen surgery (professional rugby player) and the other two because they did not arrive for their follow-up appointments within the stipulated time period. The withdrawal of these participants resulted in their replacement by new participants who were subjected to the same randomization allocation as all other participants.

4.2.1 Demographics

There was no difference between the four groups in terms of age or handicap. Thus the groups were comparable in terms of baseline demographics, and it is safe to assume that these factors did not affect the outcome of this research.

Table 4: Comparison of demographic variables between the four treatment groups

		Group				p value
		Intervention lumbar spine	Intervention thoracic spine	Intervention both	Control	
Age	Mean	31.9	31.9	35.4	33.5	0.518
	Standard Deviation	5.3	5.5	6.7	6.4	
Handicap	Mean	16.1	16.3	17.5	13.4	0.623

	Standard Deviation	5.3	6.3	8.3	8.1	

4.2.2 Baseline outcomes

There were no significant differences between the four treatment groups for any of the baseline outcomes measured. This means that the randomization process was able to achieve a good representation between the groups. This is shown in Table 5.

Table 5: Comparison of baseline outcomes between the four treatment groups

		Group				p value
		Intervention lumbar spine	Intervention thoracic spine	Intervention both	Control	
CHV pre (mph)	Mean	75.5	74.4	75.6	78.2	0.666
	Standard Deviation	7.3	8.2	5.2	7.0	
VA pre (°)	Mean	18.0	17.9	16.5	16.7	0.739
	Standard Deviation	3.7	3.6	4.7	2.8	
HA pre (°)	Mean	14.7	19.0	18.7	24.7	0.396
	Standard Deviation	8.5	16.2	8.7	16.3	
Smash pre	Mean	1.3	1.3	1.3	1.3	0.525
	Standard Deviation	0.04	0.06	0.04	0.03	
Distance pre (m)	Mean	137.9	129.8	133.7	145.0	0.569
	Standard Deviation	23.9	27.0	20.5	27.8	

4.3 Intra-group analysis

Objective 1: To assess the significance of the change from pre to post treatment (immediate effects) and from pre to final treatment (short term effects) in the combined treatment groups (n=30).

4.3.1 CHV

In terms of CHV, there was no overall time effect, nor immediate or short term time effects. Figure 13 shows a non-statistically significant immediate increase in CHV in the treatment group, and a slight non significant decrease to baseline level at the final measurement.

Table 6: Within subjects time effects for CHV in the intervention group (n=30)

Effect	Statistic	p value
Time overall	Wilk's lambda=0.969	0.644
Pre to post (immediate)	F=0.923	0.345
Pre to final (short term)	F=0.522	0.476

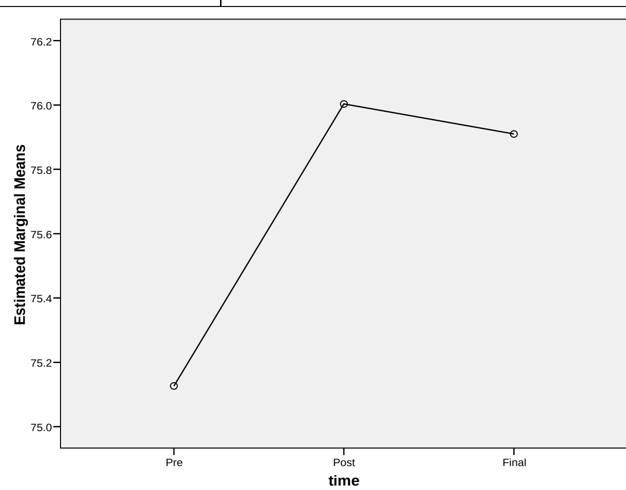

Figure 13: Mean CHV by time in the intervention group (n=30)

4.3.2 Vertical Azimuth (VA)

VA showed a significant time effect overall (p=0.046) but this difference was only statistically significant between the pre and final measurements (p=0.016) and not in the immediate term (p=0.977). This is shown in Figure 14.

Table 7: Within subjects time effects for VA in the intervention group (n=30)

Effect	Statistic	P value
Time overall	Wilk's lambda=0.803	0.046
Pre to post (immediate)	F=0.001	0.977
Pre to final (short term)	F=6.512	0.016

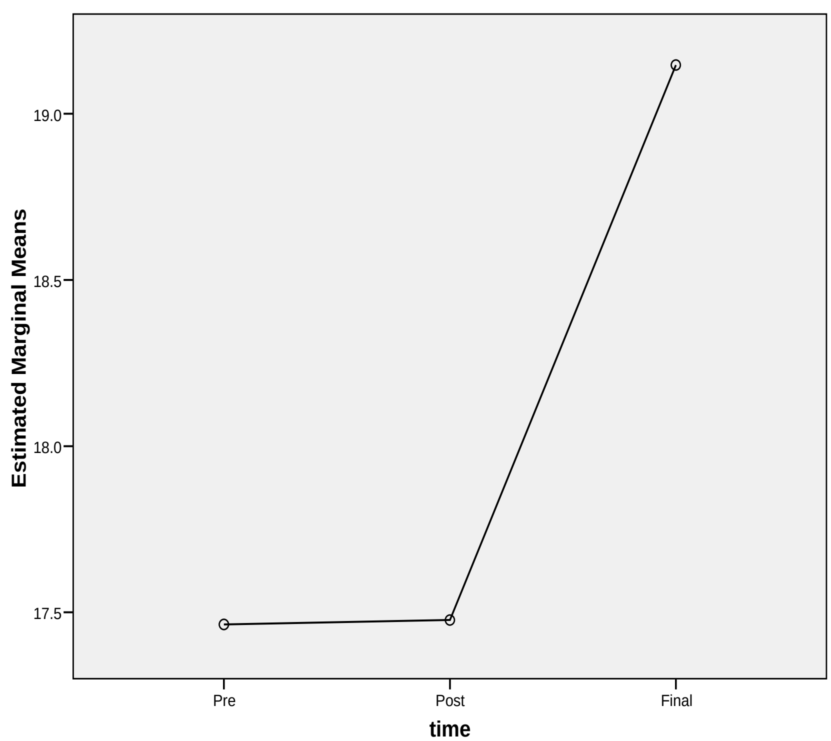

Figure 14: Mean VA by time in the intervention group (n=30)

4.3.3 Horizontal Azimuth

HA showed no statistically significant time changes overall, immediate or short term. Figure 15 shows a trend towards a decrease in HA of the treated participants in the short term but this was not statistically significant.

Table 8: Within subjects time effects for HA in the intervention group (n=30)

Effect	Statistic	p value
Time overall	Wilk's lambda=0.927	0.347
Pre to post (immediate)	F=1.744	0.197
Pre to final (short term)	F=0.146	0.705

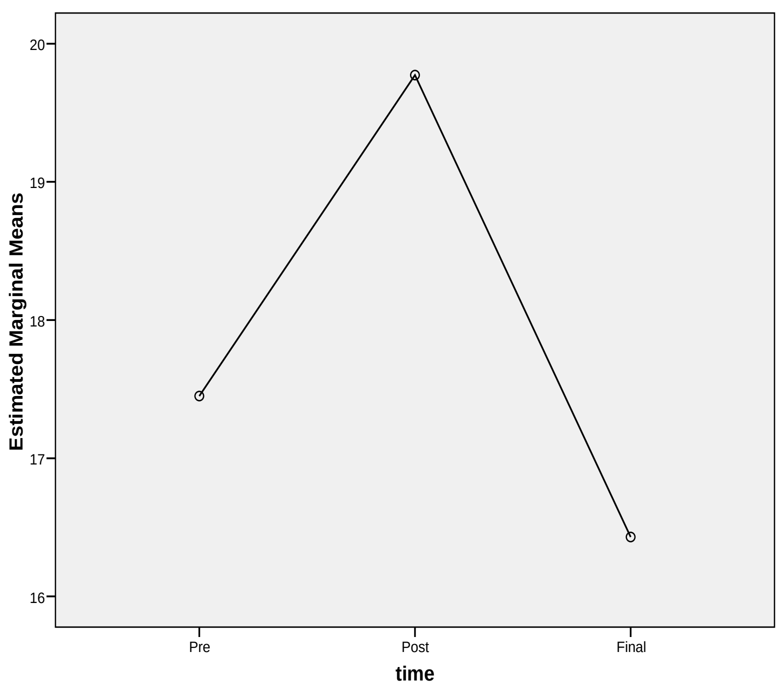

Figure 15: Mean HA by time in the intervention group (n=30)

4.3.4 Smash

Mean smash for the intervention group as a whole did not increase statistically significantly in the immediate or short term. By contrast Figure 16 shows that the immediate effect was a slight decrease, followed by an increase to final measurement that was slightly higher than the baseline measurement. The increase was not clinically important as it did not change the average category of strike from poor to a good strike.

Table 9: Within subjects time effects for Smash in the intervention group (n=30)

Effect	Statistic	P value
Time overall	Wilk's lambda=0.949	0.484
Pre to post (immediate)	F=1.276	0.268
Pre to final (short term)	F=0.013	0.909

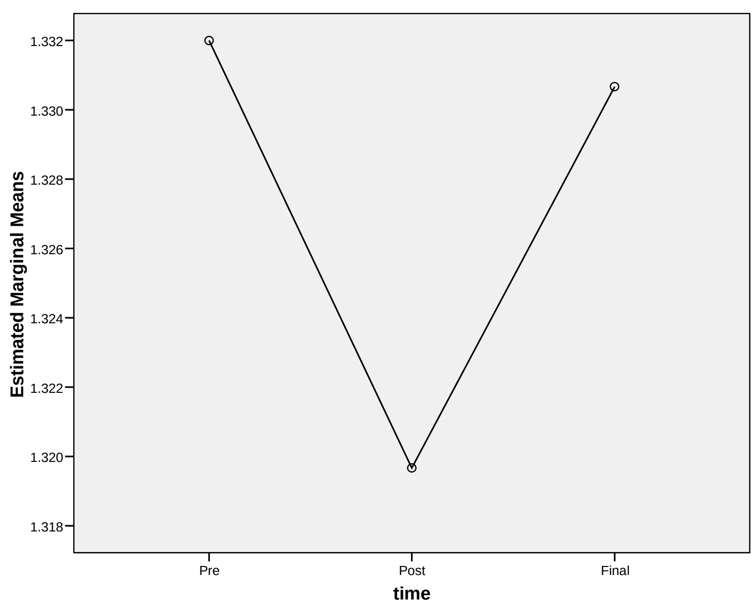

Figure 16: Mean smash by time in the intervention group (n=30)

4.3.5 Distance

Distance increased overall insignificantly (p=0.069). A significant increase in the short term (p=0.027) was noted but not in the immediate term (p=0.749).

Table 10: Within subjects time effects for distance in the intervention group (n=30)

Effect	Statistic	P value
Time overall	Wilk's lambda=0.826	0.069
Pre to post (immediate)	F=0.104	0.749
Pre to final (short term)	F=5.394	0.027

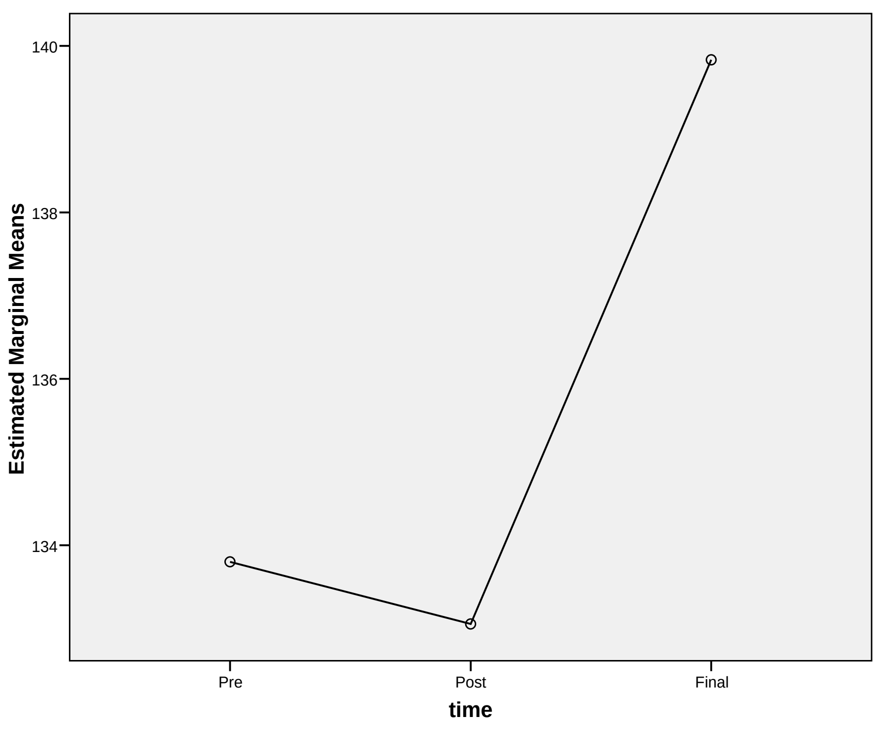

Figure 17: Mean distance by time in the intervention group (n=30)

4.4 Inter-group analysis

Objective 2: To compare the short term treatment effect between the pooled treated groups (30) and the control group (10) (2 group comparison)

4.4.1 CHV

There was no evidence of a differential treatment effect in the treated group compared with the placebo group for CHV. The time by group interaction (i.e. this indicates the difference between the groups over time) was not significant and Figure 18 shows a slight trend towards an increase in the intervention group over time whilst the control group decreased back to baseline levels at final measurement.

Table 11: Within and between subjects effects for CHV

Effect	Statistic	p value
Time	Wilk's lambda=0.916	0.195
Time*group	Wilk's lambda=0.966	0.531
Group	F=1.521	0.225

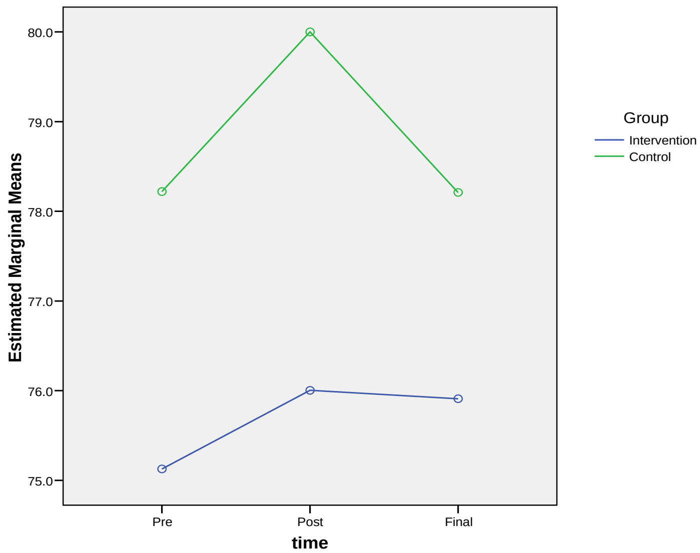

Figure 18: Mean CHV by group over time (n=40)

4.4.2 Vertical Azimuth (VA)

Although the interaction between time and group was not significant for VA (p=0.160), there was a trend towards an interaction at the final time point, where the intervention group showed an increase while the control group began to decrease.

Table 12: Within and between subjects effects for VA

Effect	Statistic	p value
Time	Wilk's lambda=0.942	0.311
Time*group	Wilk's lambda =0.906	0.160
Group	F=0.837	0.366

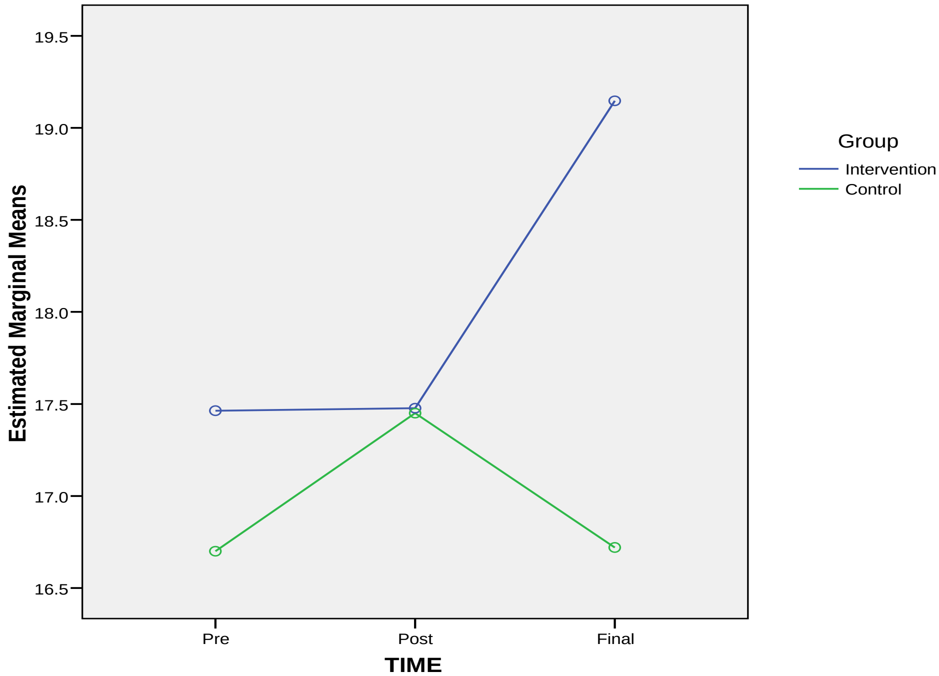

Figure 19: Mean VA by group over time (n=40)

4.4.3 Horizontal Azimuth (HA)

HA did not show a beneficial treatment effect compared with the control group (p=0.738). Figure 20 shows that the changes in the groups were almost parallel between the pre and final assessment in both groups.

Table 13: Within and between subjects effects for HA

Effect	Statistic	p value
Time	Wilk's lambda=0.915	0.194
Time*group	Wilk's lambda =0.984	0.738
Group	F=1.866	0.180

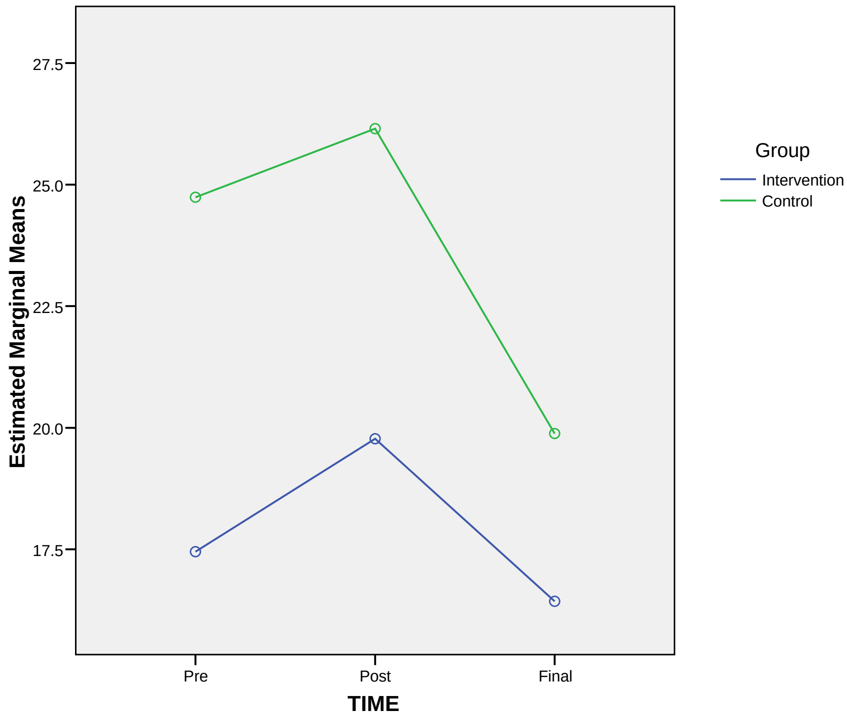

Figure 20: Mean HA by group over time (n=40)

4.4.4 Smash

There was no evidence of a beneficial treatment effect for smash (p=0.713). The intervention group showed a large immediate mean decrease followed by a sharp increase to around baseline levels while the control group showed a slight increase over time. The scale of the increase in both groups was very small.

Table 14: Within and between subjects effects for Smash

Effect	Statistic	p value
Time	Wilk's lambda =0.977	0.645
Time*group	Wilk's lambda=0.982	0.713
Group	F=3.185	0.082

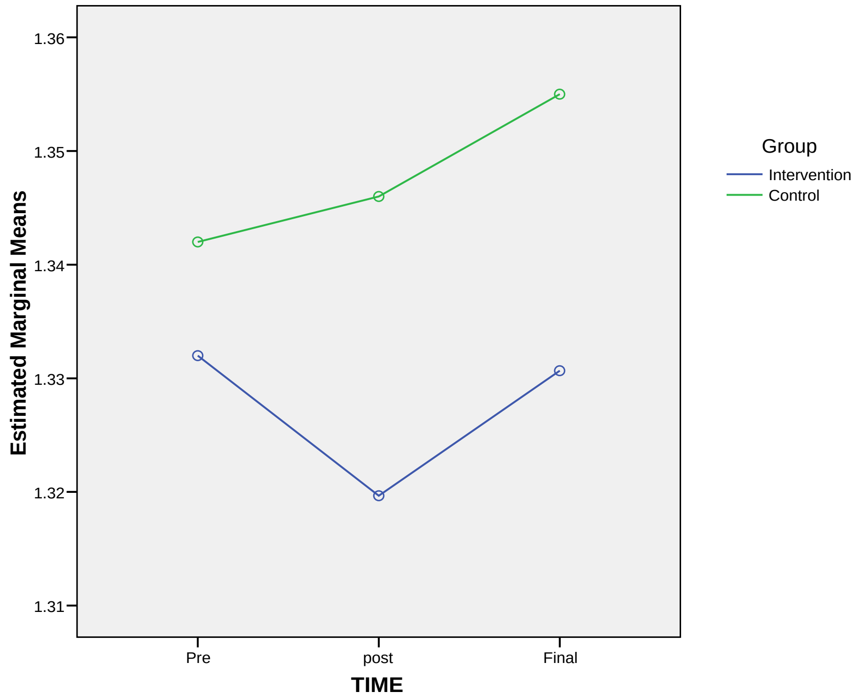

Figure 21: Mean smash by group over time (n=40)

4.4.5 Distance

There was a borderline non significant beneficial effect for distance in the treated group compared with the control group (p=0.077), where the trend (Figure 22) suggests that the treated group showed a greater rate of increase over time than the control group, especially in the short term.

Table 15: Within and between subjects effects for Distance

Effect	Statistic	p value
Time	Wilk's lambda=0.884	0.102
Time*group	Wilk's lambda=0.870	0.077
Group	F=2.279	0.139

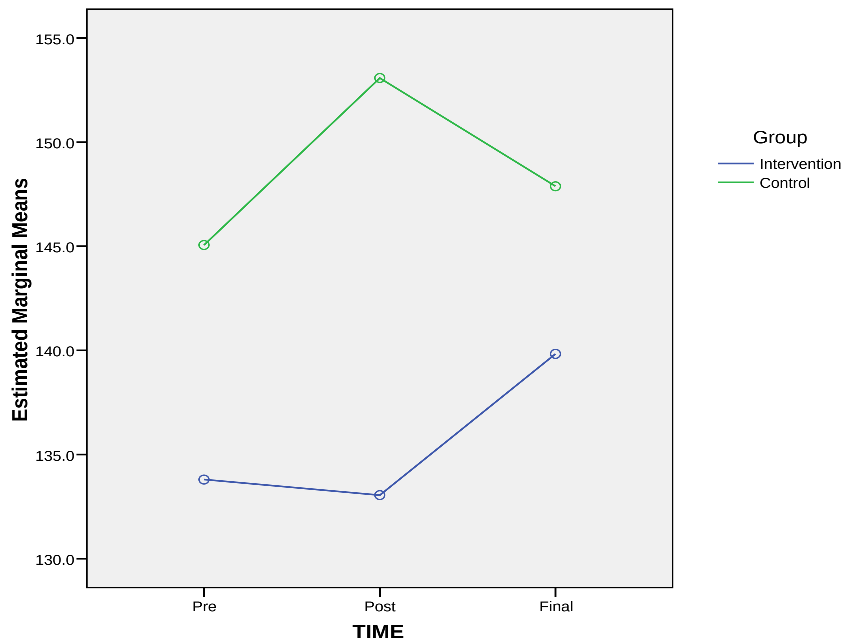

Figure 22: Mean distance by group over time (n=40)

4.5 Inter-group analysis (four way comparison)

Objective 3: To compare the treatment effect between all three treatment groups and the control group (4 group comparison)

4.5.1 CHV

There was a trend in the thoracic spine manipulation group of a differential improvement compared with the control group for CHV but this was not significant due to the small sample size and it is suggested that future studies incorporate larger sample sizes to confirm these results. All the other groups appeared to show the same effect as the control group.

Table 16: Treatment effect for CHV in all groups compared with control

Effect	Statistic	p value
Time*group overall	Wilk's lambda=0.891	0.656
Lumbar manipulation vs. control	Wilk's lambda=0.984	0.868
Thoracic manipulation vs. control	Wilk's lambda=0.819	0.183
Both vs. control	Wilk's lambda=0.989	0.911

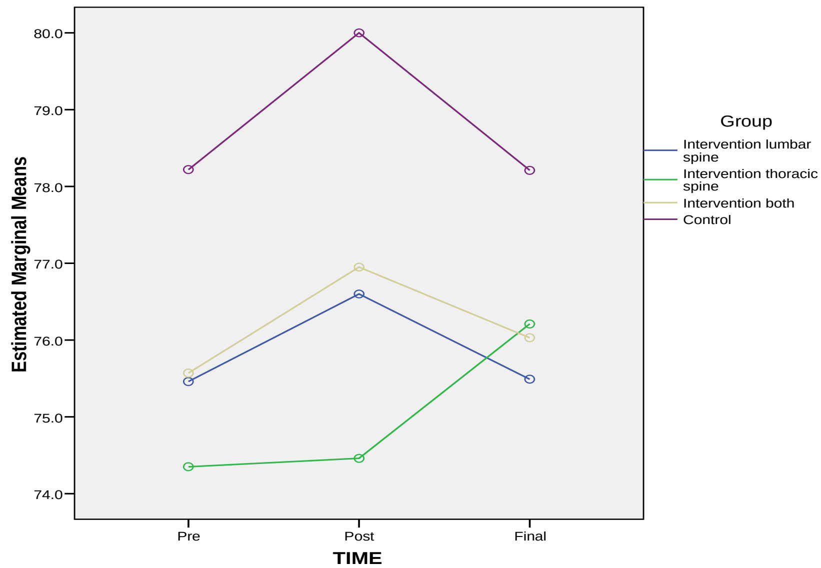

Figure 23: Mean CHV between groups over time (n=10)

4.5.2 Vertical Azimuth (VA)

There was some evidence of treatment effect for the thoracic manipulation group compared with the control group for VA (p=0.040). There was also a relatively large trend towards an interaction in the lumbar manipulation group but this was not quite significant, which may have been due to small sample sizes. This would therefore need to be tested with a larger sample size.

Table 17: Treatment effect for VA in all groups compared with control

Effect	Statistic	p value
Time*group overall	Wilk's lambda=0.781	0.179
Lumbar manipulation vs. control	Wilk's lambda=0.728	0.067
Thoracic manipulation vs. control	Wilk's lambda=0.685	0.040
Both vs. control	Wilk's lambda=0.939	0.586

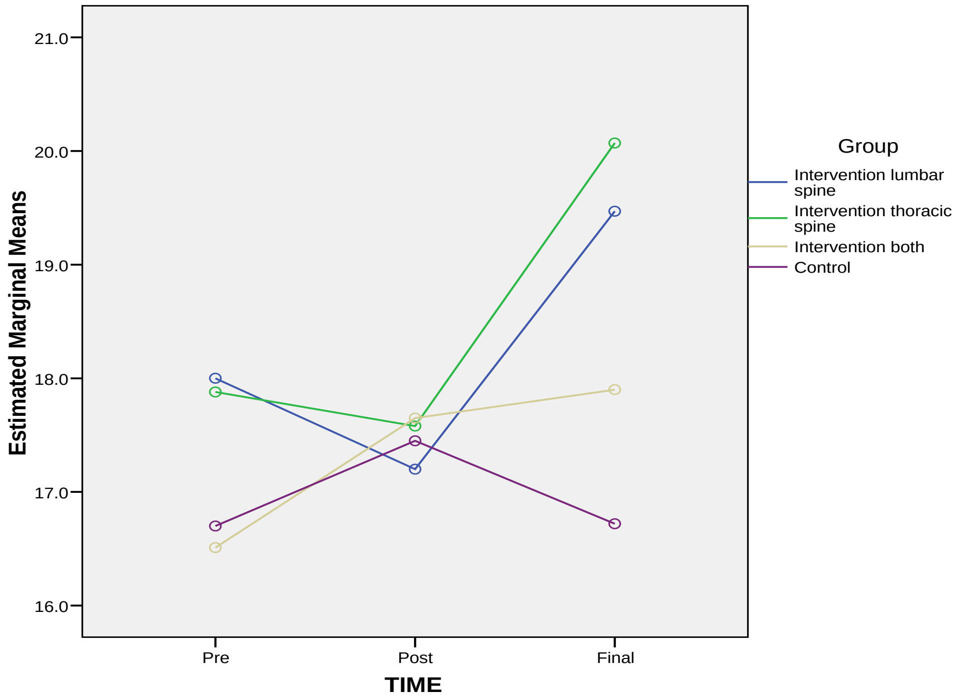

Figure 24: Mean VA between groups over time (n=10)

4.5.3 Horizontal Azimuth (HA)

There was no evidence of treatment effect for any individual group compared with the control group for HA. (HA was calculated as the sum total of five shots, with shots going left of the target (midline) receiving a negative value and shots going right of the target (midline) receiving a positive value).

Table 18: Treatment effect for HA in all groups compared with control

Effect	Statistic	p value
Time*group overall	Wilk's lambda=0.838	0.384
Lumbar manipulation vs. control	Wilk's lambda=0.830	0.204
Thoracic manipulation vs. control	Wilk's lambda=0.975	0.805
Both vs. control	Wilk's lambda=0.946	0.622

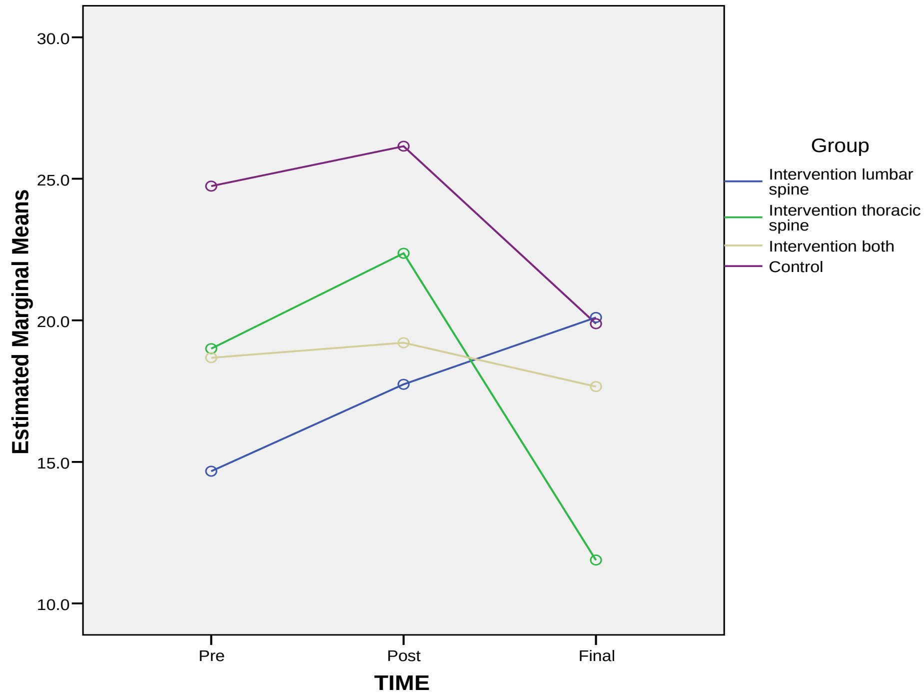

Figure 25: Mean HA between groups over time (n=10)

4.5.4 Smash

There was no evidence of treatment effect for any individual group compared with the control group for smash. This is shown in Figure 26. The thoracic spine manipulation group showed the largest immediate decrease but this was followed by a large increase.

Table 19: Treatment effect for smash in all groups compared with control

Effect	Statistic	p value
Time*group overall	Wilk's lambda=0.933	0.870
Lumbar manipulation vs. control	Wilk's lambda=0.922	0.501
Thoracic manipulation vs. control	Wilk's lambda=0.965	0.736
Both vs. control	Wilk's lambda=0.964	0.731

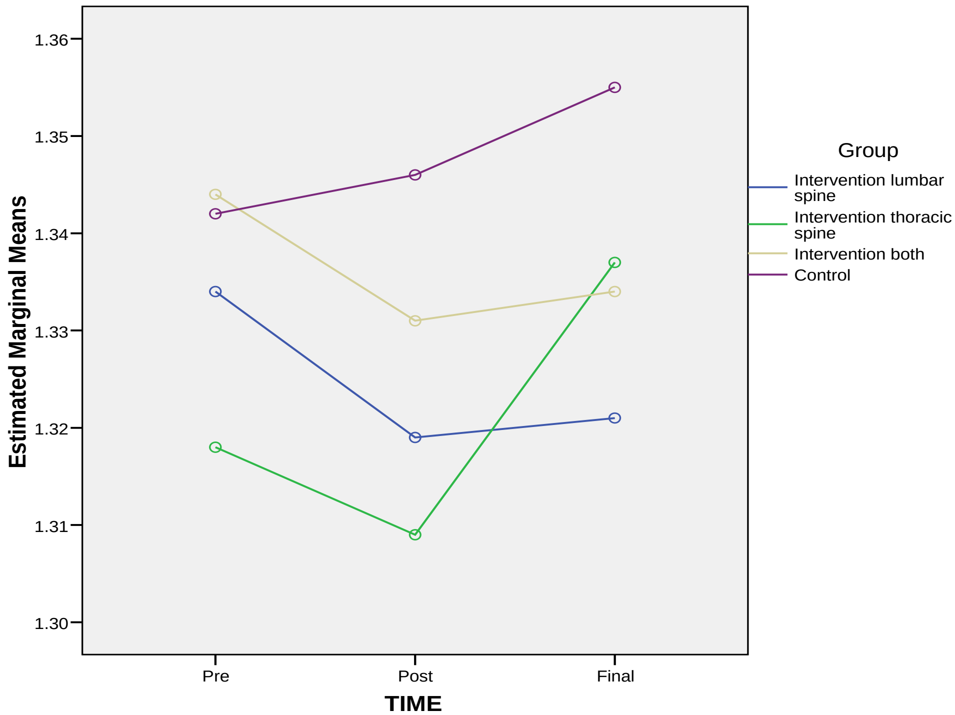

Figure 26: Mean smash between groups over time (n=10)

4.5.5 Distance

Overall there was a borderline non significant treatment effect (p=0.055) with regard to distance. There was also a significant effect for the thoracic group compared with the control group (p=0.009) and a non significant trend for the lumbar group vs. the control group (p=0.096). Both treatment groups (i.e. thoracic and lumbar group) did not do better than the control group.

Table 20: Treatment effect for distance in all groups compared with control

Effect	Statistic	p value
Time*group overall	Wilk's lambda=0.710	0.055
Lumbar manipulation vs. control	Wilk's lambda=0.759	0.096
Thoracic manipulation vs. control	Wilk's lambda=0.576	0.009
Both vs. control	Wilk's lambda=0.908	0.441

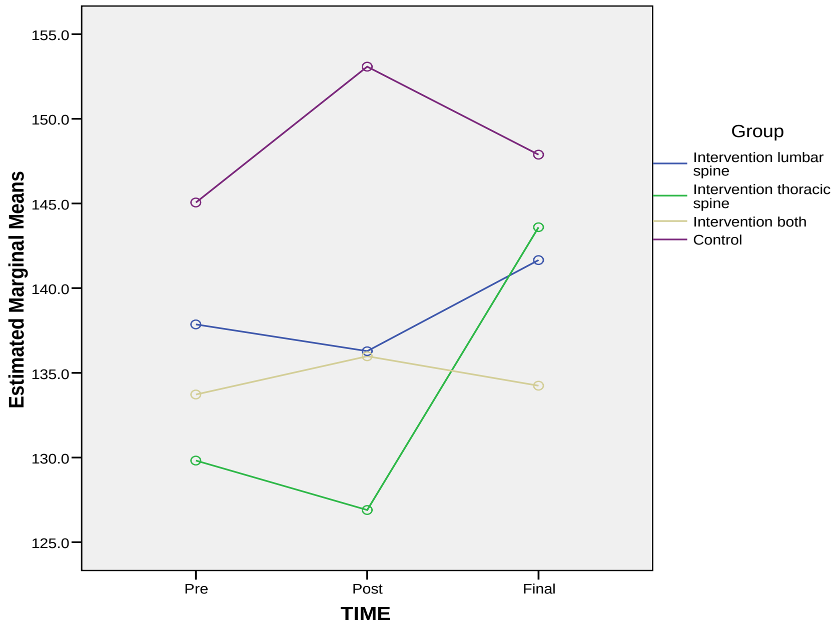

Figure 27: Mean distance between groups over time (n=10)

4.6 Summary

The main findings are that some outcomes seem to be better with lumbar manipulation (smash, horizontal azimuth) and some better with thoracic manipulation (CHV, vertical azimuth, and distance) alone, but none are better with both lumbar and thoracic manipulation. Thus the treatment groups should be analysed separately and it would seem that in practical terms that the application of a clinical intervention is not necessary more beneficial if both areas are manipulated simultaneously (or during the same consultation). This outcome may also account for the fact that there were insignificant differences between the control group of 10 and the combined group of 30 (where the combined group of 30 had a combination of outcomes that resulted in an average result being insignificant).

It should however be noted that this was an exploratory study and thus was not powered to detect significant differences between each treatment group and the control, nevertheless it has demonstrated certain trends which were unexpected and these trends should be further investigated with larger sample sizes to confirm the findings in this study.

CHAPTER 5

5.0 Conclusions and Recommendations

5.1 Introduction

The aim of this study was to evaluate the immediate and short term effect of SMT on asymptomatic amateur golfers in terms of performance indicators. Forty participants were randomly allocated to four equal groups. Three groups acted as intervention groups while one group was a placebo/control group and received no intervention.

No subjective data were recorded due to the asymptomatic status of all participants and performance indicators were measured using The FlightScope Pro-Electronic Golf Swing Analyser (Appendix G).

5.2 Discussion of Results

5.2.1 Demographics

In terms of age (p=0.518) and handicap (p=0.623) there was no difference between the four groups. It is therefore possible to infer that the results obtained in this study were as a result of the intervention applied rather than the differences between the groups with respect to the demographic data (Age, Handicap, Gender and Right Hand Golfers).

We could therefore safely assume that these factors did not affect the outcome of this study and concurs with the statement by Wright (1982) that "An unbiased sample is one in which no unrepresentitiveness can be traced to the selection procedure".

5.2.2 Baseline outcomes

For this study, consecutive convenience sampling (Mouton, 1996) occurred at the outset as a result of the manner in which potential participants responded to adverts recruiting the general public.

Once it was determined that the potential participants met the inclusion criteria and were willing to participate, then random sampling (Mouton, 1996) was utilised to assign participants to their respective groups by drawing a letter (A or B) out of an envelope. Participants were then assigned to either group A or B depending on which letter was drawn. Those participants who fell into group A were then further divided into their respective groups (A1/A2/A3) utilising purposive sampling (Mouton, 1996), depending on the presence of asymptomatic segmental joint dysfunction in the relevant spinal segments. This was done by means of motion palpation as described by the Liekens-Gillet method and set out in Bergmann's Chiropractic Technique (1993). Group B consisted of ten (10) participants that would act as the control group in this study. By means of motion palpation, they too were assessed in order to assure the presence of asymptomatic segmental joint dysfunction in the relevant spinal segments.

There were no significant differences between the four treatment groups for any of the baseline outcomes measured. The following p values (following page) clearly indicate this, which means that in terms of the randomization process, there was no tendency for one group to have a different starting / baseline value as compared to the other groups. As a result it was not necessary to control this in the statistical analysis of the data later when the changes over time were compared between the groups.

Club Head Velocity (CHV)	p=0.666
Vertical Azimuth (VA)	p=0.739
Horizontal Azimuth (HA)	p=0.396
Smash	p=0.525
Distance	p=0.569

Therefore, in respect of the outcome measures for this study, all groups were equal. This was in accordance with Mouton (1996) who stated that an unbiased sample is one in which no unrepresentitiveness can be traced to the selection procedure and one that strengthens the outcome of the study.

5.3 Intragroup analyses as it relates to objective 1

Comparing the Intervention group (n=30) to itself over time.

Outcome Measures	**P value significance**
CHV	Insignificant
VA	Significant short term
HA	Insignificant
Smash	Insignificant
Distance	Significant short term

According to research conducted at the United States Golf Association Technical Department an approximate 1:3 relation exists between club head velocity and air travel of the golf ball, i.e. distance. This means that for every 1-mph increase in club head velocity the average golfer would hit the ball 2.5 yards (rounded to the nearest yard) further according to Stude and Gullickson (2000).

Recent studies conducted by Jermyn (2004) and Delgado (2005) confirmed the abovementioned relation between CHV and distance by looking at the immediate and short term effects of SMT on amateur golfers suffering from mechanical low back pain.

In this study however it was however found that in the immediate and short term there was no significant change to the club head velocity (CHV) of asymptomatic amateur golfers following SMT. The results did however find a significant change in the short term related to the vertical azimuth and distance of asymptomatic amateur golfers. This indicates that even though CHV does not change, the distance does and therefore the abovementioned relationship cannot only be velocity driven.

A possible reason for the difference between the current study and the studies of Jermyn (2004) and Delgado (2005), is that the previous studies were performed on amateur golfers suffering from mechanical low back pain and that this particular study looked at asymptomatic amateur golfers. Golfers with low back pain have a greater possibility for improvement in terms of the perceived effect experienced (i.e. pain reduction) than those golfers that are asymptomatic at the outset of the study (as in this study). Therefore the relationship between CHV and distance may be more directly related to perceived pain (and guarding of that pain) that the golfer experiences and/or the pain inhibition of action as opposed to the purely mathematical relationship between CHV and distance as previously thought.

5.4 Intergroup analyses as it relates to objective 2

Comparing the Intervention group (n=30) to the Control group (n=10) over time.

Outcome Measures	**P value significance**
CHV	Insignificant
VA	Insignificant
HA	Insignificant
Smash	Insignificant
Distance	Insignificant

From the above analyses no significant extrapolations could be made, because of the small sample groups. It is therefore recommended that a more significant result may be achieved if a larger number of golfers were tested.

To further improve the significance of a study such as this, it was also recognized that when working with amateur golfers, who lack the consistency of professional golfers, an average of five swings were not enough to gain any significant average. In future we recommend that at least 10 swings be recorded for which an average must be calculated. This will dramatically decrease the margin of error for the amateur golfer knowing that one swing only carries 10% of the total value, in comparison to the 20% when only five swings were recorded. Alternatively, golfers must record 10 swings for which the best two / three and worst two / three values must be subtracted, as this will ensure a more accurate average for all recorded swings.

Furthermore from the above analyses we found that CHV did change in the intervention group, compared to the placebo group (even though there was no significant change). We therefore deduct that with more accurate averages these values could become significant and that this significance could be due to the effect of SMT.

5.5 Intergroup analyses as it relates to objective 3

Comparing all groups together in a four way comparison.

Outcome Measures	**P value significance**
CHV	Insignificant
VA	Insignificant
HA	Insignificant
Smash	Insignificant
Distance	Insignificant

From the above analyses no significant extrapolations could be made.

From the literature it can be seen that weight transfer from the right to the left in the asymptomatic amateur golfer requires the stabilization of the gluteus medius muscle (Seaman, 1998). In addition to this it has been noted in the literature (Thompson, 2002) that the overuse of the gluteus medius muscle has been linked to the development of sacro-iliac dysfunction. Thus it stands to reason that the lattisimus dorsi is one of the principle muscle used to transfer force between the upper and lower extremity (Seaman, 1998) and that an imbalance between the lattisimus dorsi and its antagonists, the gluteus medius and maximus on the contralateral side of the thoracolumbar fascia, could lead to decreased range of motion in the sacro-iliac joints (Mould, 2003). This confirms Harrison et al., (1997) assertion that one of the functions of the thoracolumbar fascia is that of sacro-iliac joint compression as an aid for energy transfer.

As a result of the above, the possibility that Gatterman's (1990) suggestion of one area of the spine/pelvis becoming hypomobile with an area of hypermobility having to develop elsewhere becomes plausible. Therefore if the sacro-iliac joints show decreased range of motion, it is likely that the lumbar spine has to compensate for this to sustain relative full range of motion (Mackey, 1995). Altered biomechanics as a result of this could then lead to lumbar spine / facet joint dysfunction which may lead to symptoms like facet syndromes later in the pathogenesis (Mackey, 1995).

Therefore in summary we could say that decrease range of motion (either globally or within a motion segment) in either the thoracic spine, lumbar spine or pelvis could lead to altered joint biomechanics and a predisposition to joint dysfunction with the proprioceptive changes and other changes that have been associated with joint dysfunction (Leach, 1994). Some of these could be present at a sub clinical level (dysfunctional level) in the asymptomatic amateur golfer.

Thus when manipulating the dysfunctional segment, there is a change in the ability of the motion segment and then also in the changes (proprioceptive and other) allowing for more normalized motion in the spine (thoracic / lumbar in this study).

However at present it is difficult to extrapolate any meaning from the data obtained in this study. This is based on the small sample size and the trends that indicate that there is an effect but the extent of which is not definable. This is further compounded by the fact that the literature is not very clear as to the methods of action regarding SMT on the asymptomatic amateur golfer, as at best the outline of discussion above indicates what is known hypothetically and in terms of theory (Leach, 1994).

5.6 Summary

5.6.1 The Objectives

5.6.1.1 Hypothesis 1:

SMT would show no significant immediate or short term effect on the performance indicators of asymptomatic amateur golfers.

Hypothesis 1: Rejected as there were positive responses in terms of the outcome measures. The extent of these measures requires a larger sample size and further study.

5.6.1.2 Hypothesis 2:

SMT would show no significant difference (in the short term) in treatment effect between the two groups, i.e. the pooled treated group and the control group.

Hypothesis 2: Rejected as there were positive responses in terms of the outcome measures. The extent of these measures requires a larger sample size and further study

5.6.1.3 Hypothesis 3:

SMT would show no significant difference in terms of treatment effect between all four groups, i.e. the three treatment groups and the control group.

Hypothesis 3: Rejected as there were some significant responses. The extent of these measures requires a larger sample size and further study.

From the abovementioned information obtained we can therefore deduce that SMT was most effective in the short term for asymptomatic amateur golfers in terms of performance indicators.

5.7 Recommendations

This study only involved a sample size of forty participants; it is felt that this number is not large enough for any significant result on which a categorical statement can be made. In a larger sample size, related to both the intervention and placebo groups, the validity of any study would be enhanced as the focus would be more on p-value significances obtained rather than on given trend(s). Therefore highlighting any p-value significances more clearly and allowing the possibility for categorical statements to be made.

It should also be further considered that as yet we are unsure of the mechanism of action of SMT (Leach, 1994) and thus it is felt that in an asymptomatic study such as this, the effects of the demographic variables are unknown. The golfing population that participated in this study tended to be business professionals in the middle age category. Thus maybe consideration needs to be given to the investigation of the effects obtained in other ages, in females (for example) and then compared to the results obtained from this study and other similar studies that will be done in the future.

Similarly to the above, the handicaps of the participants used in this study varied from 3 to 24. Future studies could possibly include elite or professional golfers only as this would allow for more accurate assessment of the effects of SMT on their golf swings. This could be done on the premise that golfers falling into lower handicap ranges swing more consistently and have a better knowledge of their swing mechanics than those in higher handicap ranges.

Furthermore, it is also recommended that the FlightScope Pro-Electronic Swing Analyser be used outside a retail golf shop environment. Using this machine in a more controlled and private environment could help participants feel less rushed and under less pressure from interested onlookers (Hawthorne effect (Mouton, 1996)) which might have affected the outcomes of this study.

Future Studies:

- The role of the asymptomatic / symptomatic thoracic spine in the golf swing, and the effects of SMT on performance indicators.

- The role of the asymptomatic / symptomatic lumbar spine in the golf swing, and the effects of SMT on performance indicators.

- The role of the asymptomatic / symptomatic sacro-iliac joint in the golf swing, and the effects of SMT on performance indicators.

- The role of the lattisimus dorsi and the thoracolumbar fascia in the asymptomatic / symptomatic golfer.

- The exact mechanism by which SMT influences performance indicators.

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Appendix A

DURBAN UNIVERSITY OF TECHNOLOGY
CHIROPRACTIC DAY CLINIC
CASE HISTORY

Patient: ______________________________ Date: __________

File # : __________ Age: __________

Sex : __________ Occupation: ______________________________

Intern : ____________________ Signature ____________________

FOR CLINICIANS USE ONLY:
Initial visit
Clinician: Signature :

Case History:

Examination:
Previous: Current:

X-Ray Studies:
Previous: Current:

Clinical Path. lab:
Previous: Current:

CASE STATUS:

PTT:	Signature:	Date:

CONDITIONAL:
Reason for Conditional:

Signature: Date:

Conditions met in Visit No:	Signed into PTT:	Date:
Case Summary signed off:		Date:

Intern’s Case History:

1. Source of History:

2. Chief Complaint : (patient’s own words):

3. Present Illness:

	Complaint 1	**Complaint 2**
< Location		
< Onset : Initial:		
Recent:		
< Cause:		
< Duration		
< Frequency		
< Pain (Character)		
< Progression		
< Aggravating Factors		
< Relieving Factors		
< Associated S & S		
< Previous Occurrences		
< Past Treatment		
< **Outcome:**		

4. Other Complaints:

5. Past Medical History:

< General Health Status

< Childhood Illnesses

< Adult Illnesses

< Psychiatric Illnesses

< Accidents/Injuries

< Surgery

< Hospitalizations

6. Current health status and life-style:

< Allergies

< Immunizations

< Screening Tests incl. xrays

< Environmental Hazards (Home, School, Work)

< Exercise and Leisure

< Sleep Patterns

< Diet

< Current Medication
Analgesics/week:

< Tobacco
< Alcohol
< Social Drugs

7. Immediate Family Medical History:

< Age
< Health
< Cause of Death
< DM
< Heart Disease
< TB
< Stroke
< Kidney Disease
< CA
< Arthritis
< Anaemia
< Headaches
< Thyroid Disease
< Epilepsy
< Mental Illness
< Alcoholism
< Drug Addiction
< Other

8. Psychosocial history:

< Home Situation and daily life
< Important experiences
< Religious Beliefs

9. Review of Systems:

< General

< Skin

< Head

< Eyes

< Ears

< Nose/Sinuses

< Mouth/Throat

< Neck

< Breasts

< Respiratory

< Cardiac

< Gastro-intestinal

< Urinary

< Genital

< Vascular

< Musculoskeletal

< Neurologic

< Haematologic

< Endocrine

< Psychiatric

Appendix B

Durban University of Technology

PHYSICAL EXAMINATION: SENIOR

Patient Name : ______________________ **File no :**__________ **Date :**________

Student : **Signature :**

VITALS:

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

GENERAL EXAMINATION:

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

SYSTEM SPECIFIC EXAMINATION:

CARDIOVASCULAR EXAMINATION

RESPIRATORY EXAMINATION

ABDOMINAL EXAMINATION

NEUROLOGICAL EXAMINATION

COMMENTS

NEUROLOGICAL EXAMINATION: See Regionals

Clinician: **Signature :**

DURBAN UNIVERSITY of TECHNOLOGY

Appendix C1

THORACIC SPINE REGIONAL EXAMINATION

Patient:____File: ____________ Date:_______

Intern:____Signation:___________________________

Clinician: _______________________________________Signation:___________________________

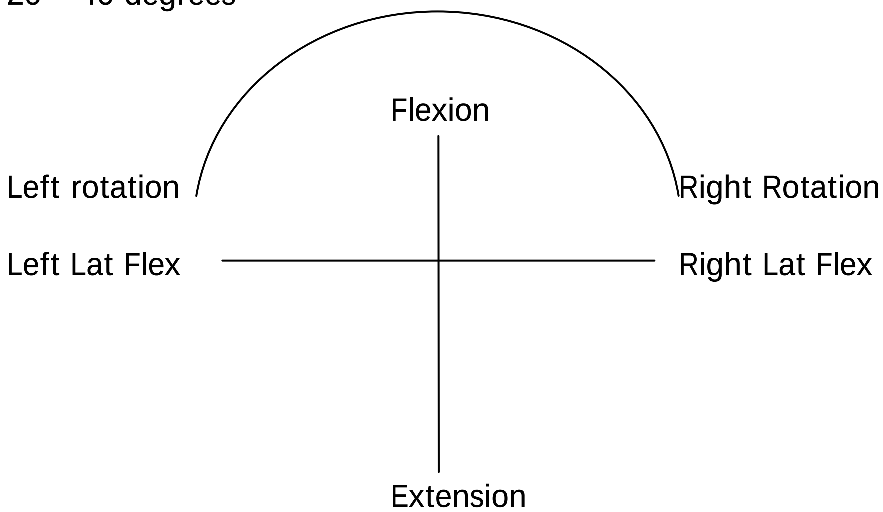
STANDING:

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

Scars
Chest deformity
(pigeon, funnel, barrel)

RANGE OF MOTION:

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



RESISTED ISOMETRIC MOVEMENTS: (in neutral)

Forward Flexion
L/R Rotation

Extension
L/R Lateral Flexion

SEATED:

Palpate Auxillary Lymph Nodes
Palpate Ant/Post Chest Wall
Costo vertebral Expansion (3 – 7cm diff. at 4th intercostal space)
Slump Test (Dural Stretch Test)

SUPINE:

Rib Motion (Costo Chondral joints)
Soto Hall Test (#, Sprains)

SLR
Palpate abdomen

PRONE:
Passive Scapular Approximation
Facet Joint Challenge
Vertebral Pressure (P-A central unilateral, transverse)
Active myofascial points:

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

COMMENTS:____

NEUROLOGICAL EXAMINATION:

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

Basic LOWER LIMB neuro:

Myotomes	
Dermatomes	
Reflexes	

KEMP'S TEST:

MOTION PALPATION:

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

BASIC EXAM	History	ROM	Neuro/Ortho
LUMBAR			
CERVICAL			

Appendix C2

REGIONAL EXAMINATION - LUMBAR SPINE AND PELVIS

Patient:________________________________ File#:______Date:_________

Intern\Resident:___________________________ Clinician:__________________

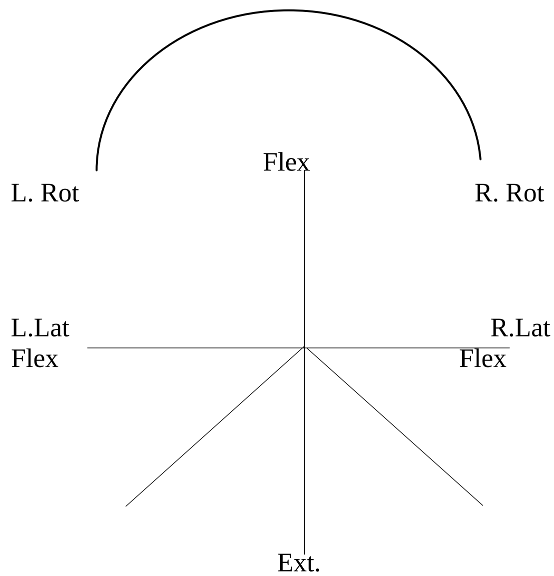
STANDING:

Posture– scoliosis, antalgia, kyphosis
Body Type
Skin
Scars
Discolouration

Minor's Sign
Muscle tone
Spinous Percussion
Scober's Test (6cm)
Bony and Soft Tissue Contours

GAIT:

Normal walking
Toe walking
Heel Walking
Half squat



ROM:

Forward Flexion = 40-60° (15 cm from floor)
Extension = 20-35°
L/R Rotation = 3-18°
L/R Lateral Flexion = 15-20°

Which movt. reproduces the pain or is the worst?

- Location of pain
- Supported Adams: Relief? (SI)
  Aggravates? (disc, muscle strain)

SUPINE:

Observe abdomen (hair, skin, nails)
Palpate abdomen\groin
Pulses - abdominal
- lower extremity
Abdominal reflexes

		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
SLR	**L**										
	R										

	L	**R**
Bowstring		
Sciatic notch		
Circumference (thigh and calf)		
Leg length: actual -		
apparent -		
Patrick FABERE: pos\neg – location of pain?		
Gaenslen's Test		
Gluteus max stretch		
Piriformis test (hypertonicity?)		
Thomas test: hip \ psoas? \ rectus femoris?		
Psoas Test		

SITTING:

Spinous Percussion
Valsalva
Lhermitte

		Degree	LBP?	Location	Leg pain	Buttock	Thigh	Calf	Heel	Foot	Braggard
TRIPOD	**L**										
Sl, +, ++	**R**										

Slump 7	**L**										
test	**R**										

LATERAL RECUMBENT:

	L	R
Ober's		
Femoral n. stretch		
SI Compression		

PRONE:

	L	R
Gluteal skyline		
Skin rolling		
Iliac crest compression		
Facet joint challenge		
SI tenderness		
SI compression		
Erichson's		
Pheasant's		

MF tp's	**Latent**	**Active**	**Radiation**
QL			
Paraspinal			
Glut Max			
Glut Med			
Glut Min			
Piriformis			
Hamstring			
TFL			
Iliopsoas			
Rectus Abdominis			
Ext/Int Oblique muscles			

NON ORGANIC SIGNS:

Pin point pain
Axial compression
Trunk rotation
Burn's Bench test
Flip Test
Hoover's test
Ankle dorsiflexion test
Repeat Pin point test

NEUROLOGICAL EXAMINATION

Fasciculations

Plantar reflex

level	**Tender?**	**Dermatomes**		**DTR**		
		L	R		L	R
T12				Patellar		
L1				Achilles		
L2						
L3				Proproception		
L4						
L5						
S1						
S2						
S3						

MYOTOMES					
Action	**Muscles**	**Levels**	**L**	**R**	
Lateral Flexion spine	Muscle QL	T12-L4			
Hip flexion	Psoas, Rectus femoris	L1,2,3,4			5+ Full strength
Hip extension	Hamstring, glutes	L4,5;S1.2			4+ Weakness
Hip internal rotat	Glutmed, min;TFL, adductors				3+ Weak against grav
Hip external rotat	Gluteus max, Piriformis				2+ Weak w\o gravity
Hip abduction	TFL, Glut med and minimus				1+ Fascic w\o gross movt
Hip adduction	Adductors				0 No movement
Knee flexion	Hamstring,	L4,5:S1			
Knee extension	Quad	L2,3,4			W - wasting
Ankle plantarflex	Gastroc, soleus	S1,2			
Ankle dorsiflexion	Tibialis anterior	L4,5			
Inversion	Tibialis anterior	S1			
Eversion	Peroneus longus	L4			
Great toe extens	EHL	L5			

BASIC THORACIC EXAM

History
Passive ROM
Orthopedic

BASIC HIP EXAM

History
ROM: Active
Passive : Medial rotation : A) Supine (neutral) If reduced - hard \ soft end feel
B) Supine (hip flexed): - Trochanteric bursa

Appendix D

LETTER OF INFORMATION

Dear patient, welcome and thank you for being part of this study.

Title of the research project:
The immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators.

Name of Supervisor(s): Dr. C Korporaal – M.Tech: Chiropractic (SA), CCFC (SA), CCSP (USA), ICCSD (USA)
Tel no. (031) 373 2611

Name of Research student: Stef le Roux
Tel no. (031) 373 2512/082 775 7827

Name of Institution: Durban University of Technology (D.U.T.)

Introduction and Purpose of the study:
This study hopes to show that spinal manipulative therapy has a positive outcome on asymptomatic amateur golfers in terms of performance indicators.

This particular study pertains to 40 participants only.

Procedures:

The visits
Each participant will be required to commit to two consultations at The Pro Shop. The Pro Shop is situated at Shop 20, Value Centre, Springfield Park (opposite MACRO). Address: 45 Electron Road (off Umgeni Rd), Durban, 4000.

The initial consultation will include a case history, physical examination, low back and/or thoracic regional examination to determine participant suitability.

Once participants have been accepted onto the study, they will be divided into groups A and B. For the purposes of this study participants falling in group A will receive clinical intervention, i.e. SMT and those participants falling in group B will act as the control group receiving no intervention.

At the initial consultation both groups will have their golf swing analyzed in terms of performance indicators, i.e. CHV, Vertical and Horizontal Azimuth, Smash and Distance. This will be done by means of a normal warm-up routine that the golfer would follow before playing a round of golf. For the sake of consistency, the participants own 7-iron will be used in the assessment. Once the averages of the performance indicators have been determined the researcher will intervene with the relevant spinal manipulative intervention (should you fall in group A). This will then be followed immediately by another set of readings for which an average will be calculated.

Participants from groups A and B will be required to attend a second consultation, no less than three and no more than seven days later. During this last consultation only performance assessment will take place and no further intervention will be received. For comparative purposes both groups have to be re-assessed in a similar fashion.

Risks/Discomfort:
Please note that spinal manipulative therapy (SMT) can cause some post treatment stiffness for 24-36 hrs, but it is a rare side effect and not present in all participants.

Benefits:
There will be no charge to the participants involved in this study. And the spinal manipulative intervention provided will be according to normal clinical practices.

New findings:
Each participant has the right to be informed of any new findings that are made relevant to this particular study.

Reasons why you may be withdrawn from this study without your consent:
1. If you experience extreme pain whilst clinical indicators are being assessed.
2. If you experience extreme pain whilst performance indicators are being assessed.

Please also note that any participant can withdraw form the study at any time without supplying a reason.

Remuneration/Cost of the study:
Please note that there will be no remuneration at all pertaining to this study and that your participation is completely voluntary.

Confidentiality:
All participant information related to this study is confidential and the results will be used for research purposes only. Note however that supervisors and senior clinic staff members will also have access to these records.

Contact details regarding any problems or questions pertaining to the study:
Should you require answers from an independent source (i.e. supervisors) please feel free to contact them on the numbers listed above.

If you are not satisfied with any area of this study, please direct your queries and concerns to the Durban University of Technology-Research and Ethics Committee.

Thank you again for your participation in this study.

Stef le Roux
(Chiropractic intern)

Dr. C Korporaal
(Supervisor)

Appendix E

LETTER OF INFORMED CONSENT
(To be completed by research participant)

Date:

Title of the study:

The immediate and short term effect of spinal manipulative therapy (SMT) on asymptomatic amateur golfers in terms of performance indicators.

Name of Supervisor:	Dr. C Korporaal
Tel no:	(031) 373 2611
Name of Research student:	Stef le Roux
Tel no:	(031) 373 2512 or 082 775 7827

Please circle the appropriate answer

	YES/NO
1. Have you read the research information sheet?	Yes No
2. Have you had an opportunity to ask questions regarding the study?	Yes No
3. Have you received satisfactory answers to your questions?	Yes No
4. Have you had an opportunity to discuss the study?	Yes No
5. Have you received enough information about the study?	Yes No
6. Do you understand the implications of your involvement in the study?	Yes No
7. Do you understand that you are free to withdraw from the study at any time without having to substantiate your reason for doing so?	Yes No
8. Do you agree to voluntary participate in the study?	Yes No

9. Who did you speak to? ____

Please ensure that the research student complete each section with you. If you have answered NO to any of the above questions, please obtain the necessary information before signing the consent form.

Please print in block letters:

Participant Name:______________________ Signature:__________________

Witness Name:________________________ Signature:__________________

Research student Name:________________ Signature:__________________

Appendix F

Data Collection Sheet

Participant Name:_________________________ H/Cap:________________

Group:___________________________________

Visit 1:

Date:

	Club Head Velocity (m/h)	Vertical Azimuth (*)	Horizontal Azimuth (*)	Smash	Distance (m)
	Pre/Post	**Pre/Post**	**Pre/Post**	**Pre/Post**	**Pre/Post**
1	/	/	/	/	/
2	/	/	/	/	/
3	/	/	/	/	/
4	/	/	/	/	/
5	/	/	/	/	/
Ave.	/	/	/	/	/

Visit 2:

Date:

	Club Head Velocity (m/h)	Vertical Azimuth (*)	Horizontal Azimuth (*)	Smash	Distance (m)
1					
2					
3					
4					
5					
Ave.					

Comments:

____

____

____

____

Appendix G

Specifications: FlightScope Pro ™

Description

Patented golf ball tracking system that provides shot statistics and performance reports for professional golf club comparison and club calibration applications.

FlightScope Pro can be used in outdoors or indoors at driving ranges and pro shops.

Components

FlightScope Pro comprises a sensor, application software, and installation parts as follows:

Sensor Unit

Power Cable (3m/ 10 ft)

Communications Cable with interface converter (10m/ 32ft)

DB25/DB9 Adapter Cable

FlightScope Pro™ Application Software

Installation Accessories

User Manual

OPTIONAL EQUIPMENT

Protective Cover (Outdoor installations only)

Notebook computer (IBM compatible P4) with XP Pro O/S

Pelican shipping case

Functions

Club Fitting / Comparison

Startup

The Startup screen provides four (4) navigation buttons: Play, Clubfitting, Club calibration, and Printing.

Play

The system will measure and display shots played within the detection area of the sensor, and display results in top view or distance view.

Club fitting / comparison

After registering the player's name and particulars, the clubs to be compared are entered.

The player proceeds through a series of shots with various clubs and the results analyzed and presented to support the selection of appropriate equipment.

The individual shot data is measured for a series of 10 shots for each club. The average performance for the club is calculated.

As the player progresses through the list of clubs, the comparative average statistics are provided.

Club Calibration

Club calibration

Used by a club fitting coach or individual player to determine the player's performance with a selection of his clubs.

The player details as well as the list of clubs are entered.

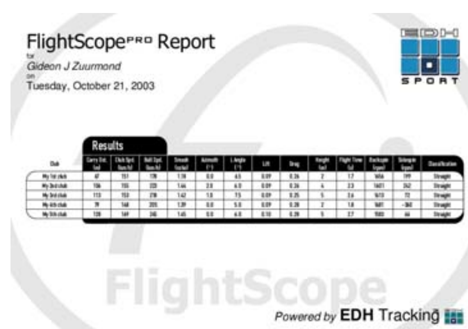
A series of shots is played with each of the listed clubs. The shot results are analyzed and presented. The average values are also determined.

Finally, the average performance with each club is listed.

Printing

Printing

Performance statistics of Club Fitting or Club Calibration sessions can be printed in hard copy on a connected printer.



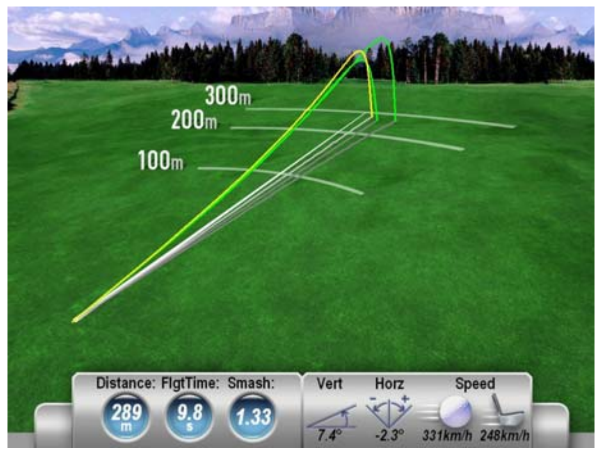
Other Views

Grouping

This screen provides a graphic "top view" display of the trajectories and fall of shots, as well as a measure of the grouping (diameter of smallest circle).

3D

This screen provides a 3-dimensional display of the trajectories and fall of shots.



Capabilities

Balls and Clubs

All regulation tournament balls and most practice range balls

All woods and most other clubs

Measurement Zone

The sensor measures in a spatial volume of 20 degrees by 20 degrees around its pointing direction

Launch Velocity

From 2 to 400 km/h (1.2 to 250 mph) within 0.5% accuracy.

Horizontal and Vertical Launch Angles

To within 0.5 degrees.

Landing Position

The x, y coordinates of the ball with a standard error of 5% of the actual flight distance.

Trajectory Height

The height the ball will reach through its flight path.

Club Head Speed

The club head strike speed accurate to 2%.

Physical Characteristics

Dimensions (approximate)

330 x 460 mm x 305 mm (13” x 7" x 12") Height x Width x Depth

Mass (approximate)

Sensor 3 kg (6.6 lbs)
Cover 2 kg (4.5 lbs)
Cables & Accessories 10 kg (22 lbs)

Environmental Characteristics

Ambient Temperature

Operates between 0 to 40 degrees C (32 to 104 degrees F).

Ingress Protection Level

IP54 / NEMA-4.

Electrical Characteristics

Electrical Supply:	100-260 Volt AC @ 0.5 Amp
Communications Interface:	RS422/RS232 serial interface, at up to 115 kbps
FCC and CE:	Certified to FCC and CE requirements

Installation Recommendations

The typical minimum requirements to use the system are as follows:

- Tee mat or grass tee
- Screen or net for indoor locations
- Work surface for notebook computer
- Sensor located 3 metres (10 ft) behind tee for outdoors and 4.5 metres (15 ft) behind screen/net for indoor facilities
- Mains power outlet
- Suitable protection against weather and other environmental factors
- Optional printer

Appendix H

PLAYING GOLF!?!

Always wanted to have your swing professionally analyzed?
Now is the time!!!

If you are between 25 and 45 years of age with an official golf handicap, you may qualify for this unbelievable opportunity.

Research is currently being conducted at the Durban University of Technology (DUT)

Chiropractic Day Clinic and the Pro Shop

FREE GOLF SWING ANALYSES

is available for the duration of the study!

For more information, please contact:

Stef le Roux
(031) 373 2512 or 082 775 7827
at the DUT Chiropractic Day Clinic